THE

CYCLOPÆDIA

OF

ANATOMY AND PHYSIOLOGY.

VOL. II.

LONDON:
MARCHANT, PRINTER, INGRAM-COURT.

THE

CYCLOPÆDIA

OF

ANATOMY AND PHYSIOLOGY.

EDITED BY

ROBERT B. TODD, M.D. F.R.S.

FELLOW OF THE ROYAL COLLEGE OF PHYSICIANS;
PROFESSOR OF PHYSIOLOGY AND OF GENERAL AND MORBID ANATOMY IN KING'S COLLEGE, LONDON, ETC. ETC.

VOL. II.

DIA —— INS.

LONDON:
SHERWOOD, GILBERT, AND PIPER,
PATERNOSTER-ROW.

1839.

CONTRIBUTORS.

ROBERT ADAMS, Esq.
Surgeon to the Richmond Hospital, and Lecturer on Anatomy and Surgery, Dublin.

B. ALCOCK, M.B. Dublin.

W. P. ALISON, M.D. F.R.S.E.
Professor of the Institutes of Medicine in the University of Edinburgh, &c.

JOHN ANDERSON, Esq. M.E.S. Richmond.

J. APJOHN, M.D. M.R.I.A.
Prof. of Chem. to the Royal Coll. of Surgeons, Ireland.

VICTOR AUDOUIN, M.D. Paris.
Professeur-Administrateur au Musée d'Histoire Naturelle.

B. G. BABINGTON, M.D. F.R.S.

THOMAS BELL, F.R.S.
Professor of Zoology in King's College, London.

CHARLES BENSON, M.D. M.R.I.A.
Prof. of Med. to the Royal Col. of Surgeons, Ireland.

JOHN BOSTOCK, M.D. V.P.R.S. London.

W. BOWMAN, Esq.
Demonstrator of Anatomy, King's College, London.

W. T. BRANDE, F.R.S.
Professor of Chemistry to the Royal Institution, &c.

J. E. BRENAN, M.D.

G. BRESCHET, M.D.
Surgeon to the Hotel-Dieu, Paris.

W. B. CARPENTER, Esq.
Lect. on Forensic Med. at the Bristol Med. Sch., &c.

JOHN COLDSTREAM, M.D. Leith.
Member of the Wernerian Natural History Society of Edinburgh, &c. &c.

DAVID CRAIGIE, M.D. F.R.S.E.
Fellow of the Royal College of Physicians, Edinburgh, &c.

T. BLIZARD CURLING, Esq.
Assistant Surgeon to the London Hospital, and Lecturer on Morbid Anatomy.

G. P. DESHAYES, M.D. Paris.

A. T. S. DODD, Esq.
Surgeon to the Infirmary, Chichester, and late Demonstrator of Anatomy at Guy's Hospital.

H. DUTROCHET, M.D.
Member of the Institute of France, Paris.

W. F. EDWARDS, M.D. F.R.S.
Member of the Institute of France, Paris.

H. MILNE EDWARDS, M.D.
Professor of Natural History to the College of Henry IV., and to the Central School of Arts and Manufactures, Paris.

ARTHUR FARRE, M.B. F.R.S.
Physician to the Gen. Disp., and Lect. on Forensic Med. and Comp. Anat. and Physiol. at St. Bartholomew's Hospital.

R. D. GRAINGER, Esq.
Lecturer on Anatomy and Physiology at the Webb-Street School of Anatomy.

R. E. GRANT, M.D. F.R.S. L. & E.
Fellow of the Royal College of Physicians, Edinburgh, and Professor of Comparative Anatomy and Zoology in University College, &c. &c.

MARSHALL HALL, M.D. F.R.S. L. & E. London.

HENRY HANCOCK, Esq.
Lect. on Anat. and Physiology at, and Surgeon to the Charing-Cross Hospital.

ROBERT HARRISON, M.D. M.R.I.A.
Prof. of Anat. and Surg. in the Univ. of Dublin.

JOHN HART, M.D. M.R.I.A.
Prof. of Anat. in the Royal Coll. of Sur. Dublin.

ISID. GEOFFROY ST. HILAIRE, M.D.
Member of the Institute of France, Paris.

ARTHUR JACOB, M.D. M.R.I.A.
Professor of Anatomy and Physiology to the Royal College of Surgeons in Ireland.

T. RYMER JONES, Esq.
Prof. of Comp. Anat., in King's College, London.

T. WHARTON JONES, Esq. London.

F. KIERNAN, F.R.S. London.

T. WILKINSON KING, Esq.
Lect. on Comp. Anat. and Physiol. at Guy's Hospital.

SAMUEL LANE, Esq.
Lecturer on Anatomy, St. George's Hospital, London.

F. T. MACDOUGALL, Esq.

JOHN MALYN, Esq.
Surgeon to the Western Dispensary.

W. F. MONTGOMERY, M.D. M.R.I.A.
Fellow and Professor of Midwifery to the King and Queen's College of Physicians in Ireland.

GEORGE NEWPORT, Esq.
Vice-Pres. of the Entomological Society of London.

R. OWEN, F.R.S. F.G.S.
Professor of Comparative Anatomy and Physiology to the Royal College of Surgeons in London.

RICHARD PARTRIDGE, F.R.S.
Prof. of Descriptive and Surgical Anat. in King's Coll. London.

BENJAMIN PHILLIPS, F.R.S. London.
Surgeon to the Marylebone Infirmary.

W. H. PORTER, Esq.
Prof. of Surgery to the Royal Coll. of Surg. in Ireland.

J. C. PRICHARD, M.D. F.R.S.
Corresponding Member of the Institute of France, Member of the Royal Academy of Medicine of Paris, and Senior Physician to the Bristol Infirmary.

G. O. REES, M.D. London.

J. REID, M.D. Edinburgh.
Fellow of the Royal College of Physicians in Edinburgh, and Lecturer on the Institutes of Medicine.

EDWARD RIGBY, M.D. F.L.S.
Lect. on Midwifery at St. Bartholomew's Hospital.

J. FORBES ROYLE, M.D. V.P.R.S. F.G.S.
Professor of Materia Medica in King's College, London.

HENRY SEARLE, Esq. London.

E. R. A. SERRES, M.D.
Physician to the Hospital of La Pitie, &c. &c. Paris.

W. SHARPEY, M.D. F.R.S.E.
Prof. of Anat. and Physiol. in Univ. Col. London.

JOHN SIMON, Esq.
Demonstrator of Anatomy in King's College, London.

J. Y. SIMPSON, M.D.
Fellow of the Royal College of Physicians, Edinburgh, and Lecturer on Midwifery.

SAMUEL SOLLY, F.R.S.

GABRIEL STOKES, M.D.
Surgeon to the South Eastern Dispensary, and Demonstrator of Anatomy in the Park-street School of Medicine, Dublin.

J. A. SYMONDS, M.D.
Physician to the Bristol General Hospital and Dispensary, and Lecturer on the Theory and Practice of Medicine at the Bristol Medical School.

ALLEN THOMSON, M.D.
Fellow of the Royal College of Surgeons, and Lecturer on the Institutions of Medicine, Edinburgh.

RUDOLPH WAGNER, M.D.
Professor of Medicine and of Comparative Anatomy in the Royal University, Erlangen.

C. WHEATSTONE, F.R.S.
Professor of Natural Philosophy in King's College, London.

REV. G. WILLIS, F.R.S. F.G.S. Cambridge.

R. WILLIS, M.D.
Physician to the Royal Infirmary for Children, and Lecturer on the Theory and Practice of Medicine in the Aldersgate-street School.

W. J. ERASMUS WILSON, Esq.
Lecturer on Anat. and Physiol. in Sydenham Coll Lon.; and Consulting Surgeon to the St. Pancras Infirmary.

W. YARRELL, F.L.S. F.Z.S.

CONTENTS OF THE SECOND VOLUME.

THE

CYCLOPÆDIA

OF

ANATOMY AND PHYSIOLOGY.

DIAPHRAGM (in anatomy), (*διαφραγμα*, *δια*, *inter*, and *φρασσω*, *sepio*, *claudo*; Lat. *diaphragma*; Ital. *diaframma*; Fr. *diaphragme*; Ger. *Zwerchfell*; Eng. *midriff*), the name given to that musculo-tendinous septum by which the cavities of the thorax and abdomen are separated from each other in the Mammalia.

Nothing analogous to the diaphragm of mammals can be detected in the Invertebrate classes of animals; the function of which it is a principal muscular agent in the Mammalia, respiration, being effected by the skin, intestines, stigmata, tracheæ, gills, &c. Most of the Vertebrata, however, exhibit something analogous to the diaphragm. Thus in Fishes the muscular septum dividing the cavity of the branchial apparatus (thorax) from the abdomen bears a certain resemblance to the diaphragm. Birds have muscles which proceed obliquely upwards in the form of flat bundles of fibres from the middle of the lower ribs to the under part of the lungs, where they are lost in the pleura covering these organs; and thus by their contraction depress the lungs themselves, expand their cells, and facilitate the ingress of air into them. These muscular fibres are particularly developed in the parrot.* But, as has been said, it is only in Mammalia that the genuine diaphragm is to be found; and all the animals of this class possess it. The organ, as might be expected, undergoes some modifications in different families. In amphibious and cetaceous mammalia it approximates to that of birds. A very strong and fleshy diaphragm is attached to the dorsal side of the cavity of the trunk so low down that it ascends considerably in order to be connected in a peculiar manner with the upper and anterior extremity of the abdominal muscles; so that the lungs lie behind rather than above the diaphragm.* In the porpoise there is no central tendon.† The horse, elephant, rhinoceros, and other animals whose ribs approach the pelvis, have a very extensive diaphragm, which forms an elevated arch towards the thorax.‡ This shape is necessary to accommodate the bulky contents of the abdomen, without altering the attachments of the muscle, which, as in man, are connected to the lowest ribs. Some other variations from the structure and form of the diaphragm in man might be noticed, but they are very unimportant. We shall therefore proceed to give a detailed account of the muscle in the human subject.

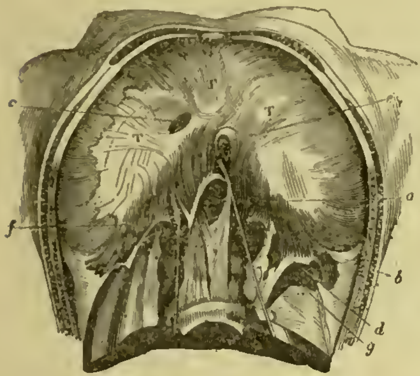
DIAPHRAGM (human anatomy).—The diaphragm in man is a muscle of great importance (*post cor facile princeps*, Haller), being the chief agent by which respiration is carried on, while it assists in the performance of many other important processes. It is placed between the thorax and abdomen, forming a convex floor to the former, and a concave ceiling to the latter. Although a single muscle, and situated in the median line, it is not symmetrical; the right side of it is more extensive than the left. Symmetry, however, was not necessary in an

* C. G. Carus, Comparative Anatomy.

* C. G. Carus, Comparative Anatomy.
† Tyson.
‡ Cuvier, Anat. Comp. vol. iv.

organ which could exert no influence on the external form; nor was it to be expected in a muscle which is not wholly voluntary. In this article it is intended to describe, 1st, the form, structure, and organization of the diaphragm; 2nd, its uses; and, 3rd, its malformations and diseases.

Fig. 1.



Abdominal surface of the diaphragm.

Fig. 2.

Thoracic surface seen from before.

Fig. 3.

Thoracic surface seen from behind, the vertebræ being removed.

For the convenience of description the diaphragm is usually divided into two portions—the *upper*, which is called the *costal*, or *true* or *greater muscle*; and the *lower*, which is named the *vertebral*, or *smaller*, and is also well known as the *crura* or *pillars*. This division is sanctioned by the situation, the shape, and the uses of the two portions.

The upper portion, placed tranversely, (*septum transversum*,) is thin, but of great superficial extent, being connected by its margins to the entire circumference of the inferior outlet of the thorax. Narrow between the sternum and spine, it spreads out on each side into large wings, and its outline bears some resemblance to the figure of eight laid on the side, thus ∞. The centre is tendinous; the border consists of fleshy fibres. The tendinous part (*fig.* 1, T) (*centrum tendineum, s. nerveum, s. phrenicum, cordiform tendon*) is of considerable size, and in shape resembles the trefoil leaf. It presents a large semicircular notch behind towards the spine, and is deeply divided on its anterior margin into three lobes, of which one points forwards and one to each side. Of these lobes the right is usually the largest, the left the smallest; the anterior is the shortest, and sometimes the broadest; the left is the narrowest and often the longest. But these proportions will be found to vary in different individuals. The tendon is composed of fibres which pursue various courses. The greater number radiate from the vertebral notch; these are crossed by others which run in every direction, and which seem to be continuous with the muscular fibres; and others again appear to be laid on the tendon as accessaries, rather than as contributing to its texture. These last are most distinctly seen in old men, and on the under surface of the right lobe. The tendinous centre forms nearly the highest part of the arch. It is less curved than the fleshy portion, and more fixed in its position. One large opening presents itself here, between the right and middle lobes, through which the vena cava passes to the heart.

From the anterior and lateral margins of this tendon the muscular fibres pass off in arches, to be inserted into all the base of the thorax by digitations which mix with those of the transversus abdominis.

Beginning in front, we find two slender fasciculi running downwards and forwards to the ensiform cartilage. These are separated from each other by a line of cellular tissue, marking the median line of the muscle; sometimes one or both of these bundles may be absent, probably resulting from an arrest of formation. To the outside of these, on each side, a considerable triangular interval exists, where the pleura and peritoneum are separated only by cellular substance. Here some small branches of the internal mammary artery pass to the abdomen; and in this situation fluids might easily find their way from the cellular tissue of one cavity to that of the other. The fibres next in order, bounding these spaces externally, are much longer; they pass outwards and downwards to the seventh rib, and are inserted by a broad digitation into the point of the bone and into about one half of the adjoining portion of its cartilage. The next fibres are still longer, usually the longest of all; they run outwards, then downwards, forming the second digitation, which is attached in a similar manner to the eighth rib. The following fibres becoming shorter as they approach the spinal notch, go to the ninth and tenth ribs, and are similarly connected. The succeeding ones, still shorter, proceed to the eleventh and twelfth, and attach themselves to a considerable portion of their length. In the two lowest intercostal spaces the diaphragm and transversus abdominis are united by a common aponeurosis, which is very thin; and here it is not very unusual to meet with a deficiency in the diaphragm. The thin portion of the muscle, near to the crura, has its short fleshy fibres inserted into the *ligamentum arcuatum externum.** (*Fig.* 1, *d.*) This last appellation is bestowed on a thin aponeurosis which stretches from the inferior margin of the last rib to the point of the transverse process of the first lumbar vertebra. In reality it is nothing more than the anterior layer of the tendon of the transversus abdominis which lies in front of the quadratus lumborum muscle, and is connected to the lowest rib. By pulling the rib outwards the aponeurosis is projected into a fold which looks like a ligament. It is designated *externum* to distinguish it from another that is much stronger and more truly ligamentous, which arches over the psoas magnus muscle, is attached to the transverse process of the first lumbar vertebra (just where the former ends), and to the body of the second. The latter is known as the *ligamentum arcuatum internum* † (*fig.* 1, *f*;) it is also called the *true*, and the external the *false*,—names derived from their structure.

The *vertebral* or *smaller* muscle of the diaphragm is placed almost perpendicularly. The fibres pass off from the concave margin of the tendon which is turned to the spine. They run downwards and a little backwards at first, then along the lumbar vertebræ, into which they are principally inserted. The shortest and most external of them go to the internal ligamentum arcuatum; but the greater number form two large and long fasciculi, the *crura*, or *pillars*, or *appendices* of the diaphragm.

The right crus is longer and thicker than the left, and is nearer to the middle line. It is attached by tendinous slips to the bodies of the three (often of the four) superior lumbar vertebræ and to the intervertebral substances. The left is attached in a similar way, but never descends so low. Both become smaller as they pass down, the more external fibres being soonest inserted. The muscular bundles, on quitting the cordiform tendon, separate immediately from each other, to permit the œsophagus to pass into the abdomen, and unite again behind that tube. Here a crossing or interlacing of the fibres takes place, a considerable bundle descending from the left side of the œsophagus to the right crus, and a smaller one from the right side to the left crus. In general the latter is placed anteriorly; and occasionally two bundles descend from each side alternating with their opposites. The fleshy fibres again separate on a level with the lower edge of the last dorsal vertebra to allow the aorta to pass, and they continue afterwards distinct.

The *foramina* or openings which present themselves in this septum require to be noticed. Three large ones have been already mentioned; but as the organs which they transmit are of great importance, they deserve more minute attention. The first is situated in the tendon of the diaphragm, toward its posterior part, a little to the right of the centre (*fig.* 1, *c*). It corresponds to the line of division between the middle and right lobes. Its shape is quadrangular, (*foramen quadratum*,) having an anterior, a posterior, a right and a left edge. The right is the longest, the anterior the shortest, and these two often appear to form but one. The inferior vena cava passes through this opening and immediately empties itself into the right auricle of the heart. The vein is firmly connected to the foramen by means of thin aponeuroses sent off from the tendinous margins; the posterior margin sending fibres upwards, the lateral downwards, and the anterior in both directions. This is the highest opening in the diaphragm, being on a level with the lower edge of the ninth dorsal vertebra and fifth rib. As the boundaries of it are entirely tendinous they cannot act on the vein themselves, and the action of the muscular fibres only serves to keep it dilated. Some branches of the phrenic nerve accompany this vein.

A little to the left of the median line, and close behind the central tendon, we find an opening of an elliptical form through which the œsophagus and pneumogastric nerves pass (*fig.* 1, *e*). Its major axis, two inches in length, is directed obliquely downwards and backwards. The borders are entirely muscular, at least very generally, for it sometimes happens that the anterior extremity is bounded by the cordiform tendon. It results from a separation of the fibres which are descending to constitute the crura, and may be said to lie between the crura. The crossing or interlacing of the fibres which takes place just behind it must enable them to shut up this opening completely when they act strongly. This foramen is on a level with the tenth dorsal vertebra, its upper and lower angles corresponding to the planes of the upper and lower surfaces of that bone.

About two inches below the inferior point of the œsophageal opening the aorta may be seen, coming out of the thorax, opposite the lower edge of the last dorsal vertebra (*fig.* 1, *a*.) This great vessel enters the abdomen by a canal which is formed posteriorly by bone, anteriorly by the decussating fibres, and on either side by the crura of the diaphragm. These crura, after passing along the sides of the artery, almost meet behind it by their tendinous expansions lower down. The margin of the aortic opening is bordered with tendon, and the fleshy fibres are so connected with it that their action does

* Arcus tendineus exterior, Senac.
† Arcus tendineus interior, Id.

not at all diminish the size of the passage Along with the aorta and to its right side we see the vena azygos and thoracic duct passing into the thorax.

Some other foramina transmit vessels and nerves, but they are very small and irregular. The sympathetic nerve usually passes with the psoas muscle under the internal ligamentum arcuatum. The right splanchnic slips out of the thorax between the fibres of the right *crus*, at a point internal, superior, and anterior to the sympathetic. The left splanchnic comes in the same way, or more frequently with the aorta. The lesser splanchnic passes at the outer side of the former, separated from it by a few fibres. Behind the external ligamentum arcuatum the last dorsal nerve may be seen. Filaments of the phrenic nerve pierce the muscle in several places, principally its tendinous part, and some pass through the opening for the vena cava. And branches of the internal mammary artery creep through those cellular spaces which are left between the xiphoid cartilage and first costal attachment.

The *upper muscle* of the diaphragm is lined for the most part of its under surface by the peritoneum, and on its upper by the pleuræ and pericardium; being thus placed between serous membranes. In some points the peritoneum is reflected off to form ligaments for the liver, and there this last organ comes in contact with the muscle. The same thing occurs to a small extent in the case of the kidneys. The upper surface too is for a little way all along its margin destitute of serous covering, and in contact with the ribs, intercostal muscles, quadratus lumborum, psoas, and triangularis sterni. Over the serous membranes on the thoracic surface we find on each side the base of the lungs, and in the centre the heart resting on the middle lobe of the tendon and on some muscular fibres to its right. The abdominal surface is related to the liver, stomach, spleen, and kidneys.

The *inferior muscle* of the diaphragm has one surface turned back to the spinal column, and in contact with it and with a little of the aorta; the other surface looks forwards, and is covered by the suprarenal capsules, the semilunar ganglia, and various nerves, the aorta and its principal branches, the ascending cava, the commencement of the abdominal vena porta and its tributaries, the pancreas, stomach, duodenum, and occasionally other parts. Little or no peritoneum can touch this portion.

Arteries.—A muscle of so much importance in the animal economy as the diaphragm, and so perpetually in action, requires a large supply of blood. This it receives through numerous channels and from distinct sources; and as all its vessels inosculate freely in its substance, no failure in the supply can well occur. The phrenic and internal mammary are distributed to its middle; the same vessels, with the intercostal, the lumbal, and some small aortic twigs, feed the circumference.

Veins.—The veins of the diaphragm accompany the arteries as in other parts of the body; each artery having one or two venæ comites. The principal veins, however, correspond to the phrenic artery, and pour their blood into two trunks, a right and a left, which empty themselves into the cava. They are usually seen on the under surface of the tendon, sometimes on the upper; or there may be two above and two below. Occasionally they lie between the two surfaces, so that their entrance into the cava is not seen; and in some cases they join the hepatic veins.

Lymphatics.—The diaphragm is furnished with lymphatic vessels as other muscles, but there is nothing peculiar in them. They are not easily demonstrated, as they do not form any very distinct trunks, but join with the lymphatics of the neighbouring organs.

Nerves.—The diaphragm receives a great number of nerves. The *lumbar* send twigs to the crura, the *lower dorsal* to the broad muscle, and there is a phrenic plexus sent off from the *solar*, which accompanies the phrenic arteries, and distributes its numerous and delicate filaments with extreme minuteness to the under surface of the muscle. From the plexus which the *eighth pair* forms on the stomach, we trace also some fine filaments. But the chief and most important nerves are the phrenic. The *phrenic nerve* arises from the cervical plexus; its principal origin is from the fourth cervical nerve, to which there is usually joined a small twig from the third. It runs down along the anterior scalenus, and gets into the thorax between the subclavian artery and vein. In the neck it generally receives filaments from each cervical nerve. As it enters the thorax, it communicates with the inferior cervical ganglion, and gets a filament from the descendens noni and the pneumogastric. The nerve thus formed is conducted by the mediastinum and pericardium, in front of the root of the lung, to the diaphragm; the left being a little longer than the right, and thrown somewhat further back by the position of the heart.

It enters the diaphragm at the anterior edge of the tendon in six or seven branches, the largest of which pass backwards. Some go through the muscle, ramify on its under surface, and anastomose with the solar plexus; and one may usually be traced through the opening for the cava on to that plexus. The influence which these nerves exert on the organ will presently be adverted to.

Uses.—The chief use of the diaphragm is to assist in the function of respiration, and it will be found to be the principal agent in the mechanical part of that process. By its action the thoracic cavity is enlarged from above downwards, whilst its circumference is increased by the intercostal and other muscles.

When the diaphragm acts, the entire muscle descends, pushing the abdominal viscera downwards and forwards; but its different portions descend very unequally. The tendinous centre is nearly fixed, and the crura are incapable of much change of position; it is only in the broad lateral expansions that the motion is very apparent. The muscular fibres of these when relaxed are pressed upwards, and present arches, convex to the thorax, and rising even above the tendon; but when brought into action, each fibre approaches to a right line, which runs obliquely down from the tendon to its point of insertion. Thus, instead of a great arch we have a number of inclined planes, very short in front, very long at the sides, and of intermediate length further back, all surmounted by a tendinous platform. The base of the lung resting on the muscle descends with it; the liver, stomach, spleen, and all the moveable viscera of the abdomen are pressed downwards and forwards against the abdominal muscles. When the diaphragm descends, therefore, inspiration takes place by the rush of air into the expanding thorax; when it ascends expiration is the result, the air being forced out. In the former case the diaphragm is active; in the latter it is completely passive, following the resiliency of the lungs, and pressed up by the action of the abdominal muscles on the viscera beneath.* The central tendon descends very little on account of its attachment to the pericardium: descent here would be useless or worse; but the lateral portions on which the broad bases of the lungs rest, freely change their place, and allow of considerable expansion of the thorax where it is most required.

From viewing the insertion of the diaphragm into the lower ribs it might be thought that they would be drawn in by its action, and the capacity of the thorax thereby diminished more than increased; but the intercostals prevent this occurrence by acting at the same moment to elevate and draw out the ribs.

The crura, besides acting in common with the broad muscle in enlarging the thorax, serve to fix the central tendon, and prevent it from being drawn to either side by the irregular action of either half of the muscle, or forced too high up. They may also by their fibres continued on each side of the œsophageal orifice, and contracting in concert with the rest of the muscle, close that opening, and thus prevent regurgitation from the stomach at the time when this viscus is pressed upon by the descent of the diaphragm.

The extent to which the diaphragm descends is not great. The central tendon will not admit of much displacement in the normal state of the parts, and the shape and motions of the liver show that even the great alæ do not undergo much alteration. Haller indeed says that he saw the diaphragm descend so much in violent inspiration as to present a convexity towards the abdomen.† But this is quite incredible. The utmost muscular effort, if there were no fixed point in its centre, could only obliterate the arch; but even this we think impossible on account of its attachments. We find on some occasions one side of the diaphragm act independently of the other.

The importance of the diaphragm in respiration is shewn by the difficulty with which that function is performed when the actions of the muscle are interfered with. Ascites and tumours in the abdomen render the breathing shorter; even a full meal will have this effect, owing to the impediments to the descent of the diaphragm. If the phrenic nerves be divided in a living animal, great difficulty of breathing follows, the entire labour of respiration being thrown on the muscles which elevate the ribs. If the spinal marrow be divided above the giving off of the phrenic nerves, respiration ceases at once, but not so if divided immediately below that point; and in a case of fatal dyspnœa Beclard could find no cause but a tumour on one of the phrenic nerves.

Besides the part which it plays in respiration, it is probable that the diaphragm, by its ordinary motions, exerts a beneficial influence on the digestive organs. The liver must be more or less affected by it in its secretion, and the gall-bladder is supposed to receive from it a compression which in some degree makes amends for the want of muscular fibres,* whilst the agitation of the hollow viscera will favour the transmission of their contents.

The chyle in the lacteals and thoracic duct may also receive an impulse from the diaphragm.

Some anatomists were of opinion that the venous circulation in the abdomen was also assisted by the pressure, but the absence of valves in these vessels must prevent them from deriving any assistance from alternate compression and relaxation. It acts powerfully, however, on the venous circulation of the whole system by the vacuum which it has a tendency to form in the thorax.

The nerves which pass through the diaphragm, as the par vagum, sympathetics, and splanchnics, were formerly supposed to suffer compression, and the alternate transmission and interruption of the nervous influence, it was thought, could account for the pulsations of the heart and the vermicular motions of the intestines. But all this is too obviously erroneous to require comment.

The diaphragm assists, though rather as a passive instrument, in the expulsion of the urine, fæces, &c. For this purpose the thorax is filled with air, the rima glottidis is closed, and the diaphragm forms a resisting surface against which the abdominal muscles press the hollow viscera, and force out their contents wherever an exit is afforded them.

The diaphragm is more or less engaged in hiccup, yawning, sighing, sobbing, groaning, which are all actions connected in various ways with the function of respiration, and some of them more especially dependent on the diaphragm, particularly hiccup, which is an explosive inspiration, in which the diaphragm acts involuntarily by a short and sudden effort, a sound being at the same time produced in the larynx.

The diaphragm also performs an important part in vomiting. A full inspiration precedes this act, then the glottis is closed, and the ab-

* Senac says the anterior fibres assist in expiration by drawing the ribs inwards and backwards. Acad. des Sciences, 1729.

† In violentissima respiratione omnino vidi deorsum versus abdomen diaphragma convexum reddi. Haller, Elem. Phys. lib. viii. sect. 1.

* Senac.

dominal muscles forcibly press the stomach against the diaphragm, so as to assist the antiperistaltic motion of that viscus. Magendie made experiments to show that unless the diaphragm or abdominal muscles acted on the stomach, no vomiting could take place. He went too far, however, when he attributed the entire result to them. Substituting a pig's bladder for the stomach, he injected tartar emetic into the veins, and vomiting followed. But he forgot that pressure might readily empty a dead bladder and have little effect on a living stomach. And that such is the case we may be certain, else every cough would evacuate the stomach.

Lastly, the diaphragm acts the part of a septum or mediastinum to separate the two great cavities between which it is placed. When this septum is wanting, the abdominal viscera get into the thorax, and in such cases the lungs are constantly found in a rudimentary state: their further evolution being impeded by the pressure exerted on them by the intruding viscera.*

It has been stated that the œsophageal opening may be closed by those fibres of the crura which curve round it. The other openings, as the aortic, and that for the ascending cava, cannot be diminished by the efforts of the muscle. This is plain from the tendinous margins which they present, and the manner in which the muscular fibres are attached to their borders.

We have not mentioned some of the uses which the ancients ascribed to the diaphragm—as, that it is the seat of the passions,† that it prevented noxious vapours from rising into the thorax, that it fanned the hypochondria, and so forth. These are too fanciful to demand serious notice.

Malformations and diseases. — The diaphragm may be *absent* in whole or in part by congenital malformation. In the very young fœtus the thorax and abdomen form one cavity, as in birds, reptiles, and fishes; and the development of the diaphragm, as of most other organs, is by a process of growth from the circumference to the centre. If, therefore, an arrest of formation occur at a very early period of fœtal existence, the muscle may be entirely wanting; if at a later period, some deficiency will be found at or near the centre. An example of the total absence of the diaphragm was dissected by Diemorbroeck. The subject lived to the age of seven years without suffering any inconvenience except a frequent cough.‡ Congenital deficiencies near its middle are not very rare. They are observed oftener towards the left than the right side, and are always accompanied with a protrusion of the abdominal viscera into the thorax, not vice versâ. The development of the thoracic viscera is impeded by this intrusion, and they remain more or less rudimentary. It sometimes happens that the natural openings of the diaphragm are too large, and then protrusions or herniæ are apt to occur by the sides of the tubes which they were intended alone to transmit.

* Andral's Pathological Anatomy, tr. by Townsend and West, vol. i.

† The word *phrenic*, used with reference to the diaphragm, as *phrenic* nerve, *phrenic* centre, &c. has its origin in this opinion, φρένες, à φρὴν, *mens*, tanquam mentis sedes.

‡ Dict. des Sciences Méd. art. Diaphragme.

Openings frequently occur in consequence of disease or violence. *Ulcers* often make a perforation, and it is common enough to see an *abscess* of the liver make its way into the lung through the diaphragm. The writer lately saw an abscess, which formed in the gastrosplenic omentum, take the same course. *Wounds* often penetrate the diaphragm, and it is remarkable that however small they may be, a ventral phrenic hernia is sure to follow.

The diaphragm has been suddenly *ruptured* during violent muscular efforts, vomiting, falls, &c. and instant death has usually followed. Various examples of such ruptures are recorded in the Dictionnaire des Sciences Méd. art. Diaphragme. The countenance in all such cases assumes the peculiar expression or grin called *risus Sardonicus*.

The diaphragm is subject to attacks of inflammation, which, in almost every case, is communicated to it by the adhering pleura or peritoneum. It is indeed usually confined to one or other of these serous membranes, chiefly the pleura, and does not affect the muscular fibre. It is, notwithstanding, termed *diaphragmitis*. Hippocrates called it *phrenitis*, and Boerhaave changed the name to *paraphrenitis*, to distinguish it from a well-known cerebral affection.

Gangrene, collections of pus, tumours, &c. are occasionally met with, and are of very difficult diagnosis.

Cartilaginous and *osseous* deposits have been found on both sides of the diaphragm in the subserous cellular tissue.

The diaphragm is often considerably displaced upwards or downwards. In ascites, and in consequence of diseases of the liver and of abdominal tumours, it may be pushed up to the second rib on one side; in thoracic affections again it has been so pushed down as to become convex, in part of its extent, towards the abdomen. Senac mentions a case of great enlargement of the heart which caused the central tendon to be buried in the abdomen, it being formed into a kind of pouch.* Dr. W. Stokes found the left ala convex towards the abdomen in emphysema of the lungs,† and it is known to yield extensively to the pressure of fluid in cases of empyema, more especially if the pleura covering it has been much engaged, as the same accurate observer has noticed and explained.

For BIBLIOGRAPHY see that of Anatomy (INTRODUCTION).

(*Charles Benson.*)

DIGESTION. (Fr. *digestion*; Germ. *Verdauung*; Ital. *digestione*.) This term is employed in Physiology to designate that function by which alimentary matter is received

* Acad. des Sciences, Mem. 1729.

† Dublin Med. Journal, vol. ix. p. 37.

into an appropriate organ, or set of organs, and where it is subjected to a specific action, which adapts it for the purpose of nutrition.* In its original and technical sense this action was confined to the stomach,† but it is generally applied more extensively, so as to include a number of distinct operations, and a succession of changes, which the food experiences, after it has been received into the stomach, until a portion of its elements are separated from the mass, and are conveyed, by means of the lacteals, to the bloodvessels.

In the following article we shall employ the term in its most extensive acceptation, and shall regard the whole as one function, the successive steps of which are intimately and necessarily connected together, and each of them essential to the completion of the whole.‡ We shall commence by a description of the organs of digestion, we shall next give an account of the nature of the substances usually employed as food; in the third place we shall trace the successive changes which the food experiences in the different parts of the process; in the fourth place we shall examine some of the hypotheses that have been proposed to explain these various operations, and shall conclude by some remarks on certain affections of the digestive organs, which are connected with, or dependant upon, their functions.

I. *Description of the organs of digestion.*— The organs of digestion, taken in their most comprehensive sense, may be arranged under three divisions: the first, by which the aliment is prepared for the chemical change which it is afterwards to experience, and is conveyed into the stomach, being principally of a mechanical nature; secondly, what have been more exclusively termed the proper digestive organs, where the aliment receives its appropriate chemical changes; and lastly, those organs by which, after the nutritive substance thus elaborated has been separated from the mass, in order to be conveyed into the blood, the residuary matter is expelled from he system.§

* The term appears to have been originally borrowed from the chemists, or the chemical physiologists, who supposed that the aliment was macerated in the stomach precisely in the same manner as substances are said to be digested in various operations in the laboratory. It was a term very frequently employed by Van Helmont.—See Castelli, Lexicon, "*Digestio.*"

† Cullen's Physiol. § 201.

‡ Magendie divides the process of digestion into eight distinct actions: 1, the reception of the food; 2, mastication; 3, insalivation; 4, deglutition; 5, the action of the stomach; 6, of the smaller intestines; 7, of the large intestines; 8, expulsion of the fæces. Phys. t. ii. p. 33. Adelon and Chaussier arrange them under seven heads: appetition, gustation, mastication, deglution, chymification, chylification, and defæcation. Dict. Sc. Méd. t. ix. p. 357.

§ Adelon considers the digestive organs to consist of six essential parts: the mouth, the pharynx and œsophagus, the stomach, the duodenum, the small intestines, and the large intestines. Dict. Sc. Méd. t. ix. p. 355.

In the higher orders of animals, where the functions are more numerous, and more varied in their nature, we find them to be so intimately connected together, and dependent on each other, that it is impossible for any one of them to be suspended without the derangement of the whole. But as we descend to animals of a less perfect and complicated structure, the functions are considerably reduced in number, and seem also to be less intimately connected, so that certain of them are either altogether wanting, or are performed, although imperfectly, by other organs, which are not exclusively appropriated to them. Thus we observe that some, even of the parts which are the most essential to human existence, as the brain, the heart, and the lungs, are not to be found in many very extensive classes of animals, some of the functions belonging to these organs being entirely deficient, or being effected in a more simple or a less complete manner, by a less complicated apparatus. As we descend still lower in the scale, we find the functions still more restricted and simplified, until we arrive at the lowest term which would appear to be compatible with the existence of an organized being, where no functions remain but those which seem to be essential to the original formation of the animal and to its subsequent nutrition. That some apparatus of this description is absolutely essential may be concluded, both from the consideration, that the nutritive matter which is received into the system must undergo a certain change, either chemical or mechanical, before it can be employed for this purpose, as well as from the fact, that a stomach, or something equivalent to it, has been found to be the circumstance, which is the most characteristic of animal, as distinguished from vegetable life.* Accordingly, with a very few exceptions, and those perhaps depending rather upon the inaccuracy of our observation, than upon the actual fact, it is generally admitted, that every animal, the size and texture of which admit of its being distinctly examined, is possessed of some organ appropriated to the purposes of digestion.†

Of the three orders of parts mentioned above, the second is the only indispensable one, or that which is alone essential to the due performance of the function. In many cases the aliment is directly received into the stomach, without any previous preparation, either chemical or mechanical, and there are not a few instances in which the residuary matter is immediately rejected from the stomach, without any distinct apparatus for its removal. In the

* Smith's Introd. to Botany, p. 5; Grant, Cyc. of Anat. v. i. p. 107. Dr. Willis, on the other hand, remarks, in the same work, that nothing resembling a stomach has been found in any vegetable, p. 107.

† Sœmmering, Corp. hum. fab. t. vi. p. 229; Blumenbach's Comp. Anat. § 82. Many of the exceptions which were supposed to exist to the general rule have been removed by the interesting observations of Ehrenberg; Ann. Sc. Nat. t. ii. 2e sér.; Roget's Bridgewater Treatise, v. ii. p. 95.

following pages our main object will be to give an account of the function of digestion as it is exercised in man and in those animals which the most nearly resemble him, referring to other animals only so far as it may contribute to illustrate or explain the nature of the operation in the human species.

In the various divisions of the Mammalia the first order of parts may be arranged under the five heads of the mouth with its muscular appendages, the teeth, the salivary glands, the pharynx, and the œsophagus. With the exception of the salivary glands, the effect of these organs is entirely mechanical; it consists in the prehension, the mastication, and the deglutition of the aliment. The first of these organs may be again subdivided into three parts, the lips, the cheeks, and the tongue; the lips being more immediately adapted for seizing and retaining the food, and the others for conveying it, in the first instance, to the teeth, for the purpose of mastication, and afterwards to the pharynx, in order that it may be swallowed. In this, as in every other part of the animal frame, we perceive that adaptation of the structure of each individual organ to the general habits of the animal, which forms a constant subject of delight and admiration to the anatomist and the physiologist. In animals that feed upon succulent and luxuriant herbage the lips are capacious, strong, and pendulous, for the purpose of grasping and detaching their food, while in those that employ an animal diet, where their prey is to be seized and divided principally by means of the teeth, the lips are thin, membranous, and retractile. Again in the muscles that are connected with the cheeks, we find the same adaptation, although perhaps not in so obvious a degree. We observe that animals who receive large quantities of food, either in consequence of its being of a less nutritive nature, or from any other peculiarity in their habits and organization, as well as those whose food is of a harder consistence and firmer texture, have larger and more powerful muscles, both for the purpose of moving the jaws with greater force, and for acting upon the larger mass of matter which is taken into the mouth.

The principle of adaptation is still more remarkable in the teeth. Among the different orders which compose the Mammalia, we observe a general analogy and resemblance between the teeth, both as to their number, form, and relative position, while, at the same time, there is so great a diversity in the different tribes of animals, that some of the most distinguished naturalists have regarded these organs as the parts the best adapted for forming the basis of their systematic arrangements, inasmuch as they afford the most characteristic marks of the habits of the animals, and of the peculiarities of their other functions.* Thus, by an inspection of the teeth we can at once discover whether the individual is intended to employ animal or vegetable food, some of them being obviously adapted for seizing and lacerating the animals which they acquire in the chace or by combat, while the teeth of others are obviously formed for the cropping of vegetables, and for breaking down and triturating the tough and rigid parts of which they principally consist. It is with a view to this double purpose of prehension and mastication that the great division of the teeth into the incisors and the molares, the cutting and the grinding teeth, depends, the former being of course situated in the front of the mouth, the latter in the sides of the jaws. The chemical composition and mechanical texture of the teeth is no less adapted to their office of dividing and comminuting the food than their figure and position. They are composed of nearly the same materials with the bones generally, but their texture is considerably more dense and compact, while they are covered with an enamel of so peculiarly firm a consistence, as to enable them, in many kinds of animals, to break down and pulverize even the hardest bones of other animals, and to reduce them to a state in which they may be swallowed, and received by the stomach, in the condition the best adapted for being acted upon by the gastric juice.*

At the same time that the alimentary matter is subjected to the mechanical action of the teeth, it is mixed with the fluids that are discharged from the salivary and mucous glands, which are situated in various parts of the mouth. The use of the saliva is to soften the food, and thus render it more easily masticated, to facilitate its passage along the pharynx and œsophagus, and perhaps, by a certain chemical action, to prepare it for the change which it is afterwards to experience, when it is received into the stomach.†

The food, after it has been sufficiently divided by the teeth, and incorporated with the saliva, is transmitted, by the act of deglutition, into the stomach. There is perhaps no part of the system, which exhibits a more perfect specimen of animal mechanism than the process of deglutition. It consists in the successive contraction of various muscles, that are connected with the contiguous parts, each of which contributes to form a series of mechanical actions, which, when connected with each other, effect the ultimate object in the most complete manner. The muscles of the mouth and the tongue first mould the masticated aliment into the proper form, and transmit it to the pharynx; this part is, at the same time, by the cooperation of other muscles, placed in the most suitable position for receiving the alimentary mass, and transmitting it to the œsophagus, while another set of mus-

* Linnæus, Sys. Nat. t. i. p. 16 et alibi; Shaw's Zool. v. i. Introd. p. vii et alibi.

* Hatchett, in Phil. Trans. for 1799, p. 328-9; Berzelius, View of Animal Chemistry, p. 78; Pepys, in Fox on the Teeth, p. 92 et seq; Turner's Chemistry, p. 1012.

† For the opinions that were entertained by the older physiologists on this point the reader is referred to Baglivi, Diss. 2, circa salivam, op. p. 412 et seq.; also to Haller, El. Phys. 18. 2. 13.

cles causes the epiglottis to close the passage into the larynx. The muscular fibres of the œsophagus itself are now brought into play, and by their successive contraction, propel the food from the upper to the lower part of the tube, and thus convey it to its final destination. These three stages, which altogether constitute a very complicated train of actions, are so connected with each other, that the operation appears to be of the most simple kind; it is one of the first that is performed by the newly born animal, and is exercised during the whole period of existence with the most perfect facility.*

The food, after having thus experienced the action of the first order of parts, which, as we have seen above, is principally, if not entirely, of a mechanical nature, is finally deposited in the stomach. The stomach is a bag of an irregular oval form, which lies obliquely across the upper part of the abdomen, in what is termed, from the presence of this organ, the epigastric region. The structure of the stomach, considered in its physiological relation, is threefold. A large portion of it is composed of membranous matter, which gives it its general form, determines its bulk, and connects it with the neighbouring parts, constituting its external coat. To the interior surface of this coat are attached a number of muscular fibres, by which the various contractile actions of the stomach are performed; these, although not capable of being exhibited as a connected or continuous structure, are considered, according to the custom of the anatomists, as composing the muscular coat, while its internal coat consists of a mucous membrane, which appears to be the immediate seat of the secreting glands, from which the stomach derives its appropriate fluids. But besides this, which may be regarded as the physiological structure of the stomach, by which its parts are so arranged as to give the organ its form and position, its contractile power, and its chemical action, the anatomists have resolved it into a greater number of mechanical divisions, depending principally upon the minuteness to which they have carried their dissections. In this way no less than six or even eight distinct strata or coats have been assigned to the stomach. First, the peritoneal covering, which it has in common with all the other abdominal viscera, the dense membrane which more especially gives the stomach its form, called in the language of the older writers the nervous coat, two muscular coats,† one composed of longitudinal and the other of circular fibres, and the innermost, or, as it has been termed, the villous coat, together with three cellular coats, which are situated between the former and connect them with each other. The nervous coat is usually described as being the seat of the glands, as well as of the bloodvessels, nerves, and absorbents which belong to the stomach; but although they cannot perhaps be actually traced beyond this part, there is some reason to suppose that their ultimate destination is on the innermost or villous coat.

The membranous part of the stomach appears to be peculiarly distensible, so as readily to admit of having its capacity greatly and suddenly increased, in order to contain the large quantity of solids and fluids that are occasionally received into it, while its muscular fibres and nerves are possessed respectively of a high degree of contractility and sensibility, by which they act powerfully on its contents, propelling them, when necessary, into the duodenum, and thus reducing the bulk of the stomach to its ordinary standard. Besides the mucous fluid which the inner surface secretes, in common with all other membranes of this description, the stomach is supposed to possess certain glands, adapted for the formation of a specific fluid, termed the gastric juice, which acts an important part in the process of digestion; but the presence of these glands has been rather inferred from their supposed necessity, than from any actual observation of their existence.*

From the peculiar form and disposition of what have been termed the muscular coats of the stomach, they not only enable the organ to contract in its whole extent and in all directions, but they give to its individual parts the power of successively contracting and relaxing, so as to produce what has been termed its peristaltic or vermicular motion.† The effect produced appears to be, in the first instance, to form in the interior of the stomach a series of folds or furrows, and at the same time to agitate the alimentary mass, so as to bring every part of it, in its turn, within the influence of the gastric juice, while the whole of the mass is gradually carried forwards towards the pylorus, and is in due time discharged from that orifice. The muscular fibres of the stomach, like all those that are connected with membranous expansions, forming what are termed muscular coats, are not under the control of the will.

In consequence of the great degree of vitality which the stomach possesses, a circumstance in which it is surpassed by scarcely any organ in the whole body, it is very plentifully provided with bloodvessels and with nerves. The arteries, according to the ordinary construction of the system, are furnished by the contiguous large trunks,

* For a minute account of the process of deglutition generally we may refer to Boerhaave, Præl. t. i. § 70..2, Haller's Phys. by Mihles, lect. 23; Prim. Lin. cap. 18, § 607..621; El. Phys. xviii. 3. 21..5; Dumas, Physiol. t. i. p. 341..353, who divides the act of deglutition into four stages, and to Magendie, Physiol. t. ii. p. 54..67, who reduces them to three.

† Boyer, ubi supra, supposes that the muscular fibres are arranged in three layers. See also Elliotson's Physiol. p. 78.

* Winslow's Anat. Sect. viii. § 63..5; Haller, El. Phys. xix. 1. 14; Bell's Anat. v. iv. p. 58.

† Haller, El. Phys. xix. 4. 9, 0; Boyer, Anat. t. iv. p. 333..5; Bertin, Mém. Acad. pour 1760, p. 58 et seq.; this writer appears to have been one of the first who gave us a correct description of the muscular coats of the stomach.

while the veins, in common with all those that belong to what are termed the chylopoietic viscera, terminate in the vena portæ.* The nerves of the stomach are not only very numerous, but they are remarkable for the number of different sources whence they derive their origin. These are, in the first instance, threefold; it is furnished with a large quantity of ganglionic nerves, in common with all the neighbouring viscera; it likewise receives nerves directly from the spinal cord, and unlike all the other parts of the body, except what are termed the organs of sense, it has a pair of cerebral nerves in a great degree appropriated to it. The specific uses of these different nerves are not certainly ascertained, and it would scarcely fall under the immediate object of this treatise to enter upon the consideration of this point; but we may observe, that no organ, in any part of the body, partakes more fully of what may be considered as the actions of the nervous system, or is more remarkably affected by its various changes, including not merely those of a physiological nature, but such likewise as are connected with the various mental impressions.†

The two extremities of the stomach, by which the food is received and discharged, are respectively termed the cardia and the pylorus. Their structure, in many respects, differs from that of the other parts of the organ. The cardia is remarkable for the great proportion of nerves which are distributed over it, and as these are principally derived from the par vagum, or the eighth pair of cerebral nerves, we may understand why this should be the most sensitive part of the stomach. The pylorus is remarkable for the mechanical disposition of its muscular fibres, which form an imperfect kind of sphincter, by which the food is detained in the cavity until it has experienced the chemical action of the gastric juice. And besides the functions which are actually possessed by this part, many imaginary and mysterious powers were ascribed to the pylorus by the older physiologists. The sensibility of the stomach was supposed to reside more especially in this extremity; it was selected by some of the visionary philosophers of the sixteenth and seventeenth centuries as being the seat of the soul, and even some of the moderns ascribe to it a kind of intelligence or peculiar tact, by which it is enabled to select the part of the alimentary mass, which has been sufficiently prepared to enter the duodenum, while it prevents the remainder from passing through its orifice, and retains it for the purpose of being still farther elaborated.‡

On account of the form and position of the stomach it is sufficiently obvious, that a considerable proportion of its contents must be, at all times, below the level of the pylorus. The food is hence prevented from passing too hastily out of the organ, while we may conclude that the transmission of the food is almost entirely effected by the contraction of its muscular fibres, aided probably by the diaphragm and the abdominal muscles, but scarcely in any degree by the mere action of gravity.* It must, however, be observed that the position of the stomach generally, with respect to the neighbouring organs, as well as the relation of its different parts to each other, varies considerably according to its state of repletion; when it is the most fully distended, its large arch, which previously was pendulous, is now pushed forwards and raised upwards, so as to be nearly on the same level with the pylorus.†

When the food leaves the stomach, it is received by the intestinal canal, a long and winding tube, which varies much in its diameter and its form, in the different parts of its course, but which, both in its anatomical structure and in its physiological functions, bears a considerable resemblance to the stomach. It may be said, in the same manner, to consist of three essential parts, the membranous, the muscular, and the mucous, which respectively serve to give it its form, to enable it to propel its contents, and to furnish the necessary secretions. With respect to the form of its individual parts, it has been divided, in the first instance, into the large and small intestines, a division which depends upon the comparative diameter of the two portions, while each of these has been subdivided into three parts, depending more upon their form and their position than upon their structure or functions.

But although it may be supposed, that the division of the tube into the great and small intestines refers to their difference of size alone, it is to be observed that they perform very different functions, and are subservient to very different purposes in the animal œconomy. It is in the small intestines, and more especially in the first portion of them, termed the duodenum, that what must be considered as the most essential or specific part of the function of digestion is effected, the formation of chyle, while it is almost exclusively in the duodenum and the other small intestines, the jejunum and the ileum, that the chyle thus produced is taken up by the lacteals, in order to be conveyed to the thoracic duct, and finally deposited in the bloodvessels.

The use of the large intestines, and more especially of the colon, which constitutes a considerable proportion of the whole, appears to be more of a mechanical nature, serving as a deposit or reservoir, in which the residuary matter is received and lodged, for a certain period, until it is finally expelled from the system. The division between the parts of the small intestines, to which the names jejunum and ileum have been applied, is entirely arbitrary, as they appear to be precisely similar to each other, both in their structure and their functions. But the case is very different with respect to the duodenum, which in both these respects possesses a clearly marked and distinctive character. Of

* Winslow, sect. viii. § 2. 72..7; Haller, El. Phys. xix. 1. 16..20; Blumenbach, Inst. Physiol. § 356; Bell's Dissect. p. 19..25. pl. 3, 4.

† Winslow, ubi supra, 78, 9; Haller, xix. 1. 21; Blumenbach, § 355; Bell's Anat. v. iv. p. 64; Walter, Tab. nerv. No. 3, 4.

‡ Richerand, Physiol. § 23. § 111, 2.

* Haller, ubi supra, § 2..4.

† Blumenbach, § 353.

this anatomists have long been well aware, and it has accordingly been made the object of particular attention, and has even received the appellation of the accessory stomach; but we shall enter more particularly into the consideration of this subject when we come to treat upon the difference between chyme and chyle, and the nature of the process by which it is effected.

The peculiarities of the digestive organs in the different classes of animals are interesting, not merely as affording remarkable examples of the adaptation of the animal to the situation in which it is placed, but are especially worthy of our notice on this occasion, as serving to illustrate the nature of the operation generally, and the mode in which its various stages are related to each other. The most remarkable examples of this kind are the complicated stomachs of the ruminant quadrupeds, and the muscular stomachs of certain classes of birds.*

The ruminant animals belong to the class of the mammalia, and are such as feed principally upon the stalks and leaves of plants. The quantity of food which they take is very considerable; it is swallowed, in the first instance, almost without mastication, and is received into the first stomach, a large cavity, which is termed the *venter magnus*, *panse*, or *paunch*.† The food, after remaining for some time in this stomach, for the purpose, as it would appear, of being macerated, is next conveyed into the second stomach, a smaller cavity, the internal coat of which is drawn up into folds that lie in both directions, so as to form a number of angular cells, from which circumstance it has received the appellation of *reticulum*, *bonnet*, or *honeycomb*. The reticulum is provided with a number of strong muscular fibres, by which the food is rounded into the form of a ball, and is propelled along the œsophagus into the mouth. It is now completely masticated, after having been properly prepared for the process by its previous maceration in the paunch; this mastication constitutes what has been termed chewing the cud, or rumination.

When the food has been sufficiently comminuted it is again swallowed, but by a peculiar mechanism of muscular contraction the passage into the venter magnus is closed, while an opening is left for it to pass into the third stomach, termed *omasum*, *feuillet*, or *maniplics*; it is smaller than any of the other cavities, and its internal coat is formed into a series of strong ridges and furrows, but without the transverse ridges of the reticulum. From the omasum the food is finally deposited in the fourth stomach, the *abomasum*, *caillette*, or *reed*, a cavity considerably larger than either the second or third stomach, although less than the first. It is of an irregular conical form, the base being turned to the omasum; it is lined with a thick mucous or villous coat, which is contracted into ridges or furrows, somewhat in the manner of the omasum, and it appears to be that part of the digestive apparatus which is analogous to the single stomach of the other mammalia, where the aliment undergoes the process of chymification, the three first stomachs being intended to macerate and grind it down, in order to prepare it for the action of the gastric juice. (See RUMINANTIA.)

Although we conceive that the operation of the different parts of this complicated apparatus is pretty well understood, it still remains for us to inquire into the final cause of the arrangement, or why the maceration and mastication of the food in certain classes of animals should be effected in a manner so different from what it is in others, which, in their general structure and functions, the most nearly resemble them. The opinion which was entertained on this subject by the older anatomists, and which may be still regarded as the popular doctrine, is, that the nature of the food of these animals, and the large quantity of it necessary for their support, requires a greater length of time for its comminution and a greater quantity of the mucous secretions than it could obtain by the ordinary process. But although there may be some foundation for this opinion, the more extended observations of modern naturalists show, that it does not apply in all cases, and that there are so many exceptions to the general rule as to lead us to doubt the truth of the position.* It is to be observed, that when animals with ruminant stomachs take in liquids, the fluid passes immediately into the second stomach,† where it is mixed with the aliment after it has been macerated in the venter magnus, and probably moulds it into the proper form, for its return along the œsophagus into the mouth. While the young animal is nourished by the mother's milk, the fluid is conveyed, in the first instance, through the third stomach into the fourth, and it is not until it begins to take solid food, that the process of rumination is established. It is hence concluded, that the animal possesses the power of conveying the food at pleasure either into the first or the third stomach, and of returning it from the second into the mouth;‡ these, like many other voluntary acts, being of the kind which are termed instinctive.

The other kind of stomach which we referred to above as possessing a peculiar structure, and acting on a different principle from that of the human species, is the muscular stomach of certain classes of birds. Birds are not provided with teeth, or with any apparatus which can directly serve for the process of mastication; yet many of them feed upon hard substances, which cannot be acted upon by the gastric juice, until they have undergone some process, by which they may be comminuted or ground down into a pulpy mass. This is effected by the *ingluvies*, the *craw* or *crap*, and the *ventriculus bulbosus* or *gizzard*. The first

* For an interesting account of the comparative anatomy of the digestive organs we may refer to Carus's Comparative Anatomy, by Gore, v. ii. p. 72 et seq.

† We have selected the terms by which each of the four stomachs is usually designated in Latin, French, and English respectively; there are, however, various other names which have been applied to them.

* Blumenbach's Comp. Anat. p. 138. note 20.

† Home, ubi supra, p. 363.

‡ Blumenbach, ubi supra, p. 138. note 18; Ray's Wisdom of God, &c., p. 188.

of these is a large membranous bag, analogous to the paunch of the ruminants, into which the food, without any previous alteration, is received from the œsophagus, and where it is macerated in the usual manner by the conjoined action of heat and moisture.

The gizzard is of much smaller dimensions than the crop, composed of four muscles, two of which are of a flattened form and of very dense texture, lined internally with a firm callous membrane, and capable of an extremely powerful action. These constitute the main part of the parietes, the two other muscles being much smaller, and situated at the extremities, serving, as it would appear, merely to complete the cavity.* The gizzard is so connected with the crop, that the food, after due maceration, is allowed to pass by small successive portions between the two larger muscles; by their contraction they are moved laterally and obliquely upon each other, so that whatever is placed between them is completely triturated. The force of these muscles, as well as the impenetrability of their investing membrane, is almost inconceivably great, so that, according to the experiments of Spallanzani and others, not only are the hardest kinds of seeds and grains reduced to a perfect pulp, but even pieces of glass, sharp metallic instruments, and mineral substances, are broken down or flattened, while the part still remains uninjured.† The action of both the crop and the gizzard must be regarded as at least essentially mechanical, mainly adapted for the purposes of maceration and trituration, and as compensating for the saliva and teeth of man and the greatest part of the mammalia. We are able in this case to observe the connexion between the habits of the animals and the peculiarities of their organs more clearly than with regard to the ruminants, for we can always perceive an intimate relation between the food of the different kinds of birds and the structure of their stomach.

II. *An account of the nature of the substances usually employed as food.*—All the articles that are employed in diet may be arranged under the two primary divisions of animal and vegetable, according to the source whence they are derived. Those in which the distinctive characters are the most strongly marked differ both in their proximate principles and their ultimate elements, although in this, as in most other cases, there are many intermediate shades. The ultimate elements of vegetables are oxygen, hydrogen, and carbon, to which, in some cases, a portion of nitrogen is added. Animal substances contain all these four ingredients, the carbon being in less quantity than in vegetables, while the hydrogen, and still more the nitrogen, are generally in much greater quantity. There are various circumstances which seem to prove that either species of diet is alone competent to the support of life, although each of them is more especially adapted to certain classes of animals. This, it is probable, depends both upon the chemical and the mechanical nature of the substances in question, but perhaps more upon the latter than the former, for we find that the processes of cookery, which act principally upon mechanical principles, render various substances perfectly digestible, which the stomach could not act upon before they had undergone these operations. We also find that animals, which, in their natural state, have the strongest instinctive predilection for certain kinds of food, may, by a gradual training and the necessary preparation of the articles employed, have their habits entirely changed, without their health being in any degree affected.

There is, however, a circumstance in the structure of the animal, which clearly points out a natural provision for the reception of one species of food in preference to the other, viz. the comparative capacity of the digestive organs. It may be concluded that, in all cases, the aliment must undergo a certain change before it can serve for the purpose of nutrition, and that this change will occupy a greater length of time, and that a greater bulk of materials will be requisite, according as the nature of the food received into the stomach is more or less different from the substance into which it is to be afterwards reduced. Hence, as a very general rule, we find that the digestive organs of carnivorous animals are less capacious than those of the herbivorous, and that even in the latter there is a considerable difference, according as the food consists of seeds and fruits or of the leaves and stems of plants.

There are indeed certain circumstances in the habits of some of the carnivora which require organs of considerable capacity, as, for example, those beasts of prey who take their food at long intervals, being supplied, as it were, in an occasional or incidental manner, so that it becomes necessary for them to lay up a considerable store of materials, and to take advantage of any opportunity which presents itself of replenishing the stomach. The anatomical structure of the human digestive organs indicates that man was intended by nature for a mixed diet of animal and vegetable aliment, but with a preponderance towards the latter;* and it appears in fact that, while a suitable combination of the two seems the most conducive to his health, and to the due performance of all his functions, either species is alone competent to his growth and nutrition.†

* Grew, ubi supra, p. 34; Blumenbach, ubi supra, § 99; Peyer, Anat. Ventr. Gall., in Manget, Bibl. Anat. t. i. p. 172; Hunter on the Animal Œconomy, p. 198-9; Clift, in Phil. Trans. for 1807, pl. 5, fig. 1; Home's Lect. v. ii. pl. 49, 62; and the art. AVES.

† Spallanzani, Dissert. i. § 5..8, and 10..22; see also Acad. del Cimento, p. 268,9; Borelli, De motu anim. t. ii. prop. 189; Redi, Esperienze, p. 89 et seq.; Grew, ch. 8; the art. "Birds" in Rees; and "Aves" by Mr. Owen, in the present work.

* Cuvier, Règne Animal, t. i. p. 86; Lawrence's Lect. p. 217 et seq.; see also the elaborate dissertation of Richter, De victus animalis antiq. &c.

† Haller, El. Phys. xix. 3. 2..4; these sections contain a very full account of the different kinds of diet employed by different nations or individuals. We have a number of curious facts of this kind in

The most important of the proximate principles employed in diet are fibrin, albumen, oil, jelly, gluten, mucilage, farina, and sugar, to which may be added some others of less frequent occurrence. They are derived, more or less, from almost all the classes of animals and vegetables, and from nearly all their individual parts, their employment being regulated, in most cases, rather by the facility with which they are procured, and reduced into a form proper to be acted upon by the stomach, than by the quantity of nutritive matter which they contain. This is one of those subjects in which we have to notice the remarkable effects of habit and custom, both on the functions and the sensations. We find whole tribes of people living on a diet, which, to those unaccustomed to it, would be not only in the highest degree unpalatable, but likewise altogether indigestible; while, by the various modes of preparing food, which have been suggested, either by luxury or by necessity, the most intractable substances are reduced into a digestible state.*

The writers on dietetics have attempted to include all substances that are competent to afford nutrition under a few general principles, of which, as they exist in nature, they are supposed to be composed. Cullen, who may be considered as the first who attempted to introduce correct philosophical principles into this department of physiology, reduced them to two, the oily and the saccharine, and endeavoured to prove that all the animal fluids may be referred to these principles.† Magendie, on the contrary, proceeding less upon their chemical composition than upon the forms under which they present themselves, classes alimentary substances under the nine heads of farinaceous, mucilaginous, saccharine, acidulous, oily, caseous, gelatinous, albuminous, and fibrinous.‡ Dr. Prout, whose views on this subject are marked by his characteristic acuteness, reverts to the mode of Cullen, admitting only of the oily, the saccharine, and the albuminous principles, which three, he conceives, form the "groundwork of all organized bodies."§

Of animal compounds which are employed in diet milk may be regarded as holding the first place, both from its nutritive and its digestible properties, and as such it has no doubt been provided by nature for the newly-born animal, when it requires a diet, which may be adapted to the delicacy of its organs in its novel state of existence, while, at the same time, it provides for its rapid growth. We accordingly find that the three principles mentioned above are combined in milk in a manner the most proper for this double purpose, and that there is no compound, either natural or artificial, which is equally well suited to it.* Next to milk, with respect to its nutritive properties, we may class eggs of various kinds, the muscular fibre of animals, and their gelatinous and albuminous parts, very few of which, however, are employed in diet until they have undergone the various operations of cookery. Of these operations the most important in their dietetical effect is the formation of decoctions or infusions, constituting soups of all descriptions, in which we retain the more soluble, and, for the most part, the more nutritive matter, while the residue is rejected. The fish which are usually employed in diet consist of a much greater proportion of jelly and albumen than the flesh of the mammalia and of birds; these principles are united, in most cases, with a considerable quantity of oil.

The most nutritive of the vegetable proximate principles is gluten; it forms a considerable proportion of certain kinds of seeds, and more especially of wheat, and we accordingly find that in all those countries which admit of the growth of this plant, and which have arrived at any considerable degree of civilization, wheaten bread forms the most important article of vegetable diet, and one which appears the best adapted for all ages and all constitutions. Next to gluten we may rank farina, both from its valuable properties and from the extent to which it is employed. It enters largely into the composition of wheat and of the other seeds of the cerealia, also of rice and maize, while it constitutes a great proportion of the whole substance of the leguminous seeds and of tubers. It also forms the principal ingredient of the chesnut, and of the esculent algæ, so that, upon the whole, we may consider it as entering more largely into the aliment of mankind, in all different climates and situations, than any other vegetable compound.

Perhaps there is no proximate principle which contains in the same bulk a larger proportion of nutritive matter than oil, and we accordingly find that oil, as derived either from the animal or vegetable kingdom, enters largely into the diet of all nations. But it affords an example of one of those articles, which, although highly nutritious, is not very digestible without a due admixture of other substances, which may in some way render it more proper for the action of the gastric juice.† It may

Stark's works, p. 94, 5; see also Lorry, Sur les alimens; Plenk, Bromatologia; Sœmmering, Corp. hum. fab. p. 241, 250; Richerand, El. Phys. § 3, p. 83; Parr's Dict. art. Aliment; Pearson's Synopsis, part i.; Lawrence's Lect. p. 201, 9; Thackrah's 2d Lect. on Diet, p. 54 et seq.; Paris on Diet; Roget's Bridgewater Treatise, part 2, ch. 3, § 1.

* Elliotson's Physiol. p. 65, 6; Roget, part 2, ch. 3, § 1.

† Physiol. § 211, and Mat. Med. v. i. p. 1, ch. 1, p. 218 et seq.

‡ Physiol. t. ii. p. 3, 4; see also Fordyce on Digestion, p. 84 et seq.; Paris on Diet, part 2, p. 117 et seq.; Richerand, El. Physiol. § 3, p. 82; Dumas, Physiol. t. i. p. 187; Davy's Lect. on Agric. Chem. p. 73 et seq.; Londe, Dict. de Méd. et de Chir. art. "Aliment," t. ii. p. 1 et seq; Rostan, Dict. de Méd. art. "Aliment," t. i. p. 523 et seq.; Rullier, Ibid. Art. "Nutrition," t. xv. p. 161 et seq.; Kellie, in Brewster's Encyc. Art. "Aliment."

§ Abstract of his Gulstonian Lecture, p. 5, 9.

* Prout, ut supra, p. 12.

† It is upon this principle, rather than to the absence of azote, that we should be disposed to account for the results of Magendie's experiments, in which

indeed be received as a very general rule that a certain quantity of matter, which in itself contains but a small proportion of the principles which immediately serve for nutrition, is necessary for the due performance of the functions of the stomach, probably in some degree for the purpose of mere dilution or mechanical division. The same remark applies to sugar as to oil. Sugar would appear to be one of the most nutritive of the proximate principles, but when taken alone or in too great quantity it deranges the digestive organs, and becomes incapable of supporting life.*

The difference in the different kinds of aliment between their capacity of affording the materials from which chyme may be produced, and the facility with which they are acted upon by the stomach, or in ordinary language, between their nutritive and their digestible quality, has been distinctly recognized by various physiologists,† although it has not always been sufficiently attended to. We have some striking illustrations of the fact in a series of experiments which were performed by Goss,‡ and in those of Stark,§ where the digestibility and the nutrition of various species of aliment bore no relation to each other, while they afford the most decisive proof of the advantage, or rather the necessity, of a mixture of substances, in order to produce the compound which is the best adapted for the action of the stomach.

We have referred above to the difference in the digestive powers of the stomachs of different classes of animals as depending on their peculiar organization. In many instances the difference is so strongly marked as to leave no doubt either as to its existence or as to the cause by which it is directly produced. But there are many cases where we observe the effect without being able to assign any immediate cause for it; where substances, which are highly nutritive and perfectly salutary to certain individuals, are apparently incapable of being digested by others. After making all due allowance for the effects of habit, association, or even caprice, there still appears sufficient ground for concluding that there are original differences in the powers of the stomach, which cannot be assigned to any more general principle. This observation applies principally to the individuals of the human species, where such variations, or, as they have been termed, idiosyncrasies, of all descriptions are much more apparent than in any other kind of animals. All other animals, even those which the most nearly resemble the human species, are much more uniform in this respect, being guided in the choice of their food principally by that instinctive feeling which leads them to select the substances which are the best adapted for their organs. But even here we meet with certain peculiarities, where animals prefer certain kinds of aliment, and where there is no obvious anatomical or physiological cause which can explain the effect. This, however, we may regard as an exception to the general rule, for there is perhaps no one of the functions in which we are enabled more clearly to trace the adaptation of the organ to the structure and habits of the animal, than in what respects the supply of nutrition, including the mode of procuring the food, and the whole of the series of changes which it experiences from the digestive organs.*

Liquids of various kinds constitute an important part of the diet of almost all individuals. They may be arranged under the two divisions of those liquids which we employ merely for the purpose of quenching thirst, or diluting our solid food, or such as are made the vehicles of nutriment, including various kinds of decoctions and infusions. The latter are derived both from the animal and the vegetable kingdoms, and when duly prepared form a species of food, which, as containing the most soluble and the most sapid portions, is, in most cases, both highly nutritive and digestible. But we observe here the same kind of idiosyncrasy to which we referred above, and which it frequently becomes necessary to attend to in the directions that are given respecting diet, and more especially to invalids and to children.

The liquids that are employed for the purpose of quenching thirst, which are more properly styled drinks, may be arranged under the two heads of vegetable infusions or decoctions and fermented liquors. Of the former a great variety have been employed in different countries and at different periods, but in Europe, almost the only kinds which are in common use are tea and coffee. These cannot be considered as in themselves affording any nourishment, but they are generally employed with the addition of some nutritive substance, and if not taken in excess, would appear to promote digestion, and to exercise a favourable influence on the system at large.

It has been observed that all tribes of people that have made the least advances in the arts of life, either by accidental observation or by tradition, have become acquainted with the process of fermentation, and have indulged in the use of certain species of vinous liquors. The making of wine is among the first transactions that are recorded of Noah after he left the ark, and the experiment which he made of its effects has been but too frequently repeated by his progeny. The basis of all vinous liquors being the saccharine principle, the grape has been naturally had recourse to in all those parts of the world which are adapted to the growth of the vine; in the more northern regions, as in our own island, different species of grains are employed, in which the sugar is evolved by an artificial process, while in the torrid zone,

he found that animals could not be fed upon pure sugar, oil, or gum; Physiol. t. ii. p. 390, and Ann. Chim. et Phys. t. iii. p. 66 et seq.; see Bostock's Physiol. v. ii. p. 467, 8.

* Haller, El. Phys. xix. 3. 12; Stark's Works, p. 94 et alibi; Pearson's Synopsis, p. 104, 5.

† Adelon et Chaussier, Dict. Sc. Méd. Art. "Digestion," t. ix.

‡ Spallanzani, Sur la Digestion, par Senebier, n. cxxxi...cxl.

§ Works, p. 89 et seq.

* Bostock's Physiol. v. ii. p. 469, 70.

other saccharine juices, procured from certain tropical plants, are employed for the same purpose. The fermented liquors of our own country generally contain a considerable quantity of mucilaginous and saccharine matter, which still remains undecomposed, and which is directly nutritive; but fully fermented wines are only indirectly so, as aiding the digestive powers by their stimulating effect on the stomach.

It is generally admitted, that the operation of alcohol, when properly diluted, and when taken in moderate quantity, is favourable to the health of most individuals who are engaged in laborious pursuits, and have occasion to exert the full powers of the system. But the almost irresistible temptation to excess, and the fatal consequences which thence ensue, both to our physical and our mental constitution, have long been the subject of deep regret and severe reprehension, both to the physician and the moralist, and it may be asserted, that of all the gifts which providence has bestowed on the human race, there is none which, according to the present state of society, would appear of such dubious advantage as the knowledge of the process by which one of the most nutritive articles of diet is converted into one of the deadliest poisons.

We have now to notice a class of substances very generally employed in diet, which are not in themselves nutritive, but are added to our food, for the purpose of rendering it more agreeable to the palate. These are the various articles styled condiments; they may be classed under the two heads of salts and spices. There is so very general a disposition among all classes of people in all countries to relish sapid food, that we are led to conceive that there must be some final cause for it, independent of the mere gratification of the senses, or that this gratification is made subservient to some more important purpose. With respect to what is termed common salt, the muriate of soda, we observe, in many cases, the same relish for it among the lower animals as in man. We have well authenticated accounts given us, by various travellers and naturalists, of the extraordinary efforts which are made by the beasts of prey which inhabit the great African and American continents, to obtain it.* We can scarcely therefore doubt that it must be, in some way or other, essential to the well-being of the animal; but whether it directly promotes the process of chymification, or whether it be taken into the stomach, for the purpose of being transmitted to the blood, and thus furnishing to the system the portion of saline matter which is always present in the animal fluids, must be considered as entirely conjectural.†

The other division of condiments, the spices, are very numerous, and are derived from various sources, but are chiefly of vegetable origin. They are generally of a stimulating nature, and such as may be supposed to act, in the first instance, on the nervous system. Some of them increase the action of the heart and arteries, and some of them augment the secretions or excretions, but they differ essentially from alcohol, in not producing any thing resembling intoxication and the subsequent exhaustion. Thus they are much less injurious to the constitution, even when taken to excess, and are seldom liable to any stronger imputation than that of being useless. They afford some of the most remarkable examples of the effect of habit on the system, in changing or modifying our original perceptions, for it is very generally found that those substances to which we become, in process of time, the most attached, are such as, in the first instance, were not only perfectly indifferent, but even positively disgusting.

Before we quit this part of the subject it remains for us to say a few words respecting the class of substances which are properly termed medicaments. The medicaments are nearly related to the condiments in their action on the system, but with this difference, that they are not only disagreeable to the palate, but are, for the most part, incapable of being reconciled to it by habit. But there is in fact no exact line of demarcation between them; many of the articles which are usually considered as condiments, being not unfrequently used in medicine, and some of what are generally regarded as the most active and nauseous medicines, being employed by some individuals as agreeable condiments. Both these classes of substances appear to differ in one essential particular from what are more properly regarded as articles of diet, that while it is essential to the operation of the latter, that they should be decomposed, and probably resolved into their constituent elements, the specific effect of the former seems to depend upon their acting on the stomach in their entire state. Nearly connected to this class of substances, and indeed differing from it only in degree, are the articles that are usually termed poisons. The term may, however, be regarded as entirely a popular designation, for as there is no active medicine which may not immediately destroy life by an excessive or improper administration, so there are no substances, among those which are usually considered as poisonous, which may not, under certain circumstances, prove valuable medical agents.

III. *An account of the changes which the food experiences in the process of digestion.*—We now proceed to the consideration of the third subject which we proposed for our inquiry, the nature of the change which the food undergoes during the process of digestion. In prosecuting this inquiry we shall consider in succession the various processes by which the aliment, after being received into the mouth, is brought into the state of chyle. These changes may be reduced essentially to three; the mechanical division of the food, as effected by the operations of maceration, mastication, and trituration; the conversion of the alimentary mass into chyme, by the action of the gastric juice;

* Among these we may select the account given us by Mr. Hodgson, in his interesting letters from North America, vol. i. p. 240, 1, note.

† Haller, El. Phys. xix. 3, 11; Fordyce on Digestion, p. 55.

and lastly, the conversion of chyme into chyle in the duodenum.*

After the account which we have given above of the organs of mastication, nothing further remains for us to say on the first part of the process; we may therefore conceive that the food, after it has been mechanically divided by means of the teeth or any analogous organ, is conveyed to the stomach, in order to be acted on by the gastric juice and converted into chyme.† The process of chymification consists in a certain chemical change, by which the aliment, from whatever source it may have been derived, and whatever may have been its original constitution, is converted into a uniform pultaceous mass, having certain specific properties, which are different from those of the substances from which it is formed.

And we may here observe, that this kind of change, which has been frequently spoken of as something of a mysterious or inexplicable nature, is perfectly analogous to what takes place in all chemical action, where the addition of a new agent imparts new properties to the mixture. The supposed difficulty in this case has arisen from an indistinct conception in the minds of many physiologists, both of the nature of chemical action generally, and of the appropriate powers which belong to a living organized system. The essential and exclusive functions of vitality may probably be all reduced to two great principles of sensation and motion, as depending primarily upon the action of the nerves and the muscles. Chemical affinity is independent of these principles, but it is, in various ways, modified by their operation, by bringing the agents into contact, by separating them from each other, and thus enabling them to produce new compounds, and when the compounds are formed, by removing them from the further action of the agents, and by conveying them to the situations when they are required, for the exercise of some new function. In the present case the glands of the stomach secrete a fluid possessed of specific properties; by the act of deglutition, and by the muscular contraction of the stomach itself, the alimentary mass is conveyed to the part where it may be brought into contact and mixed with this fluid. Each portion of the aliment is successively subjected to the due action of this agent, and when the process is completed, it is carried through the pylorus out of the stomach, while a new portion of aliment takes its place and goes through the same process.

In this part of our subject there are two points which will require our particular attention; first, we must ascertain the properties of chyme, and secondly, those of the gastric juice. It is commonly stated, that from whatever source the chyme is derived, provided the stomach be in a healthy state, its properties are always the same,* and it must be admitted that, as a general principle, this would appear to be the case. In animals of the same species, notwithstanding the miscellaneous nature of the substances that are employed in diet, the result of the complete action of the stomach is a mass of uniform consistence, in which the peculiar sensible properties of the articles of food cannot be recognized. But this statement must be received with certain limitations, and is only applicable to the ordinary diet, for we have reason to believe, not only that the chyme produced from animal matter differs from that of vegetable origin, but even that different species of vegetable aliment produce a different kind of chyme. The chyme from fruits or green vegetable matter is notoriously more disposed to pass into the acetous fermentation than chyme formed from farina or gluten, a circumstance which must depend upon a difference in their chemical constitution. We also know that the same kind of aliment is differently acted on by the gastric juice of different individuals; but this may probably depend upon some variation in the nature of the gastric juice itself, and is therefore to be referred to a different principle.

Disregarding, however, for the present what may appear only exceptions to the general rule, we must inquire into the nature of the substance which is found, under ordinary circumstances, in the proper digestive stomach, after it has experienced the full operation of the gastric juice. Although many observations have been made upon the pultaceous mass which is thus produced, our information respecting it is not very precise; we are told little more than that the texture, odour, and flavour of the food employed are no longer perceptible, and it is said to have slightly acid properties, or rather to be disposed to pass into the acetous fermentation. As we remarked above, the change which the food undergoes is to be regarded as the result of chemical action, where not merely the mechanical texture and the physical properties of the substance are changed, but where it has acquired new chemical relations.

This conclusion is deduced from a number of very interesting experiments, which were performed successively by Reaumur, Stevens, and Spallanzani, and which consisted in inserting different kinds of alimentary matter into perforated tubes or balls, or inclosing them in pieces of porous cloth. These were introduced into the stomach, and after some time were removed from it and examined, when it was found that the inclosed substances had undergone more or less completely the process of chymification, while the enclosing body was

* See on this subject Magendie, Physiol. t. ii. p. 81, 2; Dr. Prout's paper in Ann. Phil. vol. xiii and xiv. and Dr. Philip's Inquiry, ch. vii. sect. 1.

† It is necessary to remark in this place, that most of the older physiologists, and some even of a later period, have employed the terms *chyme* and *chyle* indiscriminately, or at least have not made any accurate distinction between them. The words χυλος and χυμος appear to be nearly synonymous in their original acceptation; see Castelli, Lexicon, and Stephens, Thes. in loco. The latest physiologists have, however, for the most part, employed the two terms in the restricted sense which is adopted in this article.

* Haller, El. Phys. xix. 4, 31; see the remarks of Tiedemann and Gmelin in the third section of their researches.

not acted upon, thus proving decisively that the effect was not produced by a mere mechanical operation.* The results of these experiments have been confirmed by some remarkable facts, which bear still more directly upon the point under investigation, where certain individuals have had preternatural openings made into the stomach, either from accident or disease, while the functions of the part appear to have been but little, if at all, impaired. By this means the operation that is going forwards in this organ may be minutely watched in all its various stages, and we are enabled to observe the change which the food undergoes from the time that it enters the stomach until it passes from the pylorus, and to compare the changes which the different kinds of food experience during the progress of the whole mass.

A case of this kind is related by Circaud, where an individual lived many years with a fistulous opening into the stomach;† but a much more remarkable case of the same description has been lately communicated by Dr. Beaumont. The individual in question was wounded, early in life, by a shot in the epigastric region, which perforated the stomach. After some time the wounded part healed, with the exception of an aperture two and a half inches in diameter, which communicated with the stomach. He lived many years in this state, in perfect health and vigour, so as to be capable of following a laborious occupation, while the fistulous opening still remained. Under these circumstances he was made the subject of experiment by Dr. Beaumont, who for the space of eight years continued his observations, with great assiduity and minuteness, on the action of the stomach both in its ordinary state, and when subjected to different conditions, for the immediate purpose of the experiment. We may remark generally, that the results of the experiments confirm those of Spallanzani in their most essential particulars, and at the same time enable us to decide upon some points which were left imperfect by that naturalist.‡

Among the more important points respecting the formation of chyme, which appear to be confirmed by the experiments of Dr. Beaumont, are the following; that the different kinds of aliment all require to undergo the same process, by means of the gastric fluid, in order to be reduced into chyme; that the rapidity of the process differs considerably according to the delicacy of their natural texture or the degree of their mechanical division; that the saliva is of no specific use in the conversion of aliment into chyme; that animal substances are more easily converted into chyme than vegetables; and that oily substances, although they contain a large quantity of nutriment, are comparatively difficult of digestion.*

We must next inquire into the physical and chemical properties of the gastric juice, the fluid secreted from the interior of the stomach, by which the change in the aliment, that we have been describing, is produced. Since the publication of Reaumur's experiments, about the middle of the last century, the general opinion among physiologists and chemists has been, that the gastric juice possesses specific properties, which enable it to dissolve or combine with the aliment; and many experiments have been performed for the purpose of ascertaining the chemical nature of the secretion, so as to account for the powerful action which it appears to possess over such a great variety of substances. Besides the more general account which we have of the gastric juice by Boerhaave, Haller, and Reaumur,† it was made the subject of an elaborate series of experiments by Spallanzani;‡ it was also analyzed by Scopoli§ and by Carminati,‖ and has been lately examined by Dr. Prout,¶ and by MM. Tiedemann and Gmelin.** The result is, upon the whole, rather unsatisfactory, or at least it may be said, that nothing has been detected in the fluid, which seems to account for or explain the powerful action which it exercises on the alimentary substances subjected to its influence.†† All that we learn is, that the gastric juice contains certain saline substances in small quantity, more especially the muriate of soda, in common with the other animal fluids, but that it does not differ essentially, in its chemical properties, from saliva, or from the secretions of mucous membranes generally. Dr. Prout indeed informs us, that a quantity of muriatic acid is always present in the stomach during digestion;‡‡ but as there does not seem to be any decisive evidence of its appearance previously to the introduction of the food into the stomach, we ought probably rather to consider it as developed by the process of digestion, than as entering into the constitution of the gastric juice; nor indeed, if it were so, are we able to explain the mode in which it operates in converting aliment into chyme.§§ This apparent difficulty in accounting for the mode in which chyme is formed by the gastric juice, and the supposed inadequacy

* Reaumur, Méd. Acad. pour 1752, p. 266 et seq. and p. 461 et seq.; Stevens, De Alim. Concoct. cap. xii. ex. 1 . . . 9 and 11 . . . 23; Spallanzani, Expér. sur la Digest. passim; Blumenbach, Inst. Physiol. § 358, 9; Monro (Tert.) Elem. v. i. p. 532.

† Journ. de Phys. t. liii. p. 156, 7.

‡ Beaumont on the Gastric Juice and on Digestion, sect. 1, 5.

* Beaumont, page 275 . . 8 et alibi.

† Boerhaave, Prælect. § 77 et seq.; Haller, El. Phys. xix. 1. 15. et 4. 20; Reaumur, Mém. Acad. pour 1752, p. 480, 495.

‡ Ut supra, § 81 et seq. 145, 185, 192.

§ In Spallanzani, § 244.

‖ Jour. Phys. t. xxiv. p. 168 et seq.

¶ Ann. Phil. v. xiii. p. 13.

** Recherches sur la Digestion, trad. par Jourdan.

†† Henry's Chem. v. ii. p. 410, 1.

‡‡ Phil. Trans. for 1824, p. 45 et seq.

§§ The presence of acid in the stomach, in its healthy state, has been made the subject of inquiry by many experimentalists, and of much controversy; the result is that the older physiologists generally denied its existence, except in morbid states of the stomach, while many of the most eminent modern physiologists believe it to be always present, and indeed regard it as an essenof the agent to this purpose, has led to many singular theoretical opinions, which will be noticed in a subsequent part of this article.*

But in whatever way, or upon whatever principle we may explain the action of the gastric fluid upon the aliment, we are irresistibly led to the conclusion, that it is the physical agent which produces the effect, not only from those cases, where in consequence of a preternatural opening into the stomach we are able to observe the actual phenomena of digestion, but still more so, by the experiments on what has been termed artificial digestion, especially those of Spallanzani and Beaumont, where the gastric juice has been procured, and applied out of the stomach, and where the process of chymification has proceeded, as nearly resembling that in the stomach itself as might reasonably be expected, considering the unavoidable imperfection of the experiment. This imperfection respects both the mode of obtaining the gastric juice itself, and the mode of applying it to the aliment. We reduce the action of the stomach into somewhat of an unnatural condition in order to procure the secretion, and in the application of it we are deprived of the contractile motion of the organ; yet, notwithstanding these unavoidable circumstances, the substances were reduced to a state very considerably resembling that of chyme. That this change was not produced by a mere mechanical action is proved by the circumstance, that the change in the substances operated on bore no proportion to the hardness of their texture or other physical properties. Thus we find that the gastric fluid acts upon dense membrane, and in some cases, even upon bone, while there are other substances, of a very delicate texture, which are not affected by it. This kind of selection of certain substances in preference to others bears so close an analogy to the operation of chemical affinity, that we ought not to refuse our assent to the idea of their belonging to the same class of actions, although it occurs under circumstances where we might not have expected to find it.

There are two other properties of the gastric juice, besides its solvent power, which are at least as difficult to account for, but of which we seem to have very complete evidence,—its property of coagulating albumen, and that of preventing putrefaction. It is the former of these properties which we employ in making cheese, cheese being essentially the albuminous part of milk, coagulated by means of what is termed rennet, a fluid consisting of the infusion of the digestive stomach of the calf. This is unequivocally a chemical change, yet it is very difficult to explain it upon any chemical principle, i. e. to refer this individual case to any series of facts, with which it can be connected.* We can only say in this instance, as in so many others in the physical sciences, that although the fact is clearly ascertained, its efficient cause still remains doubtful.

We are compelled to make the same remark with regard to the other property of the gastric juice, to which we have referred above, its antiseptic power. Of the fact, however, we are well assured, both as occurring in the natural process of digestion, and in the experiments that have been made out of the body. It is not uncommon for carnivorous animals to take their food in a half putrid state, when it is found that the first action of the gastric juice is to remove the fœtor; and an effect of precisely the same kind was noticed by Spallanzani in his experiments.† Here again we have a chemical change, the nature of which we cannot explain; it is, however, a circumstance which may appear less remarkable, with respect to the subject now under consideration, because the action of antiseptics generally is one which we find it difficult to refer to any general principles.

Respecting the process of chymification it only remains for us to remark, that the contractile action of the stomach is admirably fitted to aid the chemical action of the secreted fluids; the vermicular motion of the organ has the effect of keeping the whole of its contents in a gradual state of progression from the cardia to the pylorus, while, at the same time, each individual portion of the aliment is completely mixed together, and brought into the

tial agent in the process. From the first part of this remark we must, however, except Vanhelmont and Willis; Ortus Med. p. 164..7 et alibi; De Ferment, op. t. i. p. 25. See Haller in Boerhaave, Prælect. not. ad § 77, and El. Phys. xix. 1. 15, and 4. 29; Fordyce, p. 150, 1; Spallanzani, § 239..245; Hunter, p. 293 et seq.; Circaud, ut supra; Dumas, El. Phys. t. i. p. 278..0; Tiedemann et Gmelin, Recherches, t. i. p. 166, 7. It may be proper to remark that Leuret and Lassaigne do not admit of the presence of this acid; they, on the contrary, suppose that the gastric juice owes its acid properties to the lactic acid; Recherches Physiol. et Chimiques, p. 114..7; Dr. Prout has, however, as we conceive, satisfactorily answered their objections to his experiments; Ann. Phil. v. xii. p. 406. Dr. Carswell considers acidity to be the essential and active property of the gastric juice; Pathol. Anat. fas. 5.

* Montegre has lately performed a series of experiments, the results of which lead him to deny the specific action of the gastric juice; Expér. sur la Digestion, p. 43, 4. But, notwithstanding the apparent accuracy with which they were conducted, we cannot but suspect some source of error, seeing how much they are at variance with all our other information on the subject.

* This difficulty appears to be increased by the amount of effect which is produced by the very small quantity of the agent; Fordyce informs us, that a very few grains of the inner coat of the stomach, a very small proportion of which must have consisted of the secretion, was capable, when infused in water, of coagulating more than one hundred parts of milk; p. 57, 9; 176 et seq.; Prout, Ann. Phil. v. xiii. p. 13 et seq.

† Expér. § 250..2 et alibi; see also Hunter on the Anim. Œcon. p. 204. Montegre does not admit of this property, and would appear to doubt also of the coagulating power of the gastric juice, p. 21 et alibi; the same opinion is also maintained by Dr. Thackrah, lect. p. 14; but it would require a very powerful series of negative facts to controvert the strong evidence that we possess on this subject.

proper state for being received into the duodenum. The undulatory motion of the stomach is more especially effected by the circular fibres, while the longitudinal fibres are more effective in the progressive motion of its contents from the cardia to the pylorus.

The alimentary mass is now to undergo the last of the three changes to which we referred above, its conversion from chyme into chyle. These substances are obviously different from each other in their sensible properties, but respecting the exact nature of this difference, the change which they experience, or the mode in which it is produced, we have little certain information. The fact appears to be, that as soon as the uniform pultaceous mass, which composes the chyme, enters the duodenum, it begins to separate into two parts, a white creamy substance, which constitutes the chyle, and a residuary mass, which is gradually converted into fæces, and is propelled along the course of the intestine, in order to be finally expelled from the system.* Although no point in physiology appears to be more clearly ascertained than that chyle, properly so called, is never found in the stomach, and that the duodenum is the appropriate organ for its production, yet owing partly to the inaccurate mode in which the terms have been employed, and partly to the inaccuracy of our observation, some writers, even in our own times,† have spoken of chyle as being formed in the stomach, and have conceived that the only change which was effected in the duodenum was the separation of the chyle from the remainder of the mass.‡

With respect to the mode in which this change is brought about, or the agent by which it is effected, we have little to offer except conjecture. The secretions of the liver and the pancreas are, each of them, conveyed into the duodenum, and it has been stated that the completion of the chyle takes place exactly at the part where the bile and the pancreatic juice enter into the intestines. Of this, however, we do not possess any direct evidence, and the fact, that in certain cases of disease or malformation, the process of chylification has gone on, nearly in its ordinary course, although the fluids in question have not been transmitted into the intestine,§ appears to furnish a decisive objection to the hypothesis. Some physiologists have conceived that the duodenum itself secretes a specific fluid, analogous to that in the stomach, by which the process of chylification is effected; but we have no evidence of the existence of this fluid, except the supposed necessity to explain the effects that are produced. In this deficiency of direct evidence we appear to be reduced to the supposition, that the conversion of chyme into chyle is effected partly by the mutual action of its constituent elements on each other, aided perhaps, in some degree, by the intervention of the bile and the pancreatic juice.*

We have various analyses of chyle, which appear to have been made with sufficient accuracy. It is a white opaque substance, resembling cream in its appearance and physical properties. When removed from the body, it shows a tendency to concrete and undergoes a change considerably resembling the coagulation of the blood, by which it separates into two parts, a dense white coagulum, and a transparent colourless fluid, analogous respectively to crassamentum and to serum. The chemical properties of chyle appear very similar to those of the blood, and it also resembles blood in the nature of its saline contents; but it differs from it in containing a portion of oil as one of its essential constituents, while in the blood oil is only an occasional, and probably a morbid ingredient.†

The chemical analysis of chyle was first made by Vauquelin, who employed for this purpose the contents of the thoracic duct and large lacteals of a horse. The coagulum from the duct was observed to be of a light pink colour, while the corresponding part from the lacteals was nearly white; but it is not ascertained how far this difference of colour depended upon an accidental occurrence, or whether it is to be regarded as a uniform circumstance. The coagulum contained a substance which bore a considerable resemblance to fibrine, or perhaps more correctly possessed properties intermediate between fibrine and albumen. The liquid part of the chyle was found to be very similar to the serum of the blood, differing from it only in containing a quantity of an oily or fatty substance; like serum it exhibited marks of an uncombined alcali.‡

* Prout, ut supra, v. xiii. p. 12 et alibi. The difference between chyme and chyle, as well as the different organs in which they are elaborated, was well known to some of the older writers, although not acknowledged; see Juncker, Conspect. Physiol. tab. 11 et 25; Vanhelmont, Ortus Med. p. 167, 8, and Baglivi, Diss. 3. circa bilem.

† Home, in Phil. Trans. for 1807, p. 88, 9.

‡ On this subject the reader is referred to the following works: Boerhaave, Prælect. § 90..5; Haller, ibid. in notis, Prim. Lin. § 635..8 et alibi, and El. Phys. xviii. 4. 24, 31 et xxiv. 2. 1; Hunter, Anim. Œcon. p. 213; Fordyce, ut supra, passim; Bell's Anat. v. iv. p. 65 et seq.; Monro's (Tert.) Elem. v. i. p. 552; Richerand, El. Physiol. § 11, 25.

§ The experiments of Sir B. Brodie, in which the formation of chyle appears to have been suspended by tying the biliary duct, although interesting and important, cannot be regarded as conclusive, until we are more minutely informed of every circumstance connected with them; Quart. Journ. v. xiv. p. 341 et seq.

* Dr. Prout conceives, that the bile is the principal agent in this process; and that when it is added to the contents of the duodenum, it separates the chyle by a kind of precipitation; it does not, however, appear very clearly what is the exact nature of the chemical action which takes place.

† Fordyce, p. 121; Young's Med. Lit. p. 516; Dumas, t. i. p. 379..1; Magendie, t. ii. p. 154..8. Some late experiments appear indeed to prove that a certain quantity of an oily matter is always present in the blood; but the proportion in the chyle is at least very much more considerable.

‡ Ann. Chim. t. lxxxi. p. 113 et seq.; Ann. Phil. v. ii. p. 220 et seq. We have some experiments on chyle by Emmert, previous to those of Vauque-

The next experiments which we possess are those of Marcet, who operated upon the chyle as procured from dogs. One main object of his researches was to ascertain how far chyle of animal origin differs from that from vegetables, and he had the food of the dogs regulated accordingly. His results with regard to the general nature and properties of chyle correspond very exactly with those of Vauquelin. He found the coagulum to have a pink colour, and to contain a fibrous or filamentous substance, while the liquid part contained a quantity of an oily matter, which floated on its surface like cream. This oily matter appeared, however, to be confined to the animal chyle, and it is remarked generally, that this bore more resemblance to blood than the chyle from vegetables. They contained the same saline ingredients, but the solid residuum of the animal chyle was considerably greater; and as the vegetable chyle, when submitted to destructive distillation, was found to contain much more carbon, it was inferred that the animal chyle must have contained proportionably more hydrogen and nitrogen.* Upon these experiments we may remark, that the difference between the animal and the vegetable chyle in this case might perhaps depend in some degree upon vegetable food being less adapted to the digestive organs of the dog; because the chyle of the horse, as examined by Vauquelin, appeared to be more completely animalized, although it must have been derived from vegetable diet.

The experiments of Dr. Prout agreed generally with those of Vauquelin and Marcet; he found the coagulum and the fluid part analogous to the two components of the blood, and he likewise observed the oily matter. He compared the chyle derived from animal, with that from vegetable food, and detected the oil in both of them, and, upon the whole, he found them to differ less than was supposed by Marcet; he remarks, however, that the latter contains more water and less albuminous matter than the former.† We were likewise indebted to Dr. Prout for an interesting account of the successive changes which the chyle experiences, from its entrance into the lacteals, until it is finally deposited in the thoracic duct, its gradual conversion into blood corresponding to the progress along the vessels.‡

While the alimentary mass passes through the small intestines, the chyle, as it is separated from it, is taken up by the lacteals, so that when it arrives at the large intestines, nothing remains but the residuary matter, which is to be discharged from the system; this constitutes what has been termed the process of defæcation. There can be no doubt that the principal and primary use of the large intestines is to serve as a depository for this residuary mass, yet there are certain circumstances in their anatomical and physiological structure, which might render it probable that some farther purpose is served by them than the mere retention of the fæces. Dr. Prout, who has minutely examined the successive changes which the contents of the intestinal canal experience, observes that the secretions even of the rectum still possess the property of coagulating milk, which we noticed above as being one of the most distinguishing characters of the digestive system, so that it would seem that these organs, in some way or other, still assist in the process of nutrition. We may presume, however, that this is only a secondary object, and that the primary use of the large intestines is to serve as a reservoir, in which the fæcal mass might be retained, in order to be evacuated at certain intervals only.* (See Intestinal Canal.)

Before we dismiss this part of our subject, it may be proper to make a few remarks upon two of the abdominal viscera, which, from their anatomical position and their physiological relations, are generally classed among the chylopoietic organs, as being supposed to contribute to the function of digestion; these are the pancreas and the spleen. The pancreas bears a very near resemblance to the salivary glands of the mouth and fauces, both from its intimate structure and from the nature of its secretions, and it has been presumed, that it acts in the same manner upon the aliment;† it must, however, be admitted that we have little but analogy or conjecture in favour of this opinion.

The spleen is an organ which, both from its size, its situation, and the number of blood-vessels belonging to it, has been supposed to serve some important purpose in the animal economy, and from its apparent connexion with the stomach to be, in some way, concerned in the process of digestion. But although many

lin, but they do not contain much precise information; Ann. Chim. t. lxxx. p. 81 et seq.

* Med. Chir. Trans. v. vi. p. 618 et seq.

† In some late experiments which were performed by MM. Macaire and F. Marcet, on the origin of nitrogen in animals, they analyzed the two species of chyle, and found them to be nearly the same in their chemical composition, and especially in respect to the quantity of nitrogen which they contained; Ann. Chim. t. li. p. 371.

‡ Ann. Phil. v. xiii. p. 22..5. See also Magendie, Physiol. t. ii. p. 154..8.

* Prout, ut supra, p. 15..22; see also Sœmmering, Corp. Hum. Fab. t. vi. § 241. We do not perceive that there is any foundation for the hypothesis of Sir E. Home, that the colon is the organ in which the adipose matter is produced, lect. v. i. p. 468 et seq. and Phil. Trans. for 1821, p. 34. Dr. O'Beirne has lately published an essay on the process of defæcation, to which we shall refer our readers, as containing some new views on the subject. We are indebted to Berzelius for an analysis of the fæces, which appears more minute than any that had been previously made.

† For an account of the pancreas and its secretions we may refer to De Graaf, Tract. Anat. Med. as the first correct treatise on the subject; to Boerhaave, Prælect. § 101, cum notis; Haller, Prim. Lin. cap. 22. and El. Phys. xxii.; Sœmmering, Corp. Hum. Fab. t. vi. p. 142..8; Fordyce, ut supra, p. 70..2; Blumenbach, Inst. Physiol. § 24; Santorini, tab. 13. fig. 1. Tiedemann and Gmelin have given us the result of their examination of the pancreatic juice, from which they conclude that it differs in some respects from the saliva; Recherches, t. i. p. 41, 2. Leuret and Lassaigne, on the contrary, suppose these secretions to be very nearly identical; Recherches, p. 49 et seq.

hypotheses and conjectures have been formed on the subject, there is none which seems to have obtained any credit with physiologists, or indeed to be entitled to much consideration.* The latest researches on the subject are those of Home, and of Tiedemann and Gmelin. Home examined the structure of the spleen, and, as the result of his investigation, informs us that it consists entirely of a congeries of bloodvessels and absorbents, and that there are interstices between the vessels into which the blood is effused, through certain natural orifices in the veins, when they are much distended. The conclusion which he forms respecting the use of the spleen is, that it is a reservoir for any superfluous matter, which may exist in the stomach, after the process of digestion is completed, which is not carried off by the intestines, as serum, lymph, globules, and mucus; that these are conveyed to the spleen by certain communicating vessels, and are removed from it, partly by the veins and partly by the absorbents.†

The account of the structure of the spleen which is given us by Tiedemann and Gmelin is considerably different from that of Home. They inform us that it essentially resembles that of the lymphatic glands, and they conceive that it is to be regarded as an appendage to the lymphatic system. They suppose its specific function to be the secretion of a fluid which is conveyed to the thoracic duct, and being united with the chyle, converts it into blood.‡ There are many circumstances which render it probable that the spleen, in some way or other, promotes sanguification, and we have some reason to believe, that there is an immediate and a ready communication between its arterial and its absorbent systems, but we conceive that the hypothesis must still be regarded rather as a plausible conjecture, than as a deduction from facts.

There is moreover a circumstance which must not be overlooked in our speculations respecting the spleen, that we have some well authenticated cases, where it has been either originally wanting, or has been removed from the body without apparent injury.§ This argument cannot, however, be considered as decisive, because it is well known, that in consequence of the extraordinary compensating powers of the system, certain organs may be occasionally dispensed with, which, under ordinary circumstances, appear the most essential to its existence and welfare. We may therefore conclude with respect to the pancreas and the spleen, that although there is reason to suppose that they contribute, in some way, to the function of digestion, we are still unable to ascertain the precise mode in which they conduce to this end.

Before we dismiss this part of our subject, it will be necessary to make a few observations upon a question, which has been proposed in relation to the digestive process, whether any part of the aliment passes through the stomach, and is taken up by the absorbents, without decomposition. It is obvious that this cannot be the case with vegetable substances of any description, and with respect to substances of animal origin, that form a part of the diet, although they approach so much nearer to the nature of chyle, yet it appears that they are not entirely identical with it, and that they must consequently be decomposed and assimilated to the general mass, before they can serve for the purposes of nutrition. There are indeed certain substances, that are received into the stomach, which would appear to form exceptions to this general principle; these are the various saline substances, which are found in all organized bodies, as well as some others, which give their appropriate odours and flavours to the food, and also certain medical agents. There are some salts, which appear to constitute an essential part of the blood and other animal fluids, and as the same salts are introduced into the stomach with the food, we may conceive that they pass unchanged into the vessels. There are likewise certain substances which give their specific odour to the milk, and to other secretions and excretions, proving that they likewise pass into the circulating system without suffering decomposition, and the same is the case with some of the medicaments.*

IV. *Theory of digestion.*—We now enter upon the fourth branch of our inquiry, the mode in which we are to explain the action of the digestive organs upon the aliment. This has been one of the most fertile sources of conjecture and speculation from the earliest period, from Hippocrates down to our own times, and the question is one respecting which the greatest difference of opinion still exists among the most intelligent physiologists.† We shall not think it necessary to notice the opinions of the older writers, which were necessarily formed from very insufficient data, but shall select those hypotheses which appear deserving of more particular attention, either as having been supported by men of acknowledged eminence, or as

* See Haller, El. Phys. lib. xxi.; Sœmmering, t. vi. p. 149 et seq.

† Phil. Trans. for 1808, p. 45 et seq. and p. 133 et seq., and for 1821, p. 35 et seq. pl. 3..8.

‡ We have an ample and apparently correct abstract of the memoir of Tiedemann and Gmelin in the Ed. Med. Journ v. xviii. p. 285 et seq. See also on this subject Elliotson's Physiol. p. 108 et seq.; also an essay by Dr. Hodgkin, appended to his translation of Edwards's physiological work.

§ Baillie's Morbid Anat., p. 260, 1; works, by Wardrop, v. ii. p. 235. [Dupuytren observed an increased voracity in dogs from which the spleen had been removed.—Assolant, Dissertation du Rate; and Mayo has in two instances remarked a considerable obesity in dogs after the removal of the spleen, but does not say whether this may not be attributable to the increase in the quantity of their food. In both instances the duration of the obesity was for less than a year. Mayo's Pathol. vol. i.—Ed.]

* See the remarks of Fordyce, p. 122, 3; the results of the experiments that have been made on this point are somewhat contradictory; but upon the whole there seems no doubt that, under certain circumstances, various extraneous substances may be taken up by the absorbents and recognized in the blood and other fluids. See Bostock's Physiol. v. ii. p. 569, 0, note.

† For an account of the doctrines maintained by the earlier physiologists, the reader is referred to the treatise of Fernel, De Concoctionibus, Physiol. lib. vi. cap. 6; Boerhaave, Prælect. not. ad § 86; Haller, El. Phys. xix. 4 et 5 passim; and Blumenbach, Instit. Physiol. § 360.

possessing in themselves the merit of consistency and probability. Those which we shall select are the theories of trituration, of fermentation, of chemical solution, and of nervous action, under one or other of which we may comprehend all the most important speculations which have engaged the attention of modern physiologists.

The hypothesis of trituration may be considered as having originated with the mechanical physiologists of the seventeenth century, and was apparently supported by the curious facts, which were, at that time, more particularly brought into view and minutely ascertained, of the great force exercised by the muscular stomachs of certain tribes of birds. The facts, although perhaps in some instances rather exaggerated, were sufficiently curious, but the deductions from them were incorrect, first, in extending the analogy from one class of animals to other classes, where it was altogether inapplicable; and secondly, in conceiving of the trituration which takes place in these muscular stomachs, as constituting the proper process of digestion, whereas it is merely a preliminary process, equivalent to mastication. The aliment, after it leaves the gizzard, is in the same state of comminution into which it is reduced by the teeth of those animals that are provided with these organs, and is then subjected to the action of the proper digestive stomach, and undergoes the process of chymification. On this point the experiments of Stevens and Spallanzani, which were referred to above, are quite decisive; they show clearly how far the agency of mechanical action is instrumental in the process of digestion, and they also show that some other principle is essentially necessary for its completion.*

While the mathematical physiologists were thus attempting to explain the theory of digestion upon the principles of mechanical action, their rivals the chemists, who in every point strenuously opposed them, brought forward their hypothesis of fermentation. This was originally, at least in modern times, advanced by Vanhelmont, and was embraced by a large part of his contemporaries and successors.† It may indeed be considered as having been, for some time, the prevailing theory; a circumstance which we may ascribe, partly to the comprehensive, or rather the indeterminate sense in which the term was employed, and partly from the actual phenomena attending the process, which were more easily referable to this operation than to any other which was then recognized.

* For an account of the effects of trituration, as given by some of the older physiologists, the reader is more particularly referred to the works of Pitcairn, who was one of the most learned men of his time; Dissert. p, 72..95; Elem. cap, v. p. 25..7; see also Haller, El. Phys. xix. 5. 1; Hales, Statical Essays, v. ii. p, 174, 5; Cheselden's Anat. p. 152..5; Fordyce, ut supra, p. 124..138: and Richerand, Physiol. § 18.

† See particularly his singular treatise entitled "Sextuplex Digestio alimenti humani," where, together with much mysticism and false reasoning, we find many acute remarks and some curious information.

The merits, or rather the truth of this hypothesis rests, in some degree, upon the definition of the term fermentation, or the mode in which it was employed by the writers of that period. As far as we can understand their meaning, and perhaps we may even say, as far as they themselves attached any definite idea to their own expressions, they ascribed to this process every change which the constituents of the body undergo by their action upon each other. Fermentation was therefore the cause of the morbid changes which the system experiences, as well as of its natural actions; it was equally the cause of fever and inflammation, as of secretion and digestion; and so far was this theory pushed, that even muscular contraction and nervous sensation were referred to certain fermentative processes. As our ideas on this subject became more correct, in consequence of the extension of our information, our language became more precise. The change which certain vegetable infusions undergo in the formation of alcohol was assumed as the type of this class of actions; the controversy then took a new aspect, and the question at issue was, whether the change of aliment into chyme and afterwards into chyle ought to be referred to the same class of operations with that by which sugar and mucilage are converted into alcohol. This question we shall be more able to answer satisfactorily when we have taken a view of the next hypothesis, that of chemical solution.

The doctrine of chemical solution, as applied to the action of the stomach upon the aliment received into it, is, in many respects, very similar to that of fermentation, depending, as will be seen, partly upon the definition of the terms employed, and partly upon the minute observation of the various steps of the process. The hypothesis owes its origin to the experiments of Reaumur, and was very much confirmed by those of Stevens and Spallanzani, so often referred to, and especially those of the latter experimentalist, where chymification was produced out of the body, simply by exposing the various species of aliment to the gastric juice obtained from the stomach, in a proper temperature, and under circumstances, as nearly as possible, resembling those of the natural digestion.* Making a due allowance for the unavoidable causes of interference, the results may be regarded as satisfactory, and they clearly prove one part of the hypothesis, that the vital operation of the stomach consists merely in providing the agent, and in bringing the alimentary substances within the sphere of its action. This conclusion is still farther sanctioned by the power of the gastric juice in suspending or correcting putrefaction, and in coagulating milk, both which properties are observed in experiments made out of the body, apparently in as great a degree as in the stomach itself, and which can only be referred to the chemical relations of the substances employed. These considerations must be allowed to be very favourable to the hypothesis of chemical solution, but still there are many very serious difficulties which we have to encounter, before we can regard it as

* We may remark that the experiments of Dr. Beaumont lead us to the same conclusion.

fully established. Of these the most important is the objection, which has been frequently urged against it, and has perhaps never been satisfactorily repelled, that it is contrary to the ordinary operations of chemical action for the same agent to be able to reduce the various and heterogeneous matters that are taken into the stomach into a uniform and homogeneous mass, and this difficulty is further increased, when we perceive this powerful effect to be produced by a substance possessed of properties apparently so little active as the gastric juice.*

These objections, and others of an analogous nature, have appeared to many of the most eminent modern physiologists to press so powerfully upon any hypothesis of digestion which is derived from either mechanical or chemical principles, that they have conceived it necessary to abandon altogether this mode of reasoning, and have referred it entirely to the direct action of what has been termed the vital principle. It is assumed that the internal coat of the stomach is endowed with a specific property, peculiar to itself, and essentially different from any merely physical agency, by which it acts upon the food and reduces it to the state of chyme. This vital property of the stomach is supposed to be proved, both by the necessity of having recourse to this kind of power, in consequence of the inadequacy of the ordinary properties of matter, and to be farther confirmed by certain facts that have been supposed to prove that the same substance is differently affected by the gastric juice, merely in consequence of the absence or presence of this principle. Thus it has been observed, that in cases of sudden death, the stomach itself has been partially digested by the gastric juice that was secreted during life,† and upon this principle it has been found, that certain kinds of worms, which exist in the digestive organs of animals, are not affected by the gastric juice as long as they remain alive, but that after death they become subject to its action.

This hypothesis of the vital principle is the one which was supported by Fordyce in his elaborate treatise, and is probably that which, under certain modifications, may be regarded as the prevailing opinion of the modern physiologists. To a certain extent it is correct, and the position on which it is founded, that the living body differs essentially in its powers and properties from the dead body, cannot be denied. But it may still be questioned, whether the explanation thus offered be not rather verbal than real, or whether any actual explanation is afforded of the phenomena, or any actual difficulty removed by adopting this mode of expression. Every one admits that a living stomach differs from one that is deprived of life, but still it remains for us to point out in what this difference consists; is it a chemical or a mechanical action? or if it be not referable to either of these actions, to what general principle can it be referred? It is contrary to the rules of sound reasoning to invent a new agent for the urgency of the individual case, until we are able to demonstrate the absolute impossibility of employing those which were previously recognized. With respect therefore to the hypothesis of the vital principle, as maintained by Fordyce and many of the modern physiologists, we should say, that it is rather a verbal than a real explanation of the phenomena, and that it rather evades the objections than answers them.

The last hypothesis of digestion which we proposed to notice, that of nervous action, although somewhat allied to the one which we have last examined, is more precise and definite in its statement, and consequently more entitled to our consideration. It assumes, that the process of digestion depends upon the direct and immediate agency of the nervous system. It is founded upon the anatomical fact of the mode in which the stomach is connected with the nervous system, and upon the observed relations between those causes that act through the medium of this system, and the changes that take place in the action of the stomach. With respect to the anatomical argument it has been urged, that there is no organ of the body, which is provided with such a number of nerves, proceeding from so many sources, and connected in so direct a way with the cerebral system. There are equally remarkable circumstances of a physiological and pathological nature, which prove the intimate connection between the nervous system and the action of the stomach. Not only does the stomach partake of almost every change that occurs, in any part of the corporeal frame, either natural or morbid, in a way which we must conceive can only be brought about through the intervention of the nervous system, but it is affected by our mental emotions, and that probably in a greater degree than any other of our organs, except those that

* Tiedemann and Gmelin, as the result of their elaborate experimental researches into the nature of the digestive process, conclude that it consists essentially in the solution of the aliment by the gastric juice. Water alone, they observe, at the temperature of the mammalia, is capable of dissolving many of the articles employed in diet, and many which are not soluble in water are so in the acids which are found in the stomach, and to these they are disposed to refer a considerable part of the operation; Recherches, t. i. p. 363..7. We may, however, remark, that a solution of the alimentary matters in water, or even in the acids that exist in the stomach, cannot be supposed to be identical with chyme.

† This curious fact, which was first announced by Hunter, Phil. Trans. for 1772, p. 447 et seq., and afterwards more fully detailed in his Observ. on the Anim. Œcon. p. 226...1, has since been fully confirmed by the observations of some of the most eminent modern anatomists. See particularly Baillie's Morb. Anat. ch. 7. p. 148, 9, and works by Wardrop, v. ii. p. 136, 7, and engrav. to Morb. Anat. fas. 3. pl. 7. fig. 2.; Beck's Med. Jurisp. by Dunlop, p. 376..380 contains many references and good remarks. We have a valuable paper on the subject by Dr. Gairdner, Ed. Med. Chir. Trans. v. i. p. 311 et seq. and also by Dr. Carswell, Ed. Med. Jour. v. xxxiv. p. 282 et seq.; also Archives de Méd. Fev. 1830, and Amer. Jour. Med. Sc. v. vii. p. 227..9. In the Cambridge Phil. Trans. v. i. p. 287 et seq., we have a case of this description by Dr. Haviland. Dr. Carswell has given an accurate and ample account of the appearances and effects produced by the gastric juice on the stomach, in the fifth number of his Pathol. Anat.; it is accompanied by two excellent plates.

are immediately connected with the external senses. Its functions are excited or depressed by various causes, which can only act through the medium of the mind or imagination; while it is argued that in all cases its various conditions and the changes which its functions experience can be referred to no cause, except to corresponding changes in the nervous system.*

This hypothesis, like that of the vital principle, has been supported by the consideration of the inadequacy of all the other modes of explaining the phenomena, and the impossibility of referring them either to mechanical or to chemical principles. But it has this clear and decided advantage, that it rests upon the co-operation of an actual agent of great and acknowledged power, one the existence of which is universally recognized, the only question being whether it is applicable to this individual case. But although we admit the facts in their full force, we must still demur to the conclusions that must be deduced from them. If we inquire upon what principle, or by what medium the nervous system can operate on the digestive functions, two modes present themselves to the mind. We may ascribe the effect either to the general operation of the nervous energy, whatever this may be, which pervades every part of the system, and the stomach among the rest, and which gives it those powers which distinguish living from dead matter; or we may conceive that the nervous system is, in some way, more especially concerned in the production of the gastric juice, and that consequently whatever tends to decrease or diminish the nervous energy, may operate in the increased or diminished production of this secretion, and thus indirectly, although necessarily, affect the digestive function. But although we may admit the truth of both these suppositions, we gain no specific answer to our inquiry. It is not enough to be informed that the stomach acts upon its contents because it is alive, or that whatever prevents the secretion of the gastric juice puts a stop to the digestion. Our inquiry embraces a farther object, and leads us to investigate the nature of the connexion between these facts and the ultimate effect produced, or to discover the reason why certain acknowledged effects are connected with certain acknowledged causes; but to this question the nervous hypothesis gives us no satisfactory answer. It indeed rather involves the theory of secretion than of digestion, for even were it to be clearly proved that the nervous power (whether, according to the hypothesis of Dr. Philip, we identify it with the galvanic influence, or we act the more cautious part of not attempting to explain its nature,) is the immediate agent in the formation of the secretions, still we are left equally uninformed concerning the mode in which this fluid, when secreted, performs its appropriate function.*

From this brief review of the different theories of digestion we may conclude, that the hypothesis of trituration is decidedly incorrect, and that those of the vital principle and the nervous energy do not resolve the question. We are therefore reduced to the two chemical hypotheses, which, although not without considerable difficulties, are not so palpably defective or erroneous. In deciding between these two hypotheses it must be our first object to ascertain the exact sense in which the term fermentation was used by the older physiologists, and how far, according to the modern use of the term, it is applicable to the phenomena in question. The word was originally employed in a very extensive, and, as may be supposed, in a somewhat vague manner, to designate every spontaneous change which took place between bodies that were placed in contact, and which generally manifested itself by the extrication of some gaseous or volatile matter. Thus all the spontaneous changes in the body, whether natural or morbid, were considered to be different kinds of fermentations, and many of the changes that take place among inorganic substances, as well as various processes in the laboratory, were distinguished by the same appellation.

As our knowledge of the nature of these processes was extended, and we were thus enabled to ascertain more correctly what was the change which was produced, our language became more correct and better defined, and the term fermentation was restricted to a specific operation, in which certain proximate principles, derived from organized bodies,† act upon each other, and enter into new elementary combinations. The process is generally promoted by the addition of a substance called the ferment, which is employed to enable the bodies to act upon each in the first instance, although, when the action has commenced, its presence may be no longer necessary. The most familiar kind of fermentation is that by which a mixture of sugar and mucilage is converted into alcohol, and that by which the same substances, when exposed to the atmosphere, and to a certain temperature, are converted into acetous acid. How far we are to extend the number of fermentations is a point respecting which chemists are not agreed, and indeed there appears to be no reason but that of convenience which can decide the point. We accordingly find that while Mr. Brande is disposed to restrict the term to the vinous and acetous fermentation,‡ others extend it to three, four, or with Dumas,§ even to six processes.

* It was on facts of this description that Vanhelmont founded his hypothesis of the stomach being the immediate seat of the soul; Ortus Med. p. 248, 49, 50. See also on the same subject the remarks of Hartley, on Man, v. i. p. 189, and Sœmmering, § 179...4, who may be respectively considered as among the most accurate metaphysicians and anatomists of modern times.

* We may refer our readers to the judicious remarks of Dr. Prichard, in his Essay on the Vital Prin. sect. 8.

† Some of the most eminent chemists confine the process of fermentation to the proximate principles derived from vegetables; but this restriction is not universally adopted, nor does it appear to be necessary.

‡ Ut supra.

§ Ut supra.

Among these, one which is the subject of daily observation is the panary, or that by which dough is converted into bread, a change which appears to come strictly under the definition, as a spontaneous action among the elementary constituents of the body, by which a substance is produced, essentially different from the one from which it was composed. Now we are disposed to think that the same principle will apply to the conversion of aliment into chyme, and that it is little more than a difference in the mode of expression, whether we say that digestion depends upon chemical action generally, or upon that peculiar kind of chemical action which has been termed fermentation.

The foregoing remarks apply immediately to the production of chyme, and it still remains for us to consider whether the same mode of reasoning can be applied to the further conversion of chyme into chyle. And it must be confessed that this part of our subject presents us with new difficulties, and that the analogy, which in the former case was imperfect, is apparently still more so, when we apply it to the action of chylification. Here we have a chemical change in the constituents, without the intervention of any assignable agent, attended with the production of a new substance, in consequence, as far as we can judge, of the spontaneous action of the elements upon each other, and with the separation of the substance thus formed from the remainder of the mass. But although the operation may be somewhat more complicated, and although we may find it less easy to assign an efficient cause for each step of the process, there will be found nothing contrary to the recognized effects of chemical affinity. And with respect to the question, how far these effects should be referred to the specific action of fermentation, we may remark that the result of the proper fermentative processes is to form a new product, and to separate the product thus formed from the residuary mass. Upon the whole therefore we may conclude, that although there are many points in the chemical theory of digestion that are still unexplained and require to be further investigated, yet that we have no facts which directly oppose it, while the difficulties which we feel on certain points would appear to be principally owing to the imperfect state of our knowledge on the subject.

V. *Peculiar affections of the digestive organs.*—We now proceed, in the last place, to offer some remarks on certain affections of the stomach and its appendages, which are only indirectly connected with the function of digestion. Of these the most important are hunger, thirst, and nausea; we shall consider in succession the causes of each of them, and the relation which they bear to the animal economy in general.

Hunger is a peculiar perception experienced in the stomach, depending on the want of food. Its final cause is obvious, but respecting its efficient cause there has been considerable difference of opinion among physiologists, some referring it to a mechanical, others to a chemical action, while by a third set of writers it is referred exclusively to a peculiar condition of the nervous system. Before we enter into the respective merits of these opinions it will be necessary to remark concerning the feeling excited by hunger, that it is one of a specific nature, as essentially different from the mere perception of touch, as the sense of sight is from that of mechanical pressure made on the ball of the eye. In physiological language the stomach may be regarded as one of the organs of sense, in the same way with the eye and the ear; i. e. a part furnished with a specific apparatus for producing specific impressions on a set of nerves appropriated to it, which convey to the mind certain perceptions, and which, by habit or by instinct, we connect with certain conditions of the organ. In most cases we are able to point out distinctly the nature of the agent which produces these perceptions, as light when applied to the eye, and the undulations of the air to the ear; in the particular case of the stomach we are not able to point out any corresponding agent of this description, and in so far the analogy between the stomach and the organs of sense must be considered as defective.

The mechanical physiologists ascribed hunger to the friction of the different parts of the internal membrane of the stomach on each other, an opinion which, although sanctioned to a certain extent by Haller,* must be abandoned, whether we regard the anatomical structure of the part, which shows that such friction is incompatible with its rounded form, and the disposition of its muscular fibres, or the nature of the sensation itself, which is specifically different from that produced by pressure, or any species of mechanical impulse on the surface of the body. Nor can the hypothesis be maintained, which supposes that the action of the gastric juice, by its tendency to decompose organized substances, exercises a degree of this eroding quality on the internal coat of the stomach, and thus produces the uneasy sensation. But in this hypothesis the great distinction, which has been so frequently referred to, between living and dead matter as to the action of the gastric juice is disregarded; besides that from every analogy which we possess, it might be presumed that a substance so mild and apparently so little active as the gastric juice, could not produce effects, which must be attributed to a body possessed of highly acid or noxious qualities. And it may be further remarked, that in cases of the most protracted privation of food, and where death has occurred after the most severe pangs of hunger, nothing like erosion of the stomach has been observed, and that conversely, in those instances where this effect has been produced after death, we have no reason to suppose that it was in any degree caused by the deficiency of food, or had been preceded by hunger.

From what has been stated above it may be inferred that the view which we feel disposed to take of the efficient cause of hunger is to regard it as a specific perception, occasioned

* Prim. Lin. § 368; El. Phys. xix. 2, 12.

by a peculiar state induced on certain of the nerves of the stomach, in the same way that certain nerves of the eye and of the ear receive the impressions of light and of sound. There is, however, this difference between the two cases, that in the instance of the eye and the ear we are able to point out the agent by which the impression is made, whereas we are unable to do this with respect to the stomach.*

The perception of thirst, although seated in the tongue and fauces, is so intimately connected with the state of the stomach, as to be properly referred to our consideration in this place. It is immediately produced by a deficiency of the mucous secretion of the part, and consequently must be regarded as ultimately depending on a peculiar condition of the glands which secrete this substance. Although the sensation of thirst has a less specific character than that of hunger, yet we conceive that it must be referred to a peculiar action induced upon the nerves of the part, in a way analogous to what we suppose to take place with respect to hunger, and like it depending on a peculiar action, the intimate nature of which we are unable to explain.†

There are various circumstances, which differ much in their nature and origin, acting upon different parts of the system, which all concur in producing a peculiar sensation termed nausea, which is referred to the region of the stomach. It is usually attended with a considerable derangement of all the powers of the body, both muscular and nervous, and if continued, produces the effort to vomit. The act of vomiting consists in an inversion of the peristaltic motion of the stomach, commencing at the pylorus, which causes the contents to be carried towards the cardia, and to be forcibly ejected from the œsophagus. It has been generally supposed that the impression which produces nausea, and ultimately vomiting, is in the first instance made on the nerves of the stomach, that it is communicated by them to its muscular fibres, that their action is transmitted, probably by the intervention of the nerves, to the muscles of the abdomen and to the diaphragm, and that their contraction cooperates with the muscular coats of the stomach in the evacuation of its contents. It has long been a subject of controversy among physiologists in what degree the abdominal muscles assist the coats of the stomach, or how far the latter are competent to produce the effect without the aid of the former. Haller supposed that the stomach alone is capable of evacuating its contents,* while Chirac, Duverney,† and other French physiologists conceived that this organ is entirely passive in the act of vomiting, and the same opinion has been lately maintained by Magendie, and supported by a series of direct experiments. He not only found that vomiting was entirely suspended, when the abdominal muscles and diaphragm were rendered incapable of acting upon the stomach, but he even informs us, that when the stomach was removed, and a bladder substituted in its place, vomiting was still induced.‡

But we are still disposed to believe that the commonly received doctrine is the correct one; that the action commences in the muscular fibres of the stomach, and is materially assisted by the diaphragm and abdominal muscles. We rest our opinion on the analogy of the other hollow viscera, the uterus, the bladder, and the intestines, where the contraction commences in the organ itself; on the antecedent probability, that as the agent which produces the effect is, in most cases, applied to the stomach, it must be supposed to act immediately upon it, and lastly on the mechanical nature of the act of vomiting, which appears to be produced rather by a sudden and forcible contraction of the organ itself, than by any external pressure exercised upon it. We conceive also that this view of the subject is confirmed by the effect that succeeds to the division of the par vagum; it is asserted that when this nerve is divided vomiting can no longer take place, and as it is distributed principally over the stomach, so as to make it appear that this organ is its specific destination, we may presume that the incapacity for vomiting depends upon the loss of power in the stomach.§

* See the remarks of Blumenbach, ut supra, § 21; Magendie, Physiol. t. ii. p. 24 et seq. and art. "Digestion," in Dict. Sc. Méd. t. ix. p. 370..5. We have some valuable observations by Boerhaave, Prælect. § 88. cum notis; also by Sœmmering, Corp. Hum. Fab. t. vi. § 149..56. Haller describes the phenomena of long-continued fasting with his usual minute correctness; El Phys. xix. 2, 3..7; we have some interesting cases of long-protracted abstinence in Dr. Copland's Trans. of Richerand's Physiol. p. 565 et seq.

† For an account of the phenomena of thirst, and the explanations that have been offered of them, the reader is referred to Boerhaave, Prælect. § 585. 804; Haller, Prim. Lin. § 639; El. Phys. xix. 2, 9; Blumenbach, Physiol. § 330-2, cum nota B; Magendie, Physiol. t. ii. p. 31..3; Elliotson's Physiol. p. 52.

* El Phys. xix. 4. 12, 14; see also Lieutand, Mém. Acad. pour 1752, p. 223 et seq.; Sauvages, Nosol. Meth. t. ii. p. 337.

† Miscel. Curios. Dec. ii. ant. 4, obs. 125, p. 247, 8, and Mém. Acad. pour 1700, hist. p. 27. Nearly the same opinion was maintained by Hunter, Anim. Œcon. p. 199, 0.

‡ Mém. sur le vomissement, p. 19, 2, and Physiol. t. ii. p. 138..40.

§ Bell's Anat. vol. iv. p. 54 et seq. Legallois and Béclard performed a series of experiments on this subject, which consisted in injecting into the veins a solution of emetic tartar. They particularly attended to the effect produced on the œsophagus, the diaphragm, the abdominal muscles, and the stomach itself; the conclusion which may be deduced from these experiments is, that vomiting cannot take place without the compression of some of the contiguous parts upon the stomach; Œuvres de Legallois, t. ii. p. 91 et seq. Dr. Hall has lately investigated the nature of the connexion between the act of vomiting and the state of the organs of respiration. He conceives that the diaphragm is passive in the operation and that the larynx is closed, and he hence concludes that the muscles of expiration, by their sudden contraction, press upon the stomach and project its contents through the œsophagus; Quart. Journ. We must conceive, however, that a state of nausea must be, in the first instance, induced, and this must take place through the intervention of the nerves of the

With respect to the causes of nausea they may be reduced to two heads; those that act immediately on the stomach, and those that act, in the first instance, on the system at large. Of the first class the most active in their operation are the medicinal substances which are specifically styled emetics, from their peculiar tendency to produce nausea and subsequent vomiting. Besides these certain kinds of food, or food of any description, if it remain in an undigested state, and various substances of an acrid or stimulating nature frequently produce nausea and vomiting. In the second class of causes we have to enumerate various circumstances, which act upon parts of the body, sometimes very remote from the stomach, but which, either by direct nervous communication, by sympathy, or association, produce the effect in question. One of the most powerful of these is the motion of a vessel at sea, giving rise to the well-known and most distressing sensation of sea-sickness, certain morbid affections of the brain, particular odours and flavours, renal and biliary calculi, herniæ or other affections of the intestinal canal, and lastly, certain causes which can act only through the medium of the mind or imagination. These various circumstances, although so extremely different in their nature and origin, agree in producing a similar effect on the stomach, which may be explained by referring to the nervous communications which exist between the organ and every part of the system, and more especially with the other abdominal viscera and the brain.*

BIBLIOGRAPHY. — Acad. del Cimento, Esper. Fir. 1691. *Adelon*, in Dict. Sc. Méd. t. ix., xxi. *Baglivi*, Opera, Lugd. 1704. *Baillie's* Morbid Anat. Works by Wardrop, Lond. 1825. *Bauer*, in Phil. Trans. for 1821. *Beaumont* on the gastric juice, Platts. 1833. *Beccaria*, in Bonon. Acad. Com. t. i. *Beck's* Med. Juris. by Dunlop, Lond. 1825. *Bell (T.)* on the teeth, Lond. 1829. *Bertin*, in Mém. Acad. pour 1760. *Berzelius*, Progress of animal chemistry, Lond. 1813. *Blake* on the teeth, Dubl. 1801. *Blandin*, Notes to Bichat, Anat. Gén. Paris, 1830. *Blumenbach's* Comp. Anat. by Lawrence, Lond. 1807. *Blumenbach*, Inst. physiol. Gott. 1787. *Boerhaave*, Prælect. à Haller, Venet. 1751. *Borelli*, De motu anim. L. B. 1710. *Boyle's* Works, Lond. 1772. *Brodie*, in Quart. Journ. vol. xiv. *Carminati*, in Journ. Phys. t. xxiv. *Carswell's* Pathol. anat. Lond. 1833. *Carus's* Comp. Anat. by Gore, Lond. 1827. *Charleton*, Œcon. anim. Hag. 1681. *Chaussier*, in Dict. Sc. Méd. t. ix. *Circaud*, in Journ. Phys. t. liii. *Claussen*, De Duodeno, in Sandifort's Thesaurus. *Clift*, in Phil. Trans. 1807. *Cullen's* Mat. Med. Edin. 1789. *Cullen's* Physiology, Edin. 1772. *Daubenton*, in Buffon, Hist. nat. t. iv. *Davy's* Lecture 5 on agriculture, (2d ed.) Lond. 1814. *De Graaf*, Tract. Anat. Med. L. B. 1671. *Dumas*, Physiologie, Par. 1800. *Duverney*, in Mém. Acad. pour 1700. *Ehrenberg*, in Ann. Sc. Nat. t. ii. *Emmert*, in Ann. Chim. t. lxxx. *Fernel*, Univ. Med. Traj. 1656. *Fleming's* Zoology, Edin. 1822. *Flourens*, in Ann. Sc. Nat. t. xxvii. *Fordyce* on digestion, (2d ed.) Lond. 1791. *Fox* on the teeth, Lond. 1803. *Gairdner*, in Ed. Med. Chir. Tr. vol. i. *Hales's* Statical essays, (4th ed.) Lond. 1767. *Hall*, in Quart. Journ. *Hartley* on man, Lond. 1791. *Hatchett*, in Phil. Trans. for 1799. *Haviland*, in Camb. Phil. Trans. vol. l. *Hodgkin's* Trans. of Edwards, Lond. 1832. *Hodgson's* Letters from North America. *Home's* Lectures on comparative anatomy, Lond. 1814. *Home*, in Phil. Trans. for 1806, 7, 8, 21. *Hunter* on the Animal Œconomy. *Hunter*, in Phil. Trans. for 1772. *Hunter* on the teeth, Lond. 1803. *Juncker*, Conspect. Physiol. *Kellie*, in Brewster's Encyc. *Legallois*, Œuvres de, Par. 1824. *Leuret & Lassaigne*, Recherches sur la digestion, Par. 1825. *Lieutaud*, in Mém. Acad. pour 1752. *Linnæus*, Syst. nat. (ed. 10a) Holm. 1758. *Londe*, in Dict. Méd. et Chir. t. ii. *Lorry*, Sur les alimens, Par. 1781. *Lower*, De corde, Amst. 1669. *Macaire & F. Marcet*, in Ann. Chim. t. ii. *Magendie*, in Ann. Chim. et Phys. t. iii. *Magendie*, in Dict. Sc. Méd. t. ix. *Ditto*, Sur le Vomissement, Par. 1813. *Marcet*, in Med. Chir. Tr. vol. vi. *M'Bride's* Essays (2d ed.) Lond. 1767. *Montegre*, Expér. sur la digestion, Par. 1824. *Monro (Prim.)*, in Ed. Med. Essays, vol. iv. *Monro (Tert.)* on the gullet, Edin. 1811. *O'Beirne* on defæcation, Dub. 1833. *Paris* on diet, Lond. 1826. *Parr's* Med. Dict. Lond. 1809. *Pearson's* Synopsis, Lond. 1808. *Peyer*, Anat. Ventric., in Manget, Bibl. anat. *Peyer*, Mericologia, Basil. 1685. *Philip's* Inquiry, (2d ed.) Lond. 1818. *Pitcairn*, Dissert. Edin. 1713. *Pitcairn*, Elem. Hagæ, 1718. *Plenk*, Bromatologia, Vien. 1784. *Prichard* on the vital principle, Lond. 1829. *Pringle's* Observations, (3d ed.) Lond. 1761. *Prout's* Abstract of his Gulstonian Lecture. *Ditto*, in Ann. Phil. vol. xiii. xiv. *Ditto*, in Phil. Trans. for 1824. *Ray's* Wisdom of God, Lond. 1717. *Reaumur*, in Mém. Acad. pour 1752. *Redi*, Experien. diversa. cose, Firen. 1671. *Richter*, De Vict. Anim. Antiq. Gott. 1761. *Roget's* Bridgewater Treatise, Lond. 1834. *Rostan*, Dict. de Méd. t. i. *Rousseau*, Anat. comp. du syst. dentaire, Par. 1827. *Rullier*, Dict. de Méd. t. xv. *Ruysch*, Opera, Amst. 1737. *Santorini*, Tabulæ, Parm. 1775. *St. Hilaire*, Système dentaire, Par. 1824. *Sauvages*, Nosol. Meth. Amst. 1678. *Serres*, L'anat. et physiol. des dents, Par. 1817. *Serres*, in Mém. Soc. d'Emul. t. viii. *Smith's* Intr. to Botany, Lond. 1807. *Spallanzani's* Dissertations, Lond. 1784. *Spallanzani*, Sur la digestion, Gen. 1783. *Stahl*, Fund. Chym. Dogmat. Norim. 1732. *Stark's* Works, by Smyth, Lond. 1788. *Stevens*, De Aliment. Concoct., in Thes. Med. t. iii. *Sylvius*, Opera, Gen. 1781. *Thackrah's* Lect. Lond. 1824. *Tiedemann & Gmelin*, Recherches sur la digestion, Par. 1826, 7. *Vanhelmont*, Ortus Medicinæ, Amst. 1652. *Valsalva*, Opera, Venet. 1740. *Vauquelin*, in Ann. Chem. t. lxxxi. *Young's* Medical literature, Lond. 1813.

(J. Bostock.)

stomach. See also the art. "Vomissement," by Adelon, Dict. de Méd. t. xxi. p. 427 et seq.; also Blandin's Notes on Bichat, t. iii. p. 460.

* Haller, Prim. Lin. § 652, and El. Phys. xix. 4, 13; Sœmmering, Corp. Hum. Fab. t. iv. § 178; Magendie, ut supra.

DIGESTIVE CANAL (Comp. Anat.) — The digestive canal is that cavity of the body which is destined to receive the food of animals and to retain it until its nutritious part has been separated or absorbed. It is termed also the alimentary or the intestinal canal. As it is the part into which foreign matter is first conveyed for the nutriment of the system, its forms and structure are most intimately related to the kind of food, and consequently to the living habits and instincts, and the whole mechanism of animals. The most universal organs in the animal kingdom are the digestive, and most of the others may be considered as secondary or subservient to these. The lowest animals present us with no other organs than those subservient to digestion, and almost all the organs which are superadded to these as we ascend in the scale either form an extension of the nutritive apparatus, or are destined to regulate the kind of food admitted into the alimentary cavity. An animal, in the abstract, may almost be viewed as a moving sac, organized to convert foreign matter into its own likeness, and all the complex organs of animal life are but auxiliaries to this primitive digestive bag. The bones and other hard parts which form the solid frame-work of the body connected together by their various ligaments serve only as firm levers to enable the active organs, the muscles, to carry it to and fro, and the nervous system with its various organs of sense serve but to direct its motions in quest of food. Nature has placed the unorganized food of plants on the exterior of their body, and their vessels are sent there to seek it, which roots them through life to a fixed point; but animals place their food in their stomach and have their roots directed inwards and towards that central reservoir, so that they can move about and select what is most congenial to their nature. The organs of *animol life* relate to this difference between the two organized kingdoms—to this locomotion of animals and their power of selecting their food; but the *organs of vegetative life* of which the alimentary canal is the first, relate merely to the assimilation of food when already within the body, and are therefore common to animals with plants. The digestive surface of the plant is the surface of its root, ramified and fixed in the soil, which affords it a never-failing supply of food; so that the vegetable is like an animal with its stomach turned inside out. The *organs of relation* are necessarily connected with the varied circumstances in which animals are placed, and are remarkable for their variable character, and even for their inconstancy in the lower tribes, where they are often entirely wanting; but those of *vegetative* or *organic life* are more regular and constant in their character, and indeed no organ is more universal among animals than that internal digestive cavity by which they differ so much from the species of the vegetable kingdom. This primitive sac is but a development or a continuation of the mucous surface of the skin, which extends into the homogeneous cellular tissue of the body, or completely through it; and although, in the simplest conditions of animals, it performs alone all the assimilative functions, we find it, as we ascend in the scale, giving origin to various other systems to which distinct parts of the complex function of assimilation are entrusted. Thus the peripheral mode of nutrition of the plant passes insensibly into the central internal mode of the animal, and all the organs of organic life, whether they open into the digestive cavity within, or on the surface of the body without, may be considered as originating from the skin, which is itself only a portion of the primitive cellular tissue of the body, here modified by the contact of the surrounding element so as to assume the character of a mucous membrane. As the various tubular prolongations become more and more developed and isolated from this primitive source, they assume properties more and more peculiar, and thus form the numerous glandular apparatus and vascular systems.

An internal digestive cavity, the first element of all the organs subservient to individual nutrition, is observed in every class of animals and almost in every genus; and where this part has not yet been perceived, there can be little doubt, from analogy, of its existence. Its form and structure vary according to the kind of food on which the various tribes of animals are destined to subsist, and the extent of elaboration it requires to undergo to assimilate it to the animal's body; so that the diversities of this first part of the digestive apparatus are intimately related to all the living habits of animals, and to all the peculiarities they present in their other assimilative organs and in their organs of relation.

1. *Polygastrica.* In the monads a digestive apparatus is distinctly seen, and in almost all the other genera of animalcules, where, indeed, the internal cavities connected with this important function are so numerous in almost all the known forms of these animals that this lowest class of animals has been termed *polygastrica* to express their common character. From the transparency of these minute animals, their digestive sacs appear, when empty or when filled with water, like portions of the common cellular substance of the body, or like animalcules which have been swallowed, or like internal gemmules; and from not being generally recognized as alimentary cavities, many observers were led to suppose that the animalcules are nourished solely by superficial absorption like marine plants. Leuwenhoeck, however, not doubting that they possessed a stomach, believed that they devour each other; this was observed also by Ellis, and Spallanzani maintained that they devour each other so voraciously that they are seen to become distended with this food. Goeze saw the *trichoda* seizing and swallowing the animalcules which were smaller than itself. Baron Gleichen, in order to discover the form of their internal digestive cavities, placed them in infusions coloured with carmine which they soon swallowed, and in his coloured plates he has represented this red colouring matter as filling the internal stomachs of numerous *trichodæ*, *vorticellæ*, and other animalcules. Indeed those internal globular cavities of animalcules are represented in the plates of Müller, Bruguiere, and all the older writers on this class. But Ehrenberg, by adopting the plan of Gleichen and Trembley of employing opaque colouring matter to detect the forms of these internal cavities, and by using principally carmine, sap-green, and indigo, carefully freed from all impurities which might prevent their being swallowed, has succeeded better than all his predecessors in unfolding the structure of the digestive organs of animalcules. Such coloured organic matter diffused as fine particles mechanically suspended in the water in which animalcules are placed, is readily swallowed by them, and renders visible through their transparent bodies the form and

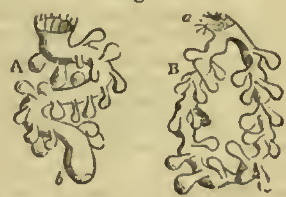
disposition of their alimentary cavities; but however long they remain in these coloured infusions, with their stomachs distended with the colouring matter, it is not perceived to communicate the slightest tinge to the general cellular tissue of their body. In most of the animals of this class there is an alimentary canal with an oral and an anal orifice, which traverses the body and is provided with numerous small round cœcal appendices, which open into its sides throughout its whole course, and which appear to perform the office of stomachs in receiving and preparing the food. In the simplest forms of animalcules however, (as in the *monas atomus* represented in *fig.* 4 A) there

Fig. 4.

is but one orifice (*fig.* 4 A, *a*) to the alimentary cavity, and the numerous cœcal appendices (*fig.* 4 A, *b*) open into this general wide orifice placed at the anterior extremity of the body. This simpler form of the digestive apparatus is found in the *monads* and in about forty other known genera of polygastrica, which, from this circumstance of their having no intestine passing through their body, have been grouped together as an order under the name of *anentera.* In the *monas termo*, which is only about the two-thousandth of a line in diameter, four and even six of these round stomachs have been seen filled with the colouring matter, although they did not appear to be half the number which might be contained in its body. Each of these round stomachs was about $\frac{1}{8000}$ of a line in diameter, and they appear to open, as in other *anentera*, by a narrow neck into a wide funnel-shaped mouth surrounded with a single row of long vibratile cilia, which attract the floating organic particles or minuter invisible animalcules as food. This anenterous form of the digestive sacs is found both in the loricated and in the naked kinds of animalcules belonging to the lowest genera of the class, many of which, however, have been found to be only the young of supposed higher genera.

The intestine which traverses the interior of the body in all the higher forms of polygastric animalcules, and connects all the internal stomachs with its cavity, presents very different appearances in different genera and even in different species of the same genus. In the *vorticella citrina* (*fig.* 4 B) the intestine (*fig.* 4 B, *b, c*) passes downwards from the mouth, nearly of equal width throughout, and after forming a curve in the lower part of the body, it ascends to terminate at the same oral funnel-shaped ciliated aperture, (*fig.* 4 B, *a*,) between the two circles of cilia around the head at which it commenced, having numerous cœcal stomachs communicating with its cylindrical equal canal throughout its whole course. This circular form of intestine opening at both its extremities in the same ciliated aperture, is seen also in the *carchesium, zoocladium, epistylis, ophrydium, vaginicola*, and other genera, which from this character are termed *cyclocœla.* In some of the animalcules of this group, as in the *stentor polymorphus*, (*fig.* 5 B,) the intes-

Fig. 5.



tine pursuing the same circular course through the body, is sacculated or irregularly dilated into round vesicles throughout its whole length, and from these enlarged parts the little stomachs commence by short narrow necks. In other species of the *stentor* the intestine is twisted in a spiral manner throughout its circular course. Many of the polygastric animalcules which approach nearer to the helminthoid classes in the lengthened form of their body, have the mouth and anus placed at the opposite extremities, as in these higher classes. In the long body of the *enchelis pupa*, (*fig.* 6,) the intestine is seen passing straight and cylindrical through the body from the wide ciliated terminal mouth (*fig.* 6, *a*) to the opposite dilated anal termination (*fig.* 6, *b*) and giving off numerous small sacs along its whole course. Such animalcules form the group termed *orthocœla* from this straight course of the intestine. The intestine, however, in the *leucophrys patula* (*fig.* 5 A) passes in a spiral course through the short and broad body of the animalcule, giving off small stomachs or cœca along its whole course, and such crooked forms of the alimentary canal compose the group of *campylocœla*, in the distribution of this class proposed by Ehrenberg.

Fig. 6.

Thirty-five genera of polygastrica present an intestine passing through their transparent body, and developing from its parietes these minute globular cœca, which have been regarded as stomachs, from the quickness with which the animalcule conveys the food into them, and from its not accumulating or retaining its food in any other part of the digestive apparatus. More than a hundred of these stomachs have been seen in the *paramæcium* and *aurelia* filled at the same time, and there may have been many more unseen from their empty and collapsed state. These little sacs are contracted, filiform, and almost invisible, when empty; but they are susceptible of great dilatation, and are sometimes seen filled with water or distended with smaller animalcules seized as food. Viewed through the microscope these minute animals present very different appearances, according to the quantity and kind of food contained in their cœcal appendices, and from this circumstance twelve different species of animalcules, belonging to six supposed distinct genera, have been formed of the single *vorticella convallaria*. No glandular organs to assist in digestion have been observed in the polygastric animalcules; and notwithstanding their almost invisible minuteness and the great simplicity of their structure, they appear to be the most numerous, the most active, the most prolific, and the most voracious of all living beings. Very recently, by the aid of an improved microscope made at Berlin, Ehrenberg has been able to detect a dental apparatus in the *kolpoda cucullulus* of Muller, one of these minute polygastric animalcules, which shews a further analogy between them and the helminthoid articulata. Notwithstanding the number of stomachs in this class of animals, and the infinite variety of prey which commonly surround them, we often observe them devouring animals, which from their magnitude are incapable of being conveyed into these cavities. I have observed a *trachelius*, after swallowing several monads which swarmed around it, proceed slowly to swallow down a *trichoda*, which appeared to be ten times the size of one of its internal sacs. It took about a minute to swallow the *trichoda*, after having turned it in different directions with its long transparent moveable upper lip. The prey could not be perceived to offer the slightest resistance, while the *trachelius*, with its upper lip spread over the small anterior end of the *trichoda*, gradually advanced and expanded the short lower lip to embrace it below. The body of the *trachelius* was much shortened during this prolonged act, being drawn forwards towards the lips, and the animalcule, become slower in its movements, was sensibly distended on one side by this large prey in the intestine; but in less than half an hour it had recovered its usual lengthened form and gliding movements, and was seen to seize again the smaller monads around it. Ehrenberg has figured an *enchelys* swallowing a *loxodes* ten times the size of its stomachs even when filled with carmine, and in the body of the *loxodes* he has represented *naviculæ* which have been swallowed, though several times the size of any of its stomachs distended with sap-green. In the capacious alimentary cavity of the *paramæcium chrysalis* I have found a constant slow revolution of the whole contents, like the cyclosis in the large cells of a chara, and the round sacs appear often to be driven to and fro like loose balls in a sac. Baron Gleichen has figured some of these round sacs of Ehrenberg separate from the animalcules, as a bolus of matter which had escaped *per anum*. These round transparent bodies are often hurried to one end of the animalcule's body and then to the opposite, or spread generally through the cavity, and they sometimes join partially in the general internal cyclosis of the abdominal cavity. In many genera of polygastric animalcules a circular proboscis is seen around the mouth, composed of long parallel straight teeth closely applied to each other, which can be extended or retracted, and forms their masticating apparatus.

(For the higher forms of the alimentary canal in all the separate classes of the animal kingdom, see the names of the several classes from the Porifera to the Mammalia, Animal Kingdom, and the preceding article Digestion.)

(R. E. Grant.)

ECHINODERMATA, (εχινος, *echinus*—δερμα, *corium*,) Fr. *Echinodermes*. A class of invertebrate animals belonging to the division Radiata or the Cycloneurose sub-kingdom. The most familiar examples of them are the common sea-urchin and star-fish.

In these the skin is covered with prickles, a circumstance from which the class has received its name; but animals of corresponding internal structure, such as the Holothuria, are also comprehended among the Echinodermata, although the skin is destitute of prickles. They are all inhabitants of the sea, examples of them are found in all climates, and the remains of extinct species exist in a fossil state in various mineral strata.

Naturalists are not agreed as to the limits of this class. Cuvier includes in it two orders of animals; the first provided with tubular retractile organs named feet, the second destitute of feet, but allied, he conceives, to the first in other respects. Other zoologists separate this second order of Cuvier from the Echinodermata. But in fact these apodous animals, comprehending the genera Molpadia, Minyas, Priapulus, and Sipunculus, are as yet so imperfectly known, at least as regards their internal structure, that naturalists seem at a loss to discover their appropriate place in the zoological system. In these circumstances we shall confine ourselves to the consideration of the true or pedicellate Echinodermata, of whose systematic arrangement the following is a tabular view.

Order I. *ASTEROIDEA* or *STELLERIDA*.

Body depressed, divided into rays like a star, or at least with prominent angles. Mouth inferior, generally no anus.

a. Holes for the feet disposed in grooves on the inferior surface.

Genus 1. Asterias, (*figs*. 298 vol. i. 7-22.)

b. No grooves for the feet.

Genus 2. Ophiura. Rays simple, elongated, cirrhous, with lateral spines.

Genus 3. Euryale. Rays long, cirrhous, divided dichotomously.

Genus 4. Comatula. Rays in two sets, dorsal and marginal. The dorsal rays simple, filiform, cirrhous. The marginal much larger and pinnated, their inferior pinnules turned downwards and surrounding the ventral disk. Border of the mouth formed by a prominent membranous tube.

Genus 5. Encrinus. Body supported on a jointed stem. (With one exception the species are all fossil.)

Order II. *ECHINIDA.*

Body globular or ovoid, without rays; skin containing a calcareous shell; anus distinct.

a. Regularia. Mouth and anus diametrically opposite in the centre of the ventral and dorsal surface respectively.

Genus 1. Echinus. (*figs.* 33 vol. i. 10-19.)

Genus 2. Cidarites.

b. Mesostoma. Mouth in the centre, anus eccentric.

Genus

Anus on the ventral surface or the border.
- 3. Galerites.
- 4. Echinoneus.

(Rows of feet extending from the anus to the inferior opening of the shell.)

- 5. Scutella.
- 6. Clypeaster.
- 7. Fibularia.

Anus above the border or dorsal.
- 8. Cassidulus.
- 9. Nucleolites.

(Rows of feet not extending to the inferior opening of the shell.)

c. Plagyostoma. Mouth and anus both eccentric.

Genus 10. Ananchites.

Genus 11. Spatangus.

Order III. *HOLOTHURIÆ.*

Body oblong, (*fig.* 34 vol. i.) coriaceous, with the anus (k) and mouth (a) at its opposite extremities. Mouth surrounded with retractile, branched tentacula (o). Organ of respiration a ramified tube (h, f, f), placed within the body and opening at the anus.

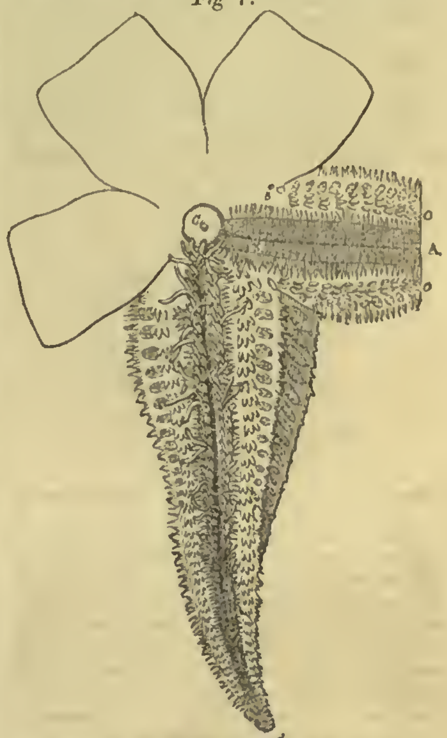
Genus. Holothuria. (*fig.* 34 p. 109, vol. i. and *fig.* 20.)

The genera *Asterias*, *Echinus*, and *Holothuria* are those in which the internal structure has been most frequently and fully investigated; they are therefore usually selected as the leading examples in anatomical descriptions of the Echinodermata, the peculiarities of other genera being mentioned in so far as they have been satisfactorily ascertained, and are of sufficient importance to demand special notice.

1. *Integuments.*—An incision made through the tough skin of the star-fish or shell of the sea-urchin, lays open the internal cavity of the body in which the viscera lie; so that in these animals the integuments in a great measure constitute the parietes of the body, there being little else except the peritoneum or lining membrane of the visceral cavity which is spread over their internal surface. In the Holothuria there are muscles of considerable thickness beneath the skin. The integuments of the former animals contain imbedded pieces of calcareous substance, which constitute a kind of cutaneous skeleton. In the latter there is merely a calcareous ring surrounding the mouth.

a In the *Asterias* the integuments consist of, 1st, a tough coriaceous membrane, with portions of calcareous substance imbedded in it, or at least connected by it; 2d, a softer external membrane; 3d, various appendages. The calcareous pieces form inferiorly a ring round the mouth and a series of transverse segments (from *a* to *A*, *fig.* 7; *C*, *fig.* 22,) placed in succes-

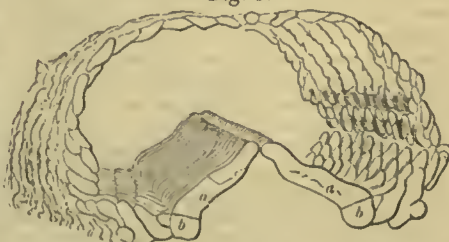
Fig 7.



Inferior view of Asterias rubens: at A part of the feet is removed.

sion along the floor of each ray. The first of these segments is connected with the ring; they decrease in size as they approach the point or distal end of the ray, and openings are left between them for the passage of the feet. In the *Asterias rubens*, which has five rays, the central ring consists of ten larger and five smaller pieces, the former disposed in pairs opposite the commencement of the rays, the latter corresponding to the angles between the rays. The segments of the rays are symmetrical; in the species mentioned they consist of two oblong pieces (*a*, *fig.* 8), united in the

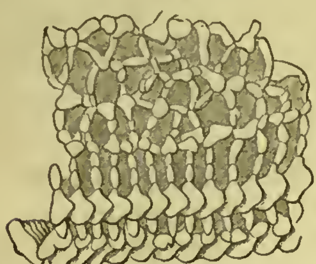
Fig. 8.



Section of a ray of Asterias rubens, showing the arrangement of the calcareous pieces.

median line, and two smaller ones (*b*, *b*,) placed laterally. On the sides of the ray the calcareous substance is disposed, as it were, in ribs (*c*, *c*, *fig.* 9); these rise from the floor at first nearly parallel with each other, and are connected by cross bars, but on approaching the upper part or roof of the ray they cross in all directions and form an irregular network, the intervals of which are occupied by softer integument. The ribs and bars are made up of small pieces joined by plane but oblique surfaces, a mode of construction calculated to admit of their being lengthened and shortened upon one another, and thus to allow of the cavity they surround being dilated and contracted.

Fig. 9.



Portion of a ray of Asterias rubens viewed laterally.

A broad calcareous disk is situated on the upper surface of the body, in the angle between two of the rays, (*figs.* 12 and 16, *z*,) which is connected internally with a singular organ named by Tiedemann the sand canal, to be afterwards described. The calcareous pieces are of a homogeneous structure, without cells or fibres; they consist, according to Hatchett's analysis, of carbonate of lime, with a smaller proportion of phosphate of lime.

The coriaceous membrane which connects the pieces of the skeleton is made up of white glistening fibres. It is contractile and irritable, for it slowly shrinks on being scratched with the point of a knife, or when it is cut through.

The external membrane is much thinner and softer than that just described; in various parts it is coloured, or in these parts there is a coloured layer underneath it.

The *appendages* or processes on the surface of the body are of three kinds. First, calcareous spines; these are found over the whole surface except the grooves for the feet. They are attached by a moveable joint at their base to the calcareous pieces of the skin, and are invested by the external soft membrane nearly as far as their point. Those on the upper surface are solitary, short, and for the most part club-shaped, their broader summit being marked with radiating points; whence they were named stelliform processes by Tiedemann. On each side of the groove for the feet the spines are thickly set (*c*, *c*, *fig.* 7); these in *Asterias rubens* form three rows, in the middle and innermost of which they are placed three deep. On this part of the surface they are also longer and pointed. The spines are slowly moved at the will of the animal.

The appendages of the second kind are of a very singular nature; they have the appearance of pincers or crabs' claws in miniature (*fig.* 298, c, *b*, *b*, p. 615, vol. i.) and were described by Müller as parasitical animals under the name of Pedicellaria. Monro gave the name of antennæ to analogous organs which are found on the sea-urchin. They probably do not exist in all species, for Tiedemann makes no mention of them in his description of *A. aurantiaca*. In *A. rubens* they cover the surface generally, and form dense groups round the spines. Each consists of a soft stem bearing at its summit, or (when branched) at the point of each branch, a sort of forceps of calcareous matter not unlike a crab's claw, except that the two blades are equal and similar. When the point of a fine needle is introduced between the blades, which are for the most part open in a fresh and vigorous specimen, they instantly close and grasp it with considerable force. The particular use of these prehensile organs is not apparent; their stem, it may be remarked, is quite impervious.

The third sort of appendages consists of those which are named the respiratory tubes; they will be considered afterwards.

The other genera of Asteroidea have also a cutaneous skeleton presenting the same general mode of construction as that of Asterias, but with certain modifications of structure and still greater differences of form in particular cases. Of these we may here notice the *crinoid echinodermata* and the genus *comatula*, as the most interesting examples. The former animals, comprehended by most naturalists in the genus *Encrinus*, are, with one exception (the *Enc. caput medusæ* or *Pentacrinite*) found only in a fossil state, and the remains of their skeletons constitute the fossils named encrinites, trochites, entrochites, &c. An idea of their structure may be obtained if we imagine an asterias placed with its mouth upwards on a columnar jointed stem, one end of which is connected to the dorsal surface of the animal, and the other most probably fixed at the bottom of the sea. The rays or arms extending from the circumference of the body are much branched, and at last pinnated; other jointed processes, named auxiliary arms, surround the stem in whorls placed at short intervals. The column is perforated in its centre with a narrow canal, down which a prolongation of the stomach extends, and lateral canals proceed from the central one through the verticillate auxiliary arms. The Comatula has rays spreading from the circumference of the body, branched and pinnated like those of the pentacrinite. It is not fixed on a column, but the dorsal surface of the body is elevated in the middle, and bears a number of smaller rays or arms, and this dorsal eminence with its rays has been sometimes compared to a rudiment of the column of the pentacrinite with its auxiliary arms. Besides the mouth there is an anal opening on the ventral surface, situated on an eminence near the margin.*

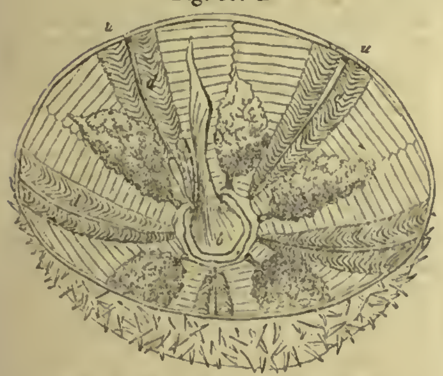
b. In the sea-urchin the calcareous matter is disposed in polygonal plates, which, being

* Meckel, Vergl. Anat. ii. p. 31.

firmly joined to one another, form by their union a shell approaching more or less to a spherical figure, (*fig.* 10, A, B.) The shell is covered outside by a membranous integument, spines, and other appendages; on the inside it is lined by the peritoneum. It is

Fig. 10. A.

Fig. 10. B.

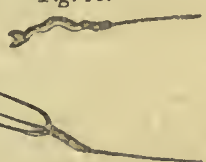


Echinus esculentus opened, intestine removed.
A, under half of shell. B, upper half. *a*, œsophagus cut. *b*, termination of the intestine. *c*, *c*, *c*, ovaries. *d*, *d*, vesicular laminæ of the feet. At *e*, *e*, the laminæ are removed to show the perforations for the feet.

perforated above for the anal orifice of the intestine (*b*), and below it presents a much larger opening, which is closed by the membranous integument, except in the middle, where the mouth is situated (*fig.* 15). The pieces composing the shell are mostly five-sided, transversely oblong, and disposed in twenty vertical rows or columns, which extend from the anus to the inferior opening. Ten of the columns are narrower, and consist of smaller pieces, (*fig.* 10, *e*, *e*,) which are perforated with holes for the feet; they are thence termed *ambulacral*. The other ten are broader, and consist of larger pieces (*f*, *f*). The ten ambulacral columns are disposed in five pairs, with which the ten larger columns, also disposed in pairs, alternate. The two columns of each pair are joined by a zigzag line. The upper ends of the columns are connected with ten plates, alternately larger and smaller, placed round the anus; the larger perforated for the passage of the oviducts, and named ovarial plates, the smaller also perforated by a smaller hole, which is connected with the vascular system. At its lower edge the shell sends inwards a process in form of an arch over each pair of the ambulacral columns (*g*, *g*, *g*). The number of plates in a row varies with the age of the animal, increasing as it grows older and larger. They are marked on the outside with tubercles or knobs, of various sizes, which support the spines. The spines themselves have a cup-like cavity at their base, which is connected with and moves on the prominent tubercle, the union being effected at the circumference of the articulation by the soft irritable integument, or, according to some, by distinct muscular fibres.

Besides the spines, there exist on the external surface of the Echinus appendages (*fig.* 11), of the same nature as the claw-like organs of the Asterias, only that in the Echinus the sort of forceps which they bear at their extremity for the most part consists of three blades.

Fig. 11.



The shell of the irregularly-shaped Echinida differs considerably in structure from that of Echinus. The division into plates is less obvious, and in some cases disappears altogether. The series of holes or ambulacra do not extend uninterruptedly from the anus to the lower orifice. Lastly, in *Clypeaster* the shell is divided interiorly, by vertical calcareous partitions, into five compartments which communicate together, the septa being incomplete.

c. The integuments of the Holothuriæ differ considerably in different species. In those species in which there is a marked distinction of the dorsal and ventral surface of the body, the integument differs in character on these two surfaces: in other cases it is pretty nearly uniform over the whole body. It in general consists of a white fibrous layer, which constitutes its chief thickness, and a soft coloured layer and epidermis placed more exteriorly. In some species the skin exhibits hard conical warts scattered over the dorsal surface; in others it contains imbricated calcareous scales. In *H. phantapus*, in addition to these scales, which are about a line in breadth, the integument, according to our observation, is thickly beset with small calcareous eminences, about $\frac{1}{100}$ of an inch in diameter, resembling, except in size, the short calcareous processes on the upper surface of the Asterias.

A calcareous ring, forming in many species the only hard part of the body, surrounds the mouth. It is made up of ten pieces alternately larger and smaller, and gives attachment to the longitudinal muscles of the body. It is regarded as the rudiment of a skeleton, while the addition of scales or plates in the skin forms in some species an approach to the more perfect cutaneous skeletons of the star-fish and sea-urchin.

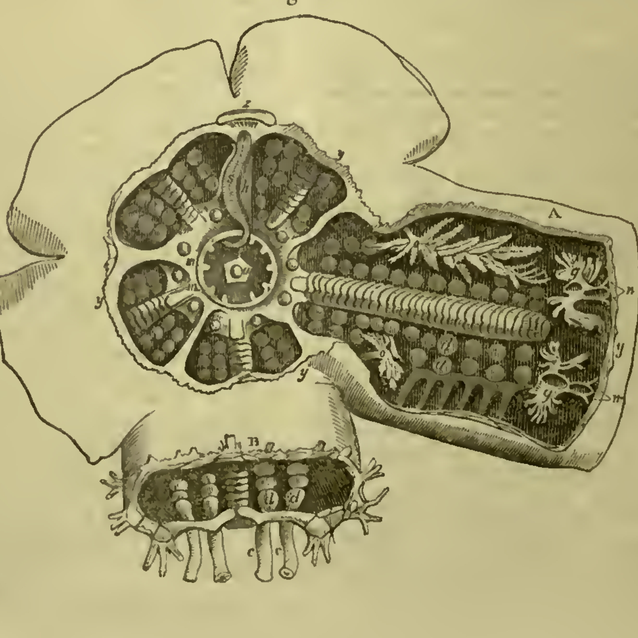
2. *Organs of motion.*—The spines of some Echinodermata are employed to a certain extent as organs of locomotion; they have been already described. The star-fish has the power of slowly moving its rays; it can bend them towards the dorsal or ventral surface, or approximate some of them while it separates others more widely, and thus prepare itself for creeping through narrow passages. Tiedemann ascribes these motions wholly to the contractile skin; they are no doubt partly effected by that tissue, but Meckel describes distinct muscles passing between the calcareous plates which form the floor of the rays, and we have ourselves observed a distinct band of muscular fibres running along the roof of each ray between the coriaceous skin and peritoneal membrane, and also transverse fibres, but less marked, lying between the same parts; the latter are seen adhering to the external surface of the peritoneal membrane when it is stript off.

The muscular system of the Holothuria is much more developed. Ten longitudinal muscles (*fig.* 20, *s, s, s,*) arise from the calcareous ring in the vicinity of the mouth, and pass along the body in the form of broad bands to the posterior extremity; between these and the skin transverse or circular muscles (*l, l,*) are situated; they extend over the whole internal surface of the skin.

The principal locomotive organs of Echinodermata are the membranous tubes named the feet. These are very numerous and are usually disposed in regular rows; they contain a clear fluid, which is conveyed to them by a peculiar system of vessels. Each foot consists of two parts, an internal and generally vesicular portion (*fig.* 12, *d,*) placed within the body, and a tubular part (*c*) on the outside, projecting from the surface and continuous with the first through an aperture in the skin or shell (*fig.* 23, *f*). The tube is closed at the extremity and terminates there in a sucker, which has usually the form of a disk slightly depressed in the centre. Both parts of the foot are evidently muscular, the fibres of the tubular portion being disposed in a circular and a longitudinal layer; the cavity is lined with a transparent membrane, and the tubular part moreover receives an external covering from the epidermis. The foot is extended by the contraction of its internal vesicle, which forces the fluid into the tube, or when a vesicle is wanting, by the projection of a fluid into the tube from a communicating vessel; the tubular part is thus distended and elongated; it retracts itself of course by its muscular fibres, and when this takes place the fluid is forced back again into the vesicular or internal part. In progression the animal extends a few of its feet in the direction in which it desires to go, attaches the suckers to rocks, stones, or other fixed objects immediately in advance, then shortening its feet it draws its body in the wished-for direction.

a. In the starfish the feet are disposed in rows along the under surface of the rays, diminishing in size as they approach the extremity (*fig.* 7, *a, b, d*). There are usually two simple rows in each ray, (*fig.* 23, *c,*) and the vesicular part is for the most part deeply cleft into two lobes (as in *A. aurantiaca, fig.* 22, *d, d*). In

Fig. 12.



other cases, as *A. rubens*, there are two double rows (*fig.* 7, *b*,) in every ray, and each foot has a round undivided vesicle (*figs.* 12 and 16, *d*).

The canals or vessels which convey the fluid to and from the feet are all connected with a circular vessel situated in the vicinity of the mouth. This vessel (*figs.* 12 and 22, *i, i*,) lies immediately within the calcareous ring already described as connecting the rays at their commencement; from it a straight canal proceeds along the floor of each ray in the median line, and in its progress gives off lateral branches which open into the vesicles of the feet. There are moreover connected with the circular vessel,—first, a certain number of bodies (ten in five-rayed species) which Tiedemann compares to glands (*figs.* 12 and 22, *m, m*); they are very small, brown, sacculated organs, each opening by a small orifice into the circular vessel; Tiedemann supposes them to be the source from which the fluid filling the feet is derived. Secondly, pyriform sacs; in *A. aurantiaca* there are four groups of these (*fig.* 22, *k*); and each group consists of three or four sacs which open by a common tubular pedicle into the circular vessel. In some other species there are five simple sacs. They are muscular, and Tiedemann conceives them to be the chief agents by which the fluid is forced into the vesicles of the feet, to which they are placed in a sort of antagonism. It would seem, however, that this purpose may be accomplished by other means, for according to Meckel's statement, and, we may add, our own observation, they are not present in all species. Lastly, the circular vessel receives the singular organ named the stone canal or sand canal by Tiedemann, (*figs.* 12 and 22, S,) who describes it as a membranous canal containing a friable mass of sandy or earthy matter, which commences by a wide origin on the inferior or internal surface of the calcareous disk (*figs.* 12 and 16, *z*,) already described as situate on the upper part of the body, descends in a duplicature of fibrous membrane, and opens by a narrow orifice into the circular vessel, the upper or wide end being closed by the disk. Ehrenberg has correctly remarked that this organ is not filled with an amorphous mass of earthy or cretaceous matter; he describes it as exhibiting a dense network of calcareous fibres with hexagonal and pentagonal meshes, resembling in some respects the cavernous structure of the penis. The result of our own examination in more than one species is different still. We have always found the earthy matter forming a jointed calcareous tube. This tube, which is about the thickness of a surgeon's probe, is composed of rings of calcareous substance connected by membrane, so that viewed externally it is not unlike the windpipe of a small animal. On cutting it across, however, it is found to be more complex in structure than appears externally, for it contains within, two convoluted laminæ of the same nature as its calcareous parietes (*fig.*13). These laminæ are rolled longitudinally; they rise conjointly or as one, from the internal surface of the tube, pass inwardly a certain way, then separating are rolled in opposite directions; something after the same manner as the inferior turbinated bone of the ox. These internal laminæ become more convoluted towards the upper end, where at last they, as well as the more external part of the tube, join the dorsal disk, appearing gradually to become continuous with its substance.

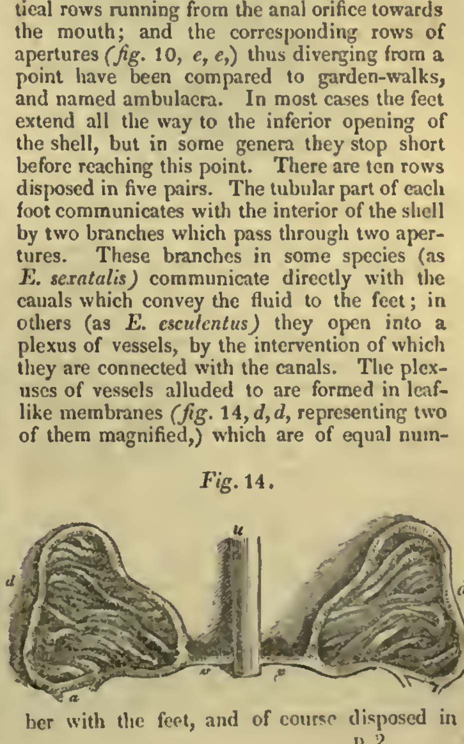
Fig. 13.

Portion of the sand canal of Asterias rubens, magnified.

The disk is perforated with numerous pores which open into the tube. Tiedemann conceives the function of the sand canal to be that of secreting the earthy matter required for the growth of the calcareous skeleton. Meckel considered this view as very improbable, and the description we have given does not tend to corroborate it. We must confess ourselves unable to offer more than mere conjecture as to the use of this singular structure. If the fluid contained in the feet and their vessels be sea-water, (either pure or with an admixture of organic particles,) which is probable from its chemical composition, may it not be introduced and perhaps again discharged through the pores of the disk and the calcareous tube, the porous disk serving as a sort of filter to exclude impurities?

In the Echinus the feet are disposed in vertical rows running from the anal orifice towards the mouth; and the corresponding rows of apertures (*fig.* 10, *e, e*,) thus diverging from a point have been compared to garden-walks, and named ambulacra. In most cases the feet extend all the way to the inferior opening of the shell, but in some genera they stop short before reaching this point. There are ten rows disposed in five pairs. The tubular part of each foot communicates with the interior of the shell by two branches which pass through two apertures. These branches in some species (as *E. sexatalis*) communicate directly with the canals which convey the fluid to the feet; in others (as *E. esculentus*) they open into a plexus of vessels, by the intervention of which they are connected with the canals. The plexuses of vessels alluded to are formed in leaf-like membranes (*fig.* 14, *d, d*, representing two of them magnified,) which are of equal num-

Fig. 14.

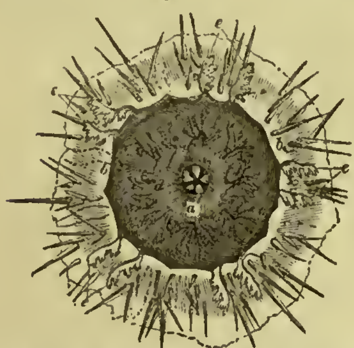


ber with the feet, and of course disposed in double rows on the inside of the shell (*fig.* 10, *d.*) Monro describes each foot as communicating with two of these laminæ, and consequently every lamina as receiving a branch from two feet; in our own dissections we have always found that both branches of each foot belonged to one lamina. These branches are represented as cut at *a* in the annexed figure.

Five longitudinal vessels run down on the inside of the shell, there being one in the middle of each double row of feet (*figs.* 10 and 14, *u*); lateral branches go off from these either directly to the feet or to the laminar plexuses when they are present. The five longitudinal vessels descending towards the mouth rise through the dental apparatus named the lantern, and open into five sacs or receptacles placed on its upper part, where according to Tiedemann they terminate. Monro on the other hand describes the sacs as communicating together, and states that from them the liquor passes down the sockets of the teeth, and is discharged into the sea. The vessels and laminæ are highly irritable, and by their contraction distend the feet.

Ten tubular tentacula, similar in structure to the feet, are situated in the vicinity of the mouth (*fig.* 15, *d, d, d.*) In *Ech. esculentus* they are attached to the small calcareous plates

Fig. 15.



Part of the inferior surface of the Echinus.
a, mouth; *b, b*, margin of the inferior opening of the shell; *e, e*, membrane which fills it.

which are imbedded in the membrane that fills up the aperture of the shell. The plates are each pierced with a hole, through which the tentacula communicate with the canals of the feet.

In Holothuriæ the feet are sometimes scattered over the whole surface of the body; in other species (as *H. pentactes)* they are placed in five longitudinal and tolerably regular rows; while in others again they are confined to the ventral surface, as in *H. phantapus*, where they form only three rows. The tubular part (*fig.* 20, *b, b,*) is in general very short, and is connected with a simple vesicle inside. The vessels of the feet arise from a circular canal which surrounds the stomach near the fore part of the body. One or sometimes two large pyriform sacs (*fig.* 34, *b*, p. 109, vol. i.) open into this canal, and a number of small brown hollow glandular-like bodies are also connected with it. Five vessels issue from it, which run forwards and terminate in a second canal situate immediately within the calcareous ring which surrounds the mouth. This second circular canal is connected with the tentacula, as will be afterwards described, and it gives off five longitudinal vessels which run towards the posterior end of the body, and distribute lateral branches to the vesicles of the feet. Tiedemann regards the fluid contained in this system of vessels as a secretion, and conceives that it nourishes the skin, the muscles, and tissue of the feet, besides supplying to the latter the mechanical means of their distension. Further observation would, however, be required in order to determine its true nature, for there is much reason to suspect that the fluid of the feet in other Echinodermata consists at least in great part of sea-water, and it is not to be supposed that in the Holothuria it should be materially different.

Under this head we may notice the tentacula of the Holothuria (*fig.* 34, *o*, p. 109, vol. i.) retracted, as they present a great analogy in structure with the feet. These organs are placed round the mouth and are twenty in number; the extremity of each is formed into a circular sucker surrounded by five or six branched processes. They are hollow, and a great part of them is lodged within the body; this internal part is long and tapering, and communicates by a small orifice with the anterior circular canal already described, from which the tentacula receive their distending fluid. In the rest of their structure and in their mode of action they resemble the feet. They seem to be very sensible, and are probably used as organs of touch as well as prehension. In *H. pentactes* the tentacula are very large, much larger than in *H. tubulosa*.

3. *Digestive organs.*—The digestive apparatus is very simple. The sea-urchin and Holothuria have an alimentary canal with a mouth and anus, but in the star-fish there is merely a stomach with cœcal appendages and only one orifice. The cavity in which the alimentary organs and other viscera are lodged is lined with a peritoneal membrane, which being reflected upon them forms their external tunic, and attaches them by a duplicature or mesentery to the inside of the cavity. The Echinodermata are said to live chiefly on testaceous mollusca and crustacea.

a. In *Asterias* a short but dilatable gullet leads to the stomach (*figs.* 16 and 22, *f*), which occupies the central part of the animal, and from the stomach a pair of lobulated cœca (*g, g*, and *g′, g′*, inflated,) pass into each ray. The stomach is connected at various places with the parietes of the body by ligamentous bands; it is thin and membranous, soft and corrugated on the internal surface, receiving externally a covering of peritoneum, and containing muscular fibres which are more obvious towards the lower part, when it adjoins the still more muscular œsophagus. Two or more blind sacs (*l*), branched in some species, open

Fig. 16.

Asterias rubens: three rays opened—in the one, at A, cœca cut short to shew the vesicles of the feet, d, d, and one ovary, o; g, g, cœca, g' g', cœca inflated.

into it from above, which are probably secreting organs. The cœca are thin and membranous like the stomach; each consists of a central tube with lateral branches, which in their turn are lobed or branched, and terminate in cellular dilatations. The two cœca of a ray sometimes communicate with the stomach by a short single tube (*h*); in other cases they have separate orifices. They do not reach so far as the distal end of the ray; each one is attached to the roof by what might be called a double mesentery, for the peritoneum forms here two duplicatures (*figs.* 12 and 16, *n*,) between the cœcum and the roof of the ray. A space is inclosed between these duplicatures which opens into the central part of the body at the root of the cœca.

Such is the structure in the *Asterias*, but in some other genera belonging to the tribe of Asteroidea it is different. In *Ophiura*, *Euryale*, and *Comatula*, in which the rays are very long and slender, the cœca are mere cellular dilatations of the stomach, and do not extend into the rays. *Comatula* moreover differs from all the tribe, inasmuch as its alimentary canal has two openings, a mouth and anus, situated near to each other on the ventral surface.

The mouth of the star-fish is very dilatable, so as to admit large mollusca in their entire shell. The gullet and part of the stomach are usually everted, protruded, and applied round the object to be swallowed, which is then drawn in. The hard or indigestible matters, such as the shells of mollusca, are discharged by the mouth. The star-fish is said to be very destructive to oyster-beds, and is popularly believed to suck the animals out of their shells. Bishop Sprat, in his History of the Royal Society, informs us that great penalties are laid by the Admiralty Court upon those engaged in the oyster-fishery who "do not tread under their feet or throw upon the shore a fish which they call a *Five-finger*, resembling a spur-rowel, because that fish gets into the oysters when they gape, and sucks them out." Tiedemann found the cœca to contain a greyish-white fluid which he supposed to be digested aliment; others again, such as Meckel, regard the cœca as secreting organs, analogous to the biliary organs of many invertebrate animals, with which, it must be allowed, they agree in several respects.

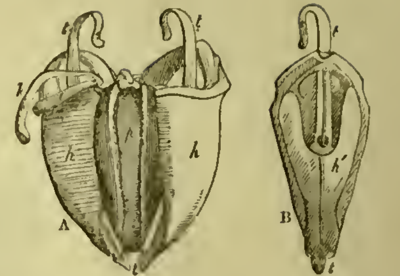
b. The mouth of the Echinus is an orifice situated in the middle of the circular membrane which fills up the lower aperture of the shell (*fig*. 15, *a*.) The points of the five teeth are seen within it, and at no great distance from its circumference the ten tubular tentacula (*d*) are observable, which have been already described. The teeth are set in five moveable sockets or jaws which surround the commencement of the gullet, and with the addition of some accessory pieces form the singular structure usually named *Aristotle's lantern*. The lantern (*figs*. 10, 17, and 18) has the appearance of a five-sided pyramid placed with its apex

Fig. 17.

Dental apparatus of the Sea-urchin viewed from above.

downwards or towards the mouth, the gullet (*a*) rising through its centre. It is made up of five smaller hollow pyramids (*h*,) which are the sockets of the teeth. Each lesser pyramid is three-sided; its external side (*fig*. 18, *h'*,) which forms one of the faces of the greater pyramid, presents an opening in its upper half which is closed by membrane; its lateral faces (*fig*. 18, *h*, *h*,) are applied to the corresponding sides of the adjacent sockets, with which they are connected by short muscular fibres (*p*); they approach each other at the inner

Fig. 18.



A, *two sockets with teeth, of Echinus esculentus.*

B, *single socket with its tooth viewed on the outside.*

edge of the socket, but do not meet. The tooth (*t*) is prismatic, very long, and lodged in a groove formed in the external side of the socket; its point projects beyond the apex of the socket; its opposite extremity or root rises above the base, where it is bent inwards and downwards and inclosed in a membrane. The teeth are very hard at the point, but softer towards the root, where they are easily separable into transverse scales or plates with a fine silky or asbestine lustre; they seem to grow continually at the root, and wear at the point as in the Rodentia.

Ten additional pieces contribute to form the lantern. Five of these (*i*) are oblong and flattened, and are placed horizontally, in a radiating manner, on the upper surface of the lantern, occupying the intervals between the bases of the lesser pyramids. The other five (*k*) are placed directly over the first; they are longer but more slender, and bent in a semicircular form, the convexity being upwards; their central ends are articulated with the corresponding extremities of the horizontal pieces; the outer ends are bifid and give attachment to ligaments.

The muscles and ligaments belonging to the dental apparatus partly pass between its different pieces, and partly connect it with the border of the shell. It will be recollected that the border of the shell forms five processes (*figs*. 10 and 17, *g*, *g*, *g*,) which rise in the form of arches into its cavity round the lower aperture. Ten muscles (*m*, *m*,) arise from these arches, and descending inwardly are inserted into the lesser pyramids or sockets near the point. Two of these muscles come from every arch, and diverging are inserted into different pyramids, so that each pyramid receives its two muscles in a converging manner from two adjacent arches. The muscles described draw outwards the sockets separating them and widening the mouth. Other ten muscles (*n*, *n*,) arise in pairs from the border of the shell in the intervals of the arches, and, ascending, are inserted into the outer surface of the sockets near their base, each socket receiving a pair. These are antagonists to the last described; they move the points of the pyramids, and consequently the teeth inwards and against each other. Five muscles composed of short transverse fibres (*p*, *fig.* 18,) unite the lateral surfaces of the sockets, and serve to approximate them, acting collectively as a sort of sphincter, and as antagonists to those first described. Lastly, five muscles (*figs.* 10 and 17, *o*, *o*, *o*,) pass between the semicircular pieces on the upper part of the lantern. Besides the muscles described, there are ten very thin whitish bands (*s*, *s*,) which arise in pairs from the external forked extremities of the semicircular pieces, and are inserted into the border of the shell in the intervals between the arches. Tiedemann describes these bands as muscles; Meckel, on the other hand, considers them as ligaments; in the *E. esculentus* they certainly seem to us to be ligamentous. Two ligamentous filaments pass from the central end of every semicircular piece to the gullet. A covering of the peritoneum envelopes the dental apparatus, extending to it from the border of the shell.

The œsophagus (*fig.* 19, *a*,) rises through the lantern, to which it is connected by fine ligaments, and after a few curvatures terminates in a wider part of the alimentary canal, somewhat in the same way as the small intestine joins the great in the human body. The wider portion (*b*, *b*,) of the canal turns twice round the inside of the shell in a waving manner, and terminates at the anus (*c*). In

Fig. 19.

Internal view of Echinus sexatilis.
A, under half; B, upper.

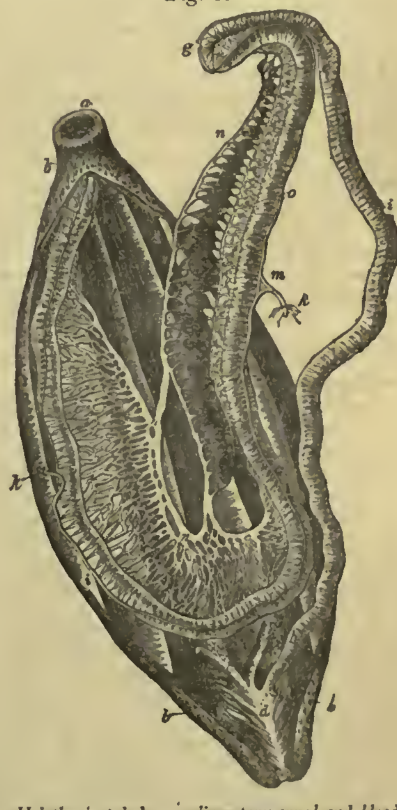
its second or superior circuit it changes to an opposite direction, but its flexures in both circuits are parallel. The tissue of the alimentary canal is very delicate, the external tunic is formed by the peritoneum, which attaches the intestine by a mesentery to the shell, lines the inside of the latter, and is reflected over the ovaries and the lantern. The inner coat of the intestine is soft and of a brownish-yellow colour; between it and the external, Tiedemann states that delicate longitudinal and circular muscular fibres are distinguishable.

The Echini are generally believed to feed on mollusca and crustacea, and in corroboration of this, Tiedemann states that he has found in the Echinus sexatilis small univalve and bivalve shells entire among the excrements, besides fragments of larger ones. Blainville,* on the other hand, could never find any thing else than sand in the alimentary canal, and he remarks that the general opinion as to the carnivorous habits of the sea-urchin is probably more an inference from the structure of the teeth and jaws than the result of observation; he, however, adds that M. Bosc had witnessed an echinus in the act of seizing and devouring a small crustaceous animal. In the intestine of the *E. esculentus* we have usually found numerous small morsels of sea-weed, for the most part encrusted with a flustra. The excrements, which are in the form of small round pellets about the size of peppercorns, consist chiefly of sandy matter with fragments of shells, but it would be difficult to say whether these are the remains of digested mollusca or merely a portion of the usual testaceous debris so abundant in sand and mud.

The principal difference of the alimentary organs in the different genera of Echinida depends on the position of the anus and the presence or absence of teeth. In *Scutella*, *Clypeaster*, *Fibularia*, *Echinoneus*, *Galerites*, *Ananchites*, and *Spatangus*, the anus as well as the mouth opens on the under surface. In *Echinus*, *Cidaris*, *Cassidula*, and *Nucleolites*, it is situated on the upper surface; in the first two exactly in the centre, in the last two at a greater or less distance from it. The teeth are wanting in *Spatangus* and *Cassidula*.

c. The alimentary canal of the Holothuria is

Fig. 20.



Holothuria tubulosa: alimentary canal and blood-vessels.
The respiratory organ, *c*, *c*, is cut short.

* Dict. des Sc. Nat. art. *Oursin.*

very simple (*fig.* 20, *e*, *f*, *g*, *h*.) At the mouth it is surrounded by the tentacula and calcareous ring already described, it passes backwards on the right side the whole length of the body (from *e* to *f*,) then bending forwards it returns to near the mouth (from *f* to *g*,) and at last runs back again to the posterior extremity (from *g* to *h*,) where it terminates in a short and wide cloacal cavity (*d*), common to it and the respiratory organ, and opening externally at the anus. The intestine is fixed by a mesentery, and the cloaca is connected to the parietes of the body by numerous muscular bands derived from the transverse muscles. The coats of the canal are thin; Tiedemann enumerates three, an external derived from the peritoneum, a middle which is very vascular and contains muscular fibres, and an internal or mucous. In *H. tubulosa* a small part of the canal near its commencement is wider than the rest, has thicker coats, and is more decidedly muscular; Tiedemann regards this part as the stomach. In *H. pentactes*, the part immediately succeeding the œsophagus and extending nearly to the first flexure, is somewhat cellular and at the same time wider, but thinner in its coats than the rest of the canal; this part is considered to be the stomach by Meckel.

It is a singular fact, which it appears was first noticed by Redi, that several species of Holothuria, on being taken from the sea and put into a vessel of sea-water, discharge their intestine and part of the respiratory organ through the anus. This operation is effected by repeated contractions of the cutaneous muscles, and some naturalists are disposed to regard it as a voluntary act.

4. *Respiratory organs.*—The Echinodermata breathe through the medium of sea-water. In the star-fish and urchin the water enters the body, passing into the space in which the viscera are lodged, and this cavity, which, as already stated, is lined by a peritoneal membrane and occupies the greater part of the body, is generally regarded as the chief seat of the respiratory process. In the Holothuria the water is alternately drawn in and expelled from a tubular respiratory organ ramified within the body.

a. In the star-fish the water is generally believed to enter and issue from the body by numerous small tubes on the surface, which have accordingly been named the respiratory tubes. These are very small, membranous, and in figure somewhat conical (*fig.* 298, *c*, *c*, p. 615, vol. i.); they communicate at their base with the interior of the body, and are perforated at the summit by an orifice which can be very accurately closed. Most of them are placed in groups or patches, and opposite

Fig. 21.

Portion of the skin of Asterias rubens, seen on the inside and magnified.
c, *c*, peritoneal membrane raised.

each group the fibrous membrane forming the wall of the body presents on its inside a shallow pit (*fig.* 21, *a*; *fig.* 298, vol. i. *e*; *fig.* 16, *s*, *s*,) perforated with holes, through which the tubes communicate with the internal cavity. The tubes are formed externally of the superficial layer of the skin, and are lined in the inside by a prolongation of the peritoneal membrane. This membrane lines the parietes of the body, and is reflected over the contained parts; at least it covers the stomach and cœca, and probably also the ovaries and vesicles of the feet; opposite the perforated pits it sends prolongations (*b*, *b*,) through the holes into the tubes, as may be easily seen on stripping off a portion of it.

There can be no doubt that sea-water enters the peritoneal cavity. The animal slowly distends itself with that fluid, and again, but at no stated interval, gives out a portion of it: this is obvious from the fact that the same animal may be seen distended at one time and flaccid at another. Naturalists are generally of opinion that the water enters and issues by the respiratory tubes, and indeed no other orifices have been discovered; we must, however, freely own that we have never been able actually to observe its passage through these tubes.

The peritoneal membrane seems to be the principal seat of respiration; spread over the viscera and the parietes of their containing cavity, and lining the respiratory tubes, it presents a great extent of surface continually in contact with the surrounding medium; and we have found that a beautiful provision exists for maintaining currents of water along the membrane, and thus effecting that constant renovation of the fluid in contact with its surface which is required in the respiratory process. These currents are produced by means of cilia; they are more particularly described in the article CILIA, to which we refer the reader. Ciliary currents take place also on the external surface of the body, which probably partakes in the process of respiration; we have moreover observed them within the tubular feet and on the internal surface of the stomach and cœca; in this last situation they are probably subservient to digestion, but their use is more fully considered in the article referred to.

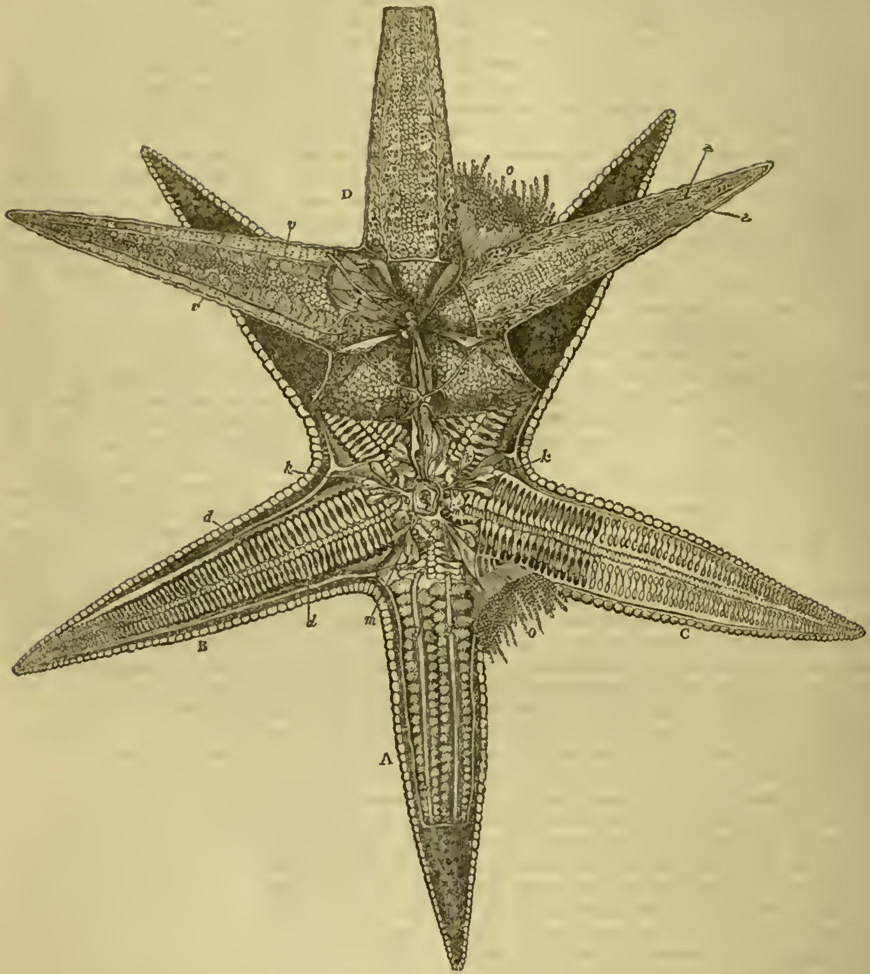
b. The respiratory system of the sea-urchin is very similar. The water enters the body through membranous respiratory tubes, which are collected into ten small bunches (*fig.* 15, *e, e*), situated on the under surface of the animal at the border of the shell, and opening internally by ten perforated pits like those of the Asterias. The fluid being introduced into the peritoneal cavity, is moved along its parietes and over the surface of the alimentary canal, the ovaries and the vascular laminæ of the feet, by the action of cilia. Ciliary currents have also been observed on the external surface of the body.

c. The respiratory organ of Holothuria (*fig.* 34, *f, f, h*, p. 109, vol. i.) has some resemblance in form to that of air-breathing animals. It is a very long membranous sac, placed within the body, which opens into the cloaca near the rectum and extends forwards from thence nearly the whole length of the body, either single, or (as in Holothuria tubulosa) divided into two main branches (*fig.* 20, *c, c*, cut short, *fig.* 34, *f, f*, p. 109, vol. i.), which in the vicinity of the cloaca are joined by a short common stem. One of these branches is intimately connected by bloodvessels to the intestine, the other by muscular fasciculi to the parietes of the body. The sac, whether single or bifid, gives off a great many lateral branches, which after successive divisions terminate in shut or blind extremities. Both stem and branches contain distinct circular and longitudinal muscular fibres, and contract on being irritated. In the act of respiration sea-water is drawn into and expelled from this organ, and its entrance and exit, which may be readily seen at the cloaca, occur in some species so often as once, twice, or even three times in a minute. The alternate inhalation and expulsion of the fluid are effected partly by the action of the muscular parietes of the body, but principally, it would appear, by the muscular fibres of the organ itself, for Tiedemann observed the process still to go on, though with diminished activity, when the animal was cut open and the organ exposed. Cuvier states that the sac in some species is without branches.

5. *Vascular system.*—A system of vessels for the circulation of the blood exists in the animals under consideration. The tenuity of their coats, however, and pale colour of their contents render it extremely difficult to trace completely the distribution of these vessels, and we accordingly find that the descriptions of them given by Tiedemann and Delle Chiaje, the principal authorities on the subject, differ materially from each other. According to Tiedemann the proper sanguiferous system is, in its distribution, in a great measure confined to the alimentary organs and ovaries, or to these and the respiratory organ where such is present; he therefore supposes that the canals which convey the fluid of the feet serve moreover as nutritious vessels to parts of the body also supplied by the sanguiferous system. In short he conceives that there are two systems of nutritious vessels distinct from each other, the sanguiferous system, confined to certain organs already named, and the vessels of the feet, destined to nourish another set of parts; the vessels of the first system carrying blood, those of the second a nutritious fluid secreted from the blood. Delle Chiaje on the other hand maintains that the two orders of vessels communicate together and form but one system. From our own observations on the Asterias we are disposed to conclude that the vessels of the feet form a system apart from the bloodvessels, as is maintained by Tiedemann; but there seems considerable reason to doubt whether, as that author supposes, they serve as the nutritious vessels of the parts in which they run; for even according to his own admirable description it does not appear that they ramify in the tissues, if we except, perhaps, the skin of the Holothuria. Moreover their contained liquid does not present the usual characters of blood or of a fluid adapted to nourish the textures; it is true there are floating particles suspended in it, but the clear fluid when filtered yields no trace of animal matter, but agrees almost entirely in composition with sea-water; at least such is the result of our examination of it in the Asterias. The vessels of the feet having been already described, we have here only to give an account of the proper sanguiferous system, following Tiedemann as our leading authority, but at the same time stating the more material points in which Delle Chiaje differs from him.

a. In *Asterias* a delicate vessel runs along the upper surface of each of the cœca. There are, of course, ten such vessels in Asterias *aurantiaca* (from which the description is taken) corresponding in number with the cœca (*fig.* 22, *v, v*). They commence near the extremity of the rays, and, receiving branches from the branches and lobes of the cœca, proceed to the central part of the animal, where they terminate in a circular vessel (*x*) which runs round the upper part of the body on the internal surface. The circular vessel also receives ten branches (*y, y*) from the ovaries, and five from the stomach, which before joining it unite into two (*w*). The vessels described seem to constitute the venous system, and Tiedemann further supposes that the cœcal and gastric veins convey the chyle or nutritious part of the food from the alimentary organs. The circular vein opens into a vertical canal (*h*, and *fig.* 12, *h*), which descends along the prominent angle between two rays, inclosed in the same membranous sheath with the sand canal already described, and terminates in an

Fig. 22.



Asterias aurantiaca opened from above.

A, ray with the cœca *g, g*, in their place. B, cœca removed; vesicles of feet *d*, seen. C, vesicles of feet removed to shew the calcareous segments of the ray. D, skin forming roof of the body and rays A, B, C, raised; vessels seen on its inner surface with collapsed stomach, *f*, &c.

inferior circular vessel. The descending canal is dilated in the middle; its comparatively thick brown coloured parietes are smooth externally, but reticulated on the inside and composed of interlaced fibres, which Tiedemann found to possess muscular irritability. He accordingly considers this canal as the heart. The inferior circular vessel (which must not be confounded with the circular canal connected with the feet) surrounds the mouth on the outside or inferior surface; it sends out five branches which pass into the interior of the body, and are distributed to the stomach, cœca and ovaries. Tiedemann regards these branches with the circular vessel from which they proceed as arteries, and he thinks it probable that their minute ramifications open into the radicles of the veins, though from their delicacy he has not been able to ascertain the fact by injection.

Tiedemann's view of the function of the respective vessels is derived solely from a consideration of their anatomical disposition, and while in the same way it may be inferred that the blood circulates in a direction conformable with this view, it must nevertheless be kept in mind that no direct physiological proof of such a course of the blood has been yet obtained. Besides the vessels described, Tiedemann found yet another circular vessel surrounding the mouth on the under surface and placed more superficially than the last mentioned; it is of an orange colour and sends a branch along each of the rays, in the groove which is on the middle of their inferior surface. He could trace no connection between this vessel or its branches and the rest of the vascular system, and he professes himself at a loss to conjecture what may be its function.

According to Delle Chiaje the circular vessel (*i*, *i*, *figs.* 12 and 22,) into which the canals of the feet open receives also the veins from the upper surface of the cœca and stomach. The same vessel, which he names the venous sinus, gives out—1. twenty short *dental* arteries; 2. the *mesaraics* to the under surface of the cœca; 3. five *vertebral* arteries which open into the vesicles of the feet; 4. the *radial* to the under part of each ray; 5. the *dorsal* arteries to the upper part of the ray, which extend their ramifications to the external surface of the body.

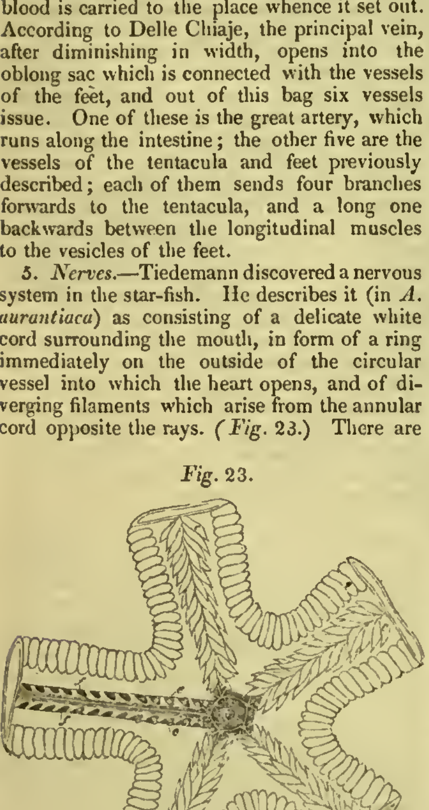
b. Echinus. A circular vessel, supposed to be of a venous nature, surrounds the anal extremity of the intestine (*fig.* 19, at *c*), being situated on the internal surface of the shell. A vertical vessel (*e*, cut short) descends from it towards the lantern and opens into a short oval canal (*h*) with muscular parietes, which exhibits during life slow but distinct contractions and dilatations, and which is therefore considered as a heart. The heart is situated near the commencement of the intestine; a vessel (*i*, *i*, *i*, *i*) issues from it which first sends branches to the œsophagus and the muscles and membranes of the lantern, and then runs along the whole intestine on its inner border, first increasing somewhat in diameter, afterwards gradually diminishing as it approaches the anus, where it terminates. This vessel gives off at all points of its course small branches to the intestine; it contains a dark yellow fluid coagulable by alcohol, and its parietes contract on mechanical irritation; Tiedemann conceives it to be an artery. Another vessel (*k*, *k*, *k*, *k*) equal in length to the last described, but not directly connected with the heart, runs along the intestine on its outer or mesenteric border; it also is widest in the middle of its course, from whence it may be traced in one direction as far as the lantern, and in the other to the vicinity of the anus. Along its whole course this vessel receives small branches from the intestine, and gives off branches from its other side, which pass along the mesentery to the internal surface of the shell, and are ramified on the lining or peritoneal membrane. Tiedemann regards this vessel as a vein; but as it does not directly communicate with either the heart or the circular vessel, he conceives that the fluid which it circulates is conveyed into it by one set of branches, and out of it by the other, the intestinal being its entering and the mesenteric or peritoneal its issuing branches. Lastly, the circular vessel placed round the termination of the intestine receives several vessels which come from the peritoneal lining of the shell, and whose commencing branches are probably continuous with the terminations of the peritoneal branches from the longitudinal vein. Tiedemann conceives the circulation to take place in the following manner. The blood passes from the circular vessel into the heart; it is then propelled along the artery and its branches; from these it passes into the veins of the intestine, which also absorb the chyle, and the mixed fluid is conveyed into the great longitudinal vein; it next passes into the branches of this vessel, which are distributed to the lining membrane of the shell, and is at last conveyed back by another set of vessels into the circular vein, from which we have supposed it to set out. That this is the course of the circulation is inferred from the anatomy of the circulating organs. On similar grounds Tiedemann with great probability supposes that the blood undergoes its respiratory change, at least chiefly, in its passage through the vessels of the peritoneal membrane, being there most effectually exposed to the influence of the water; he accordingly compares the branches of the great vein which ramify on that membrane to pulmonary or branchial arteries, and the vessels which return the blood to the circular vein, together with that vein itself, to pulmonary veins. He found that the fluid contained in the longitudinal vein was of a yellowish white colour, from which circumstance, as well as from the fact that he could discover no special chyliferous vessels, he inferred that the chyle was absorbed by its intestinal branches. This vein did not contract on the application of stimuli.

Delle Chiaje's description of the vessels of the Echinus is in substance as follows. An *annular vessel* surrounds the œsophagus; it receives the termination of the *intestinal vein*, and gives out the *intestinal artery*, which like the vein runs along the intestine, and also five *œsophageal arteries*, which before ramifying on the mouth communicate (by means of a branch passing between the muscles of the teeth) with the *dorsal arteries*. These last are the canals of the feet; they run along the ambulacra to the anus, where, according to Delle Chiaje, they form a ring, and in their course send lateral branches into the feet.

c. Holothuria. A vessel (*fig.* 20, *i*, *i*, *i*, *i*,), which Tiedemann conceives to be the great artery, runs along the free border of the intestine. It is widest in the middle, and gradually disappears posteriorly in the neighbourhood of the cloaca, while anteriorly it forms an annular vessel (at *e*) round the stomach, out of which branches proceed to the stomach, the ovaries and the sac connected with the canals of the feet and tentacula formerly described. A short but wide anastomosing branch (cut at *k*, *k*,) passes from the artery about the middle of the first portion of the intestine, to join it again at the middle of the second portion (*m*), that is, nearly about the middle of the arterial trunk itself. Slow contractions, followed by dilatations, were observed by Tiedemann in this vessel; they commenced at the middle or widest part, and proceeded in opposite directions to its two extremities, carrying on the light brown-coloured blood contained within it in a corresponding manner. The main artery, which seems thus also to serve the purpose of a heart, sends in its course numerous branches to the intestine, from these the blood is received by the commencing veins, which, uniting together at the opposite or attached border of the intestine, form a plexus along its first portion, whose branches ultimately terminate in a large longitudinal venous trunk (*n, n, n, n*). The blood is conveyed from this great vein to the right branch of the respiratory organ, (which lies between the first and second portions of intestine,) by a considerable number of vessels which divide like arteries into smaller ramifications on the lung, and may therefore be compared to pulmonary arteries. The capillary branches of these vessels transmit the blood into the commencing pulmonary veins, which, uniting into larger and larger branches, terminate in a third longitudinal vessel (*o*), situated on the second portion of intestine. This last-mentioned vessel, which may be considered as the great pulmonary vein, sends branches on the intestine which open into the wide part of the main artery, and thus the blood is carried to the place whence it set out. According to Delle Chiaje, the principal vein, after diminishing in width, opens into the oblong sac which is connected with the vessels of the feet, and out of this bag six vessels issue. One of these is the great artery, which runs along the intestine; the other five are the vessels of the tentacula and feet previously described; each of them sends four branches forwards to the tentacula, and a long one backwards between the longitudinal muscles to the vesicles of the feet.

5. *Nerves.*—Tiedemann discovered a nervous system in the star-fish. He describes it (in *A. aurantiaca*) as consisting of a delicate white cord surrounding the mouth, in form of a ring immediately on the outside of the circular vessel into which the heart opens, and of diverging filaments which arise from the annular cord opposite the rays. (*Fig.* 23.) There are

Fig. 23.



c, feet; e, feet cut across; f, apertures for the feet.

three filaments for each ray; one runs along the under surface in the median line, and appears to send small branches to the feet; the other two, which are shorter, pass between the first and second segment of the ray into the interior of the body, and are probably distributed to the stomach. Tiedemann could discover no ganglia, but others describe minute ganglia as existing at the points where the diverging filaments originate.*

The Echinodermata have not generally been supposed to possess any other sense than that of touch. Professor Ehrenberg has however recently called attention to certain parts in the Asterias, which he is disposed to regard as organs of vision.† These have the appearance of small red spots, one of which is seen at the extremity of each ray. They have been long known to exist in several species of Asterias, but no one ever assigned to them any particular use till lately, when Professor Ehrenberg, struck with their resemblance in aspect to the eyes of Entomostraca and Infusoria, conjectured that they might be of the same nature. He states that he has traced the long nerve of the ray as far as the extremity, where it swells into a sort of ganglion with which the red point or supposed eye is connected.

In the *Echinus* Tiedemann observed fine filaments on the internal surface of the membrane which fills the inferior opening of the shell, and on the dental apparatus and the longitudinal vessels of the feet, from which he inferred that a nervous system probably existed in the Echinus analogous in form to that of the Asterias. In the same way he was led to suspect the existence of such a system in the Holothuria, though by dissection he could make out nothing more than several exceedingly delicate filaments, some of which were situated in the neighbourhood of the mouth, and appeared to enter the tentacula, and others lay on the longitudinal muscles. Dr. Grant describes a connected nervous system in the Echinus and Holothuria, but without mentioning on whose observations his description, which we here transcribe, is founded. "A nervous chord," he states, "is seen round the œsophagus of the Echinus, which sends delicate white filaments to the complicated muscular and sensitive apparatus of the mouth; other nerves are seen extending upwards from the same œsophageal ring, along the course of the vessels in the interior of the abdominal cavity. In the Holothuria the nervous system is extensively developed. Interior to the osseous apparatus of the mouth is a white nervous ring around the œsophagus, from which nerves pass outwards to the large ramified tentacula around the mouth, and others extend upwards along the course of the eight strong longitudinal muscular bands. Fine white filaments are likewise seen passing inwards to the stomach and alimentary apparatus."‡ In a recent notice of some observations on the Echinus by M. Van Beneden, it is stated that he distinctly recognized a nervous collar surrounding the œsophagus.

6. *Generative organs.*—The only organs hitherto discovered in the Echinodermata, which

* Grant's Comparative Anatomy, p. 184.

† Müller's Archiv für Anatomie, Physiologie, &c. 1834. p. 577.

‡ Comparative Anatomy, p. 184.

can with certainty be regarded as belonging to the generative system, are the ovaries, which are found in all. These animals would therefore appear to have no distinction of sex. Whether the concurrence of two individuals is in general necessary for propagation is uncertain; O. Fabricius affirms it of the star-fish, but further observation would be required satisfactorily to establish the fact; he says "congreditur" (Ast. rubens) "mense Maio, oribus arcte connexis, altera supina."*

a. The ovaries of Asterias seem to vary in number according to the species. In *A. rubens* and *aurantiaca* there are ten, two being situated in each ray, above the vesicles of the feet. Each of these organs consists in the former species of an oblong cluster of ramified tubes, (*figs.* 12 and 16, *o*, and at *o'*, cut short), proceeding all from a single stem by which the organ is fixed, and terminating in round vesicular dilatations. In *A. aurantiaca* the tubes are not all connected by a single stem, but form about twenty fasciculi, each of which has a distinct attachment (*fig.* 22, *o*, *o*).

The vesicles contain a whitish pulpy substance, with which they are more or less distended according to the season of the year; so that the ovary, varying thus in size, is found to occupy sometimes a greater at other times a less extent of the ray, to the commencement or base of which it is attached. Tiedemann could discover no excretory duct of the ovary; and nothing positive is known as to the way in which the ova are formed and discharged from the body. Tiedemann conjectures that they escape by openings situate in the neighbourhood of the mouth, in the angles between the rays.

The Ophiura has also ten ovaries, which do not lie in the rays, but in the central part of the animal, and which, according to Meckel, open externally by orifices on the ventral surface.

b. The Echinus has five ovaries, (*fig.* 10, *c*,) attached to the inside of the shell in the upper part of the body, and occupying the spaces between the five rows of feet. They are often joined together laterally. They consist of an assemblage of small round bodies, which are the ova. Five short tubular oviducts come from the upper end of the ovaries and open externally by an equal number of orifices, pierced in five oval plates which surround the anus. The size of these organs, as in the star-fish, varies much according to the degree of maturity of the ova. The ovary, or row as it is named, is the part used as food. Mr. Pennant states that the E. esculentus is "eaten by the poor in many parts of England, and by the better sort abroad;" in ancient Rome the Echini formed a favourite dish at the tables of the great.

c. The ovary of Holothuria tubulosa (*fig.* 34, *m*, p. 109, vol. i) is situated at the fore part of the body near the stomach and first portion of the intestine. It is a tube with many clustering branches, which terminate in blind and slightly dilated extremities. The main tube or oviduct runs forwards along the stomach, and opens externally on the dorsal aspect of the body a little way behind the mouth. Between the insertion of its branches and its external orifice, eight or ten pyriform vesicles open into it, close to each other, by long tubular pedicles.

The size of the ovary varies excessively at different periods; its branches usually contain a whitish fluid; but Tiedemann states that about the end of October he has in some instances found the organ enlarged to twice or three times its usual dimensions, and containing oblong brown-coloured bodies from half a line to a line in length, which he supposes were eggs or perhaps embryos. From a statement of O. Fabricius it would appear that the Hol. pentactes is ovo-viviparous: he says, "est vivipara: mense enim Martio in illa versus anum pullum libere natantem, rubicundum vidi."* The pyriform vesicles are found enlarged at the same time with the ovary itself, and Tiedemann conjectures they may be male organs, by which a fecundating fluid is produced and applied to the ova.

7. *Regeneration of lost parts.*—The star-fish affords an example of great regenerating power. Individuals are often found which have evidently sustained the loss of one or more rays, and in which new rays, as yet incomplete in their growth, occupy the place of the old. Experiments have been even purposely made which were attended with the same result; but we are not aware that the process of regeneration in these animals has been carefully traced in its successive steps, or at least fully described. In 1741 and 42, Messrs. Bernard de Jussieu, Guettard, and Gerard de Villars made observations and experiments on this subject at various parts of the coast of France. These researches were undertaken at the request of M. de Reaumur, who thus describes them. "They (M. de Jussieu and Guettard) brought me specimens of star-fish with four large rays and a small one still growing; they found others with only three large and two extremely small rays; others again with two large rays and three very small, and, as it seemed, very young ones. Lastly they more than once met with a single large ray from which four small ones had begun to sprout." After remarking that the fact had been long familiarly known to the fishermen, M. Reaumur continues, "The portions into which Messrs. Jussieu and Guettard had divided the animals appeared to go on well, the wounds cicatrized and consolidated, but the experimenters were obliged to limit their stay on the coast to about fifteen days; too short a period to trace the progress of a reproduction which apparently is not completed till after several months, or perhaps even upwards of a year."†

BIBLIOGRAPHY.—*Kleinius*, Naturalis dispositio

* Fauna Groenlandica, p. 368.

* Fauna Groenlandica, p. 353.

† Reaumur, Mémoires pour servir à l'histoire des insectes, tome vi. preface, page lx. sq.

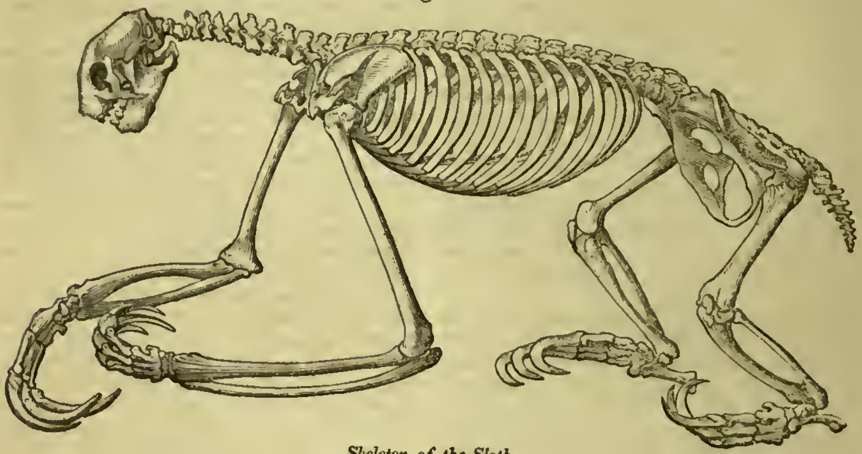
Echinodermatum, 4to. Lips. 1778. *Linkius*, De stellis marinis, fol. Lips. 1733. *Blainville*, Dict. des Sc. Nat. art. Oursin. *Tiedemann*, Anatomie der Rohrenholothuric, &c. Heidelberg, 1820. *Ehrenberg*, in Meckel's Archiv fur Anat. &c. 1834. *Delle Chiaje*, Memorie sulla storia degli animali senza vertebre del regno di Napoli.

(W. Sharpey.)

EDENTATA.—A group of mammiferous animals, exhibiting no very distinct general characters to indicate any close mutual affinities between them, but agreeing in the unimportant character of the absence of incisive teeth and the possession of long claws. They may indeed be considered as consisting of two very distinct groups; the one exclusively vegetable feeders, the other generally insectivorous in their habits. To the first belong the Sloths (*Bradypus*), (*fig.* 24), constituting the *Tardigrada* of Illiger; to the second, the Ant-eaters (*Myrmecophaga*), (*fig.* 25), the Armadillos (*Dasypus*), (*fig.* 26), the Pangolin (*Manis*) (*fig.* 27), with their congeners, and the recently discovered American fossorial animal, the *Chlamyphorus*, forming the *Edentata proper*. The enormous extinct animal, the *Megatherium* (*fig.* 28), may be considered as an additional form, and a very interesting and important one, as it certainly exhibits some characters which appear to connect the *Tardigrada* and the true *Edentata*. The organization of these forms is so different as to require a separate description. The *Ornithorynchus* and the *Echidna* are necessarily excluded from the *Edentata*, with which they had been united by Cuvier and others, and form the group called *Monotremata* by Geoffroy.

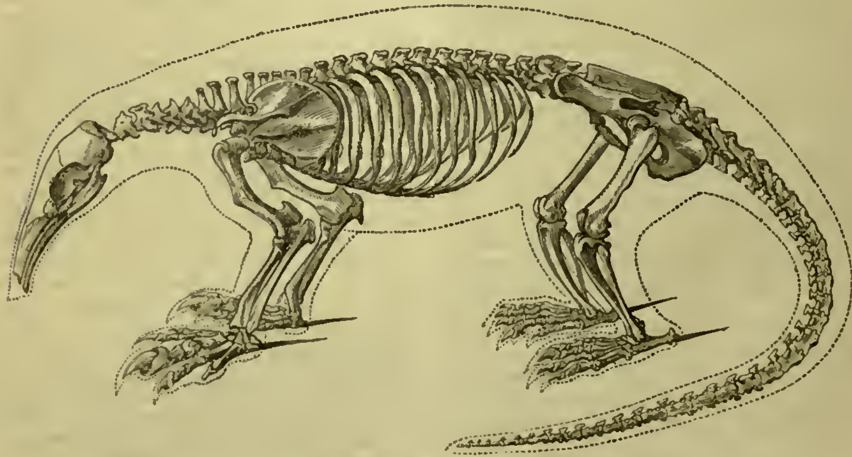
In the Sloths, the whole structure is evidently formed to enable them to pass their life in trees, amongst the branches of which they constantly reside, hanging with the back downwards and creeping slowly along in this remarkable position, embracing the bough, and

Fig. 24.



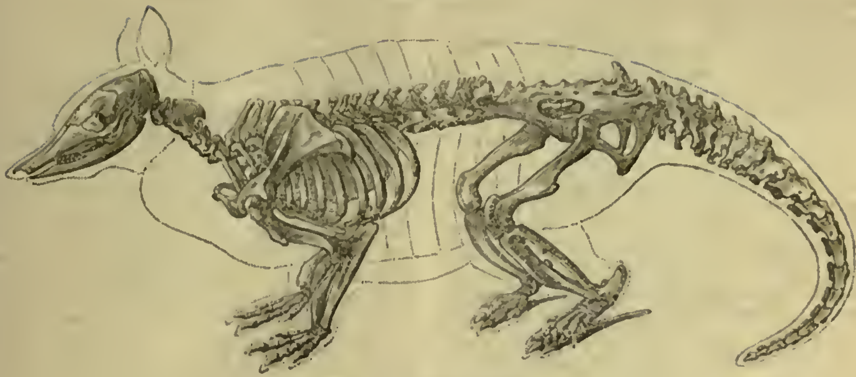
Skeleton of the Sloth.

Fig. 25.



Skeleton of the Ant-eater.

Fig. 26.

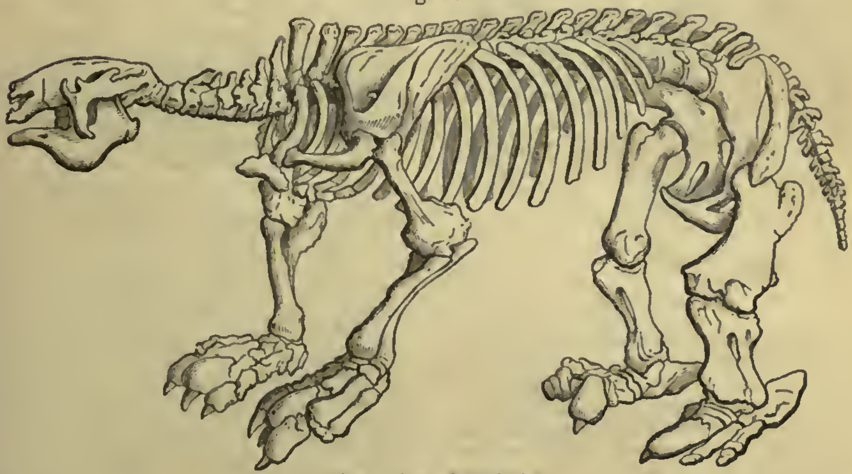


Skeleton of the Armadillo.

Fig. 27.

Skeleton of the Manis.

Fig. 28.



Skeleton of the Megatherium.

stretching out their hands, which in the Aï or *Bradypus tridactylus* are of great length, to enable them to lay hold of the extreme twigs, and bring them to the mouth. Their progression on the ground is excessively slow and awkward, and should they be obliged to have recourse to it either from accident or from being forced by famine to seek a new tree on which to obtain their subsistence, they quit it as speedily as their peculiar organization will permit, and ascend the nearest tree with an awkward attempt at alacrity. The whole of their structure is admirably adapted to these extraordinary habits; and although upon a comparison of these slow-moving creatures with the active and intelligent and elegant animals which form the more conspicuous groups of the Edentata, they may appear to possess but few advantages of structure, and little to excite interest in their habits, yet a careful investigation into the relation between their organization and their mode of life will shew that not even in the most elevated forms of the animal creation, does the wisdom of the

Creator display itself more fully than in the construction of these contemned and apparently apathetic beings. I must refer the reader to a highly interesting paper by Professor Buckland in the Linnæan Transactions, in which the libels of Cuvier on this maligned animal are beautifully and satisfactorily refuted.

The Ant-eaters and Armadillos, on the other hand, which may be considered as the true *Edentata*, are constructed for very different habits, and the *Chlamyphorus* must be considered as offering a very near affinity to the latter genus. The Ant-eaters with their thick long hair and fossorial claws, and the long extensile tongue with which they are furnished, are thus enabled to scratch or dig up the ant-hills and to receive their minute but multitudinous inhabitants on the mucous surface of the tongue; whilst by their long dense hair they are protected from the annoyance or danger which their little troublesome victims would otherwise inflict. The Armadillos and the *Chlamyphorus*, on the other hand, pursue their insect prey either on or beneath the surface of the earth, and are protected from the attacks of their enemies by the panoply of mail with which they are furnished.

The osseous system. The cranium.—The general character which at once strikes us in looking at the cranium of the Sloths (*fig.* 29) is its

Fig. 29.

Head of the Sloth.

extreme shortness, particularly with regard to the facial portion, and the roundness of its whole contour. In the insectivorous forms the muzzle, on the contrary, is greatly elongated. The *frontal bone* in the Tardigrada is large, and the anterior portion convex; it has no zygomatic process, and the frontal and orbital portions pass into each other by a very obtuse angle. The *parietal bone* in most is of a square figure. In the Armadillos (*fig.* 30) and in the

Fig. 30.

Head of the Armadillo.

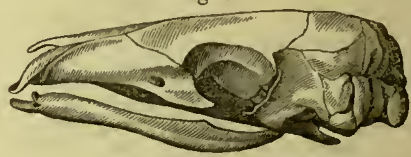
Orycteropus the two parietals are united from an early period; in the Ant-eaters, on the contrary, they remain separate. In the Sloth the squamous portion of the *temporal bone* is of large dimensions, and the acoustic portion of but moderate size. The zygomatic process is small and does not reach the jugal bone; a construction which is still more conspicuously seen in the Ant-eaters. The *occipital bone* is large; the squamous portion broad and rounded, the superior part being continued to the inferior by an obtuse angle in the Sloths, and by nearly a right anglein the true Edentata. The occipital foramen is round. The *jugal bone* offers some remarkable peculiarities in its form. In the Ant-eaters (*fig.* 31) it occurs in a

Fig. 31.

Head of the Ant-eater.

very imperfect condition, being merely an oblong plate of bone, terminating posteriorly in a rounded point, situated in the posterior extremity of the superior maxillary bone, and beneath the lachrymal, extending posteriorly scarcely beyond the latter; consequently it is remote from the temporal bone throughout the whole length of the temporal fossa, and there is no zygomatic arch. In the *Manis* (*fig.* 32) it is absolutely wanting. In the Arma-

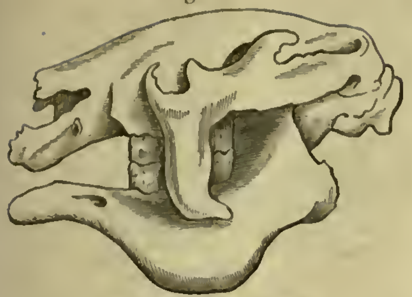
Fig. 32.



Head of the Manis.

dillos it is somewhat more fully developed; it is larger and higher and reaches the temporal bone by its posterior portion. In the Sloths, especially in the *Bradypus didactylus*, or Unau, it attains a much greater size, and has on its inferior margin a long process extending downwards and backwards almost to the base of the lower jaw. This remarkable process is also found in the enormous fossil animal the *Megatherium* (*fig.* 33). The posterior extremity of the jugal bone is remote from the zygomatic process of the temporal in the Sloths, but in the *Megatherium* these bones are united, and the zygomatic arch is therefore complete. The inferior maxillary bone varies excessively in this order. In the *Oryeteropus*, *Manis*, and *Myrmecophaga*, it is extremely long and depressed; its height does not greatly vary in the whole of its length. In the Armadillos it is much shorter, and in the Sloths it is extremely short and truncated. The *intermaxillary bone* is excessively small in the Ant-eaters and the Sloth, which are not furnished with any incisive teeth, but in Armadillos it attains a somewhat greater degree of development, especially in the genus Da-

Fig. 33.



Head of the Megatherium.

sypus. The *inferior maxillary bone* varies no less in its form in the different genera of this incongruous order than the superior. It is greatly elongated and very slender in the *Edentata proper*, particularly in the Ant-eaters; the ascending plate is thin and small, the right and left branches of the bone are united at the symphysis to a considerable extent, and at a very acute angle. In the Sloths this bone exhibits a very different structure; it is short and deep, the ascending plate is broad and almost square, the angular process is very large, and the two branches of the jaw unite at the symphysis without an angle, the anterior portion of each side being curved inwards to meet its fellow. In the *Megatherium* the body of the bone is still higher and shorter, but the anterior part is prolonged into a narrow and depressed groove somewhat similar to that of the elephant.

The vertebral column.—The variation in the form and construction of the vertebræ will be found to bear an exact relation to the habits of the different genera. The *cervical vertebræ* of the Aï, *Bradypus tridactylus*, have always, until very recently, been believed to form an exception to the general law, which assigns seven as the strict number of these bones in the mammiferous animals. That this number should exist equally in the hog and the giraffe is indeed a remarkable fact, and may be considered as a striking illustration of the law by which variations in volume in any particular system of organs are provided for rather by the difference in volume or in the relative proportions of the organs themselves, than by any abrupt change in their number. The supposed exception to this law which now comes under our notice consists in the fact that the neck of the animal in question, (speaking of the part rather in reference to its use than in strict anatomical language,) is formed of nine vertebræ. Two skeletons in my own possession, however, have enabled me to demonstrate that the posterior two of these vertebræ (*fig.* 34) have attached to them the rudiments of two pair of ribs in the form of small elongated bones articulated to the transverse processes of these bones, which are therefore to be considered as truly dorsal vertebræ, modified into a cervical form and function, suited to the peculiar wants of the animal. The object of the increased number of vertebræ in the neck is evidently to allow of a more extensive rotation of the head; for as

Fig. 34.

Neck of the Sloth.

each of the bones turns to a small extent upon the succeeding one, it is clear that the degree of rotation of the extreme point will be in proportion to the number of moveable pieces in the whole series. When the habits of this extraordinary animal are considered, hanging as it does from the under surface of boughs with the back downwards, it is obvious that the only means by which it could look downwards towards the ground must be by rotation of the neck; and as it was necessary, in order to effect this without diminishing the firmness of the cervical portion of the vertebral column, to add certain moveable points to the number possessed by the rest of the class, the additional motion was acquired by modifying the two superior dorsal vertebræ, and giving them the office of cervical, rather than infringing on a rule which is thus preserved entire without a single known exception.

In the two-toed Sloth there is but one pair of these rudimentary ribs, and consequently only the first dorsal vertebra enters into the composition of the neck.

The dorsal portion of the vertebral column is particularly long in the Ant-eaters as well as the Sloth. These vertebræ are also generally more numerous in this than in most other groups—the great Ant-eater having sixteen, the Aï fourteen, and the Unau no less than twenty-three—a larger number than is found in any other mammiferous animal. The ribs offer some striking peculiarities in their construction. In the Ant-eaters and Armadillos they are excessively broad with the exception of the first and second. In the *Myrmecophaga jubata* and *M. didactyla* they overlap each other in an imbricated manner on the upper part,—a conformation which gives great solidity to the chest. The Sloths and the *Megatherium* exhibit also considerable breadth of the ribs, but to a much less extent than that just described, and the latter animal, at least in the remains lately described by Mr. Clift, the part joining the sternum, and answering to the cartilages of the ribs, is bony and is connected to the rib itself by a moveable articulation. The *lumbar vertebræ* are generally broad and furnished with strong spinous processes. The transverse processes are inconsiderable in the Sloths, but large in the *Edentata proper*. In the Armadillos the anterior articular processes are particularly strong and larger even than the spinous. This is the case, but to a less degree, in the Ant-eaters. In the *Orycteropus* there are slight indications of inferior spinous processes on most of the lumbar vertebræ, consisting of a small longitudinal crest. The *caudal vertebræ* vary excessively in number. In the Unau and *Bradypus didactylus* they are very few—not more than seven or eight; in the large Ant-eater forty, and in the African Manis forty-five. In the remains of the *Megatherium* lately deposited in the Museum of the Royal College of Surgeons, the tail would appear, according to Mr. Clift's computation, to consist of eighteen vertebræ at least. The caudal vertebræ of the *Edentata proper* have inferior spinous processes of a remarkable form, being constituted of two branches meeting inferiorly in the median line. The *Megatherium* possesses similar V-shaped processes. In the *Myrmecophaga didactyla* the two branches are not united in the anterior two of them. The *sternum* offers a considerable developement of the *manubrium* or anterior bone in the whole of the *Edentata*, particularly in the Ant-eaters and Armadillos. It is also rather large in the *Megatherium*.

The *pelvis* in the *Edentata proper* is much elongated, and the *acetabulum* rather behind the middle of the whole length of the bones. The *ileum*, which forms the anterior half of the pelvis in the Armadillo, is fixed to the *sacrum* by its posterior portion, a surface of considerable extent. The *ischium* and *pubis* are large, the ischiatic notch wide, and the cavity of the pelvis capacious. In the Sloths and *Megatherium* the pelvis is of large dimensions, the ilia very broad, especially in the latter; the cavity capacious, and the outlet large. The *ossa pubis* are joined at the symphysis in most of the *Edentata*, as is now ascertained by Mr. Clift, in the *Megatherium*. In the *Myrmecophaga didactyla*, it is stated by Cuvier to be open. The size of the pelvis in the *Megatherium* is enormous. On comparison of it with the pelvis of an elephant eleven feet in length, Mr. Clift found that in the former the ilia are 5ft. 1in, and in the latter only 3ft. 8in.

The anterior extremity.—The principal characteristic of the bones of the arm in the Sloth is their extraordinary length. The *humerus* is very much elongated and cylindrical, with the elevations but slightly marked. The ulna and *radius* are also very long, and bowed, so that the bones are distant at the middle of their length; the *radius* is very broad anteriorly. The very complete power of pronation and supination enjoyed by this animal is no less obviously suited to its habits than the great length of its anterior extremities; both of which peculiarities are admirably subservient to the complicated objects of holding by the boughs, of advancing along their under-surface, and of reaching and bringing to the mouth the leaves on which it feeds; and the structure of the hand (*fig.* 35) is no less suited to the same pur-

Fig. 35.

Hand of the Sloth.

poses. The *carpus* is as long as it is broad; it is composed of six pieces only, of which four form the first series, and two the second. The *os scaphoïdes* is the largest of the whole, and is articulated with the *os semilunare* by a convex articular surface: the *os cuneiforme* presents on its ulnar side an oblique flattened surface; the *os pisiforme*, which is not named by Cuvier, does however exist, though it is of small size. The inner and larger piece of the anterior series probably consists of the *os trapezium, trapezoideum*, and *magnum* united; and the external one solely of the *os unciforme*. In the Unau the *os trapezoïdes* is distinct. The *metacarpal bones*, to return to the Aï, consist of three perfect and two rudimentary, the whole of which are united at their base to each other and to the inner solid carpal piece, consisting of the three bones before mentioned; so that in fact the five metacarpal bones, with the *os trapezium, trapezoideum*, and *magnum*, form one solid osseous piece. The fingers, which are three only, are very long, and consist each of two moveable phalanges only, the first being very small and early anchylosed to the metacarpal bone. In a very young skeleton in my possession, these bones are not yet united. There is but very little flexion between this part and the second phalanx, but between the latter and the third or ungueal phalanx the flexion is complete, the latter being bent down to the palm with perfect ease. These ungueal bones are very long, curved, laterally compressed, large at the base, at which part there is, as in the cats, a bony sheath to cover the base of the claw; and the latter envelopes the phalanx for about five-sixths of its length.

The *posterior extremity* in this remarkable animal offers no less striking peculiarities. The breadth and openness of its pelvis have been already noticed. The *femur* is articulated to the acetabulum so as to stand obliquely outwards from the pelvis; it has a short head, and is itself rather short, strong, and flattened. The *tibia* and *fibula* are long and slender, and somewhat curved; the superior articular surfaces of the *tibia* are flat, that of the inferior extremity small, triangular and slightly concave; but the most extraordinary articulation is that of the *fibula* with the *astragalus;* its inferior extremity terminates in a conical point, which enters and plays in a corresponding cavity in the latter bone. This peculiarity of the articulation of the ankle, which was considered by Cuvier as only additional evidence of the imperfection of the animal's structure, is no less admirably adapted to its habits than those points which have been previously noticed. The feet, it is true, are turned inwards, and there is no possibility of placing the sole on the ground; but it is the better adapted for clasping boughs, and the freedom of rotation which is provided by this curious joint allows of every kind of motion required in such circumstances. The *tarsus* consists of the *astragalus* and *os calcis,* which are separate, and of the usual anterior series of bones, which in the aged individuals are anchylosed together as well as to the metatarsal bones, which are themselves united as in the *carpus.* The tubercle of the *os calcis* is very long, and so situated as to afford a sort of opposing thumb to the flexed phalanges. The latter bones very nearly resemble those of the anterior extremity.

It is impossible not to be struck, even on a superficial view of the extraordinary structure of the anterior and posterior extremities of the Sloth, with the complete adaptation of this deviation from the normal form to its peculiar mode of life. Grasping the boughs of trees on which it both feeds and reposes, crawling along with the back downwards and the belly pressed against the tree, and culling, with the long arms, the leaves at the inaccessible extremities of the branches, the usual construction of the members would be absolutely useless, and an incumbrance instead of an assistance. But by the great breadth of the pelvis, the direction of the femora, the long and curved claws, the consolidation of the tarsus, and the curious structure of the articulation of the fibula with the astragalus, every requirement of security and progression is obtained; whilst in the anterior extremity the extensive motion of the shoulder-joint, the great length of the arms, the complete flexion of the fingers, and other peculiarities, combine, with that security and facility of progression, the most effective means of obtaining the animal's peculiar food.

Of the Edentata proper.—The extremities in animals of this class are, as may be concluded from their habits, very differently constituted from those which have just been described. In all of them the object to be obtained is facility in digging the ground, or scratching up immense nests, in search of the insects which constitute the principal food of most of these animals. The gigantic *Megatherium,* however, appears to have combined the phytophagous character of the Sloth with the fossorial habits of the *Dasypus,* and is supposed to have lived upon roots, which it snatched or dug up with its enormous claws. The scapula of the Ant-eaters and Armadillos is found nearly like that of the Sloth; in the *Myrmecophaga jubata* a process of bone extends from the coracoid process to the anterior margin, rendering that which is a notch in other species a complete foramen. A second spine inferior to the true one is also observed in that species, in which respect it resembles the Unau or two-toed Sloth. The scapula of the Armadillos is very high and narrow. In that of the *Megatherium* there exists a large process of bone extending from the coracoid process to the acromion, and thus completely uniting these processes. The *clavicle* exists in many of the *Edentata,* as the Armadillos and Ant-eaters, but is wanting in the *Manis* or Pangolin. That of the *Megatherium* offers a remarkable peculiarity. It extends from the *acromion,* not to the sternum as in all other cases, but to the first rib. The *humerus* is in most of the order very short and robust, and its elevations strongly marked. In the Ant-eaters the part above the inner condyle is extremely developed, to give attachment to the powerful flexors of the claws; and the crests for the insertion of the deltoid and great pectoral muscles are very prominent and angular,—a structure which is also conspicuous in the Armadillos and Manis. The humerus of the *Megatherium* has a similar general form; it is rude, short, and excessively strong, with abrupt and large elevations for the different muscular attachments; the inferior part especially becomes suddenly larger, from the existence of a strong and elevated external crest.

The habits of the *Edentata proper* demand a very different construction of the fore-arm from that of the Sloth. Requiring immense strength in digging the ground, the short *olecranon* which exists in the Sloth would be wholly inefficient. A long lever is necessary, and hence we find that in the whole of these the olecranon is of an extraordinary length, and that in the *Megatherium* its more moderate length is compensated for by its immense strength. In the five-toed Armadillo this process is so extensive as to render the *ulna* no less than twice the length of the *radius,* and in the other species of the same genus it is not much less. The *radius* is broad, robust, and strongly marked, particularly towards the carpal extremity. The hand in the *Myrmecophaga (fig* 36) and its kindred genus *Manis*

Fig. 36.

Hand of the Ant-eater.

offers a very remarkable structure. The *ungueal phalanges*, like those of the Sloth, are restricted in their motion to simple flexion, in which position they are retained during repose by strong ligaments. In the *Myrmecaphaga* the terminal phalanges are deeply grooved in the margin; in the latter they are bifid. The phalanges of the fingers themselves are very unequal in length and thickness. The middle finger is of extraordinary size, every articulation being very robust, and almost twice as thick as either of the others; the next on each side are nearly as long but much smaller, and the outer shorter still and very slender. The outer finger has no claw; the four others are furnished with claws. The hand in *Dasypus* and *Oryctcropus* is also of a very remarkable conformation, particularly in the gigantic species of Armadillo, *Priodonta gigantea* (*fig* 37)

Fig. 37.

Hand of the Gigantic Armadillo.

of Fr. Cuvier. Amongst the peculiarities of structure in this animal are the following. In addition to several remarkable anomalies in the carpal bones, the bone which results from the ossification of the *flexor profundus* muscle is very large, developed posteriorly into a large and irregularly formed head, articulated by large surfaces to the *os semilunare* and *pisiforme*, presenting concave surfaces on the side of the fore-arm, and terminating towards the hand by an enlargement which is compressed and smaller than the head. The metacarpals are no less extraordinary. Those of the thumb and index, as well as their phalanges, are slender, of the usual construction, but that of the middle finger is irregularly rectangular and broader than it is long; and the phalanx which it supports is of a corresponding form and size, being extraordinarily short and broad. The corresponding bones of the fourth finger are similarly formed, but somewhat smaller. The ungueal or terminal phalanx of the middle finger is enormously large and strong, curved outwards, and having at its base a large bony hood or case for the lodgement of the claw; the terminal phalanx of the fourth finger is similar, but of somewhat smaller dimensions. The fifth or little finger is much smaller, but is furnished with a claw of some size. The conformation of the hand of this animal affords a most formidable weapon, or as a powerful fossorial instrument, in the three outer claws, whilst the two inner ones are only formed for scratching or other similarly slight actions.

The posterior extremity of the *Edentata proper* offers perhaps less striking peculiarities of structure. The femur in general is of moderate length, but large and strong; and an elevated crest, arising from the great *trochanter*, extends nearly the whole length of the bone. In the Ant-eaters and the Megatherium, it is particularly broad and flattened, and the greater and lesser trochanters are not particularly prominent. In the genus *Dasypus* the great trochanter on the contrary is of great size, and from the middle of its outer margin arises a large process which is directed outwards. The *tibia* and *fibula* in the latter genus are extremely broad, arched, and anchylosed at both extremities. In the Ant-eaters, on the other hand, these bones are of the ordinary form, and have no osseous union. In the *Megatherium* they are united by the superior third of their length, and closely in contact at the lower part; they are both short and extremely thick, particularly the tibia. The *tarsus* is composed in the two-toed Ant-eaters of at least eight distinct bones, the largest of which is a supernumerary bone, situated at the inner part of the foot, upon the *scaphoid;* it extends backwards as far as the tuberosity of the *os calcis*, and thus forms a broad base to the posterior part of the sole of the foot. The *Myrmecophaga jubata* has also a supernumerary bone, but of smaller dimensions; but the Armadillos and Orycteropus have but the seven ordinary bones of the *tarsus*. The *metatarsal bones* and the toes are probably invariably five throughout the Edentata proper; the toes of the posterior extremity offer few peculiarities of any consequence. Both the anterior and posterior feet of the *Megatherium* are peculiar in their structure. In the former, those fingers which are completely formed are the three middle ones, the little finger being rudimentary, and the thumb having no claw. The ungueal phalanges of the three former are enormously developed, principally as regards the bony envelope for the base of the claw; the size and thickness of which indicate that the claws themselves must have been of great size and immense strength, and have afforded powerful implements for tearing up the surface of the ground in search of roots. On the hinder foot, there is a single toe of a similar construction, which is the third; the fourth and fifth, although of considerable size, bore no claws. This enormous extinct animal is certainly among the most extraordinary productions of the ancient world. Of dimensions the most unwieldy, and with a skeleton as solid as that of the most enormous amongst the Pachydermata, we find a cranium, and especially teeth, which exhibit a very near relation to those of the Sloth, and members which are no less remarkably allied to the Ant-eaters and the Armadillos. However the difference in bulk may appear at first sight to interfere with the idea of these affinities, and however difficult it may be at once to reconcile the relation between a small active animal like the Armadillo, or an inhabitant of trees like the Sloth, and this enormous and unwieldy tenant of the earth's earlier surface, the affinities are neither less true nor more probable than those which subsist between the light rabbit-like hyrax and the ponderous rhinoceros of the present world.

There is still another very interesting animal, the account of whose osteology I have not intermixed with that of the other Edentata, because it is as yet but little known, and because its peculiarities are particularly interesting. This is the *Chlamyphorus truncatus* (*fig.* 38) of Dr. Harlam, of which I have the opportunity of offering a very correct figure, for which I am indebted to the kindness of my friend Mr. Yarrell. This very remarkable animal was discovered in the interior of Chili, burrowing like the mole, and like that animal residing principally underground. The detail of its organization will be found, as given by Mr. Yarrell, in the third volume of the Zoological Journal, to which I refer. The general results of that gentleman's observations are as follow:

"It has much less real resemblance to the mole, *Talpa Europea*, than its external form and subterranean habits would induce us to expect. In the shortness and great strength of the legs, and in the articulation of the claws to the first phalanges of the toes, it is similar; but in the form of the bones of the anterior extremity, as well as in the compressed claws, it is perfectly different; nor do the articulations of the bones nor the arrangement of the muscles, allow any of the lateral motion so conspicuous in the mole. The hinder extremities of the Chlamyphorus are also much more powerful.

"It resembles the Bradypus tridactylus in the form of the teeth, and in the acute descending process of the zygoma, but here all comparison with the Sloth ceases.

"The skeleton of the *Chlamyphorus* will be found to resemble that of the Armadillo (Dasypi species plures) more than any other known quadruped. In the peculiar ossification of the cervical vertebræ; in possessing the sesamoid bones of the feet; in the general form of all the bones, except those of the pelvis, as well as in the nature of the external covering, they are decidedly similar; they differ however in the form and appendages of the head, in the composition and arrangement of the coat of mail, and particularly in the posterior truncated extremity and tail.

"There is a resemblance to be perceived in the form of some of the bones of the *Chlamyphorus* to those of the *Orycteropus capensis* and *Myrmecophaga jubata*, as might be expected in animals belonging to the same order. To the *Echidna* and *Ornithorynchus* it is also similar in the first bone of the sternum, and in the bony articulations as well as the dilated connecting plates of the true and false ribs.

"In the form of the lower jaw, and in other points equally obvious, the *Chlamyphorus* exhibits characters to be found in some species of *Ruminantia* and *Pachydermata*. On this sketch of its relations it is unnecessary to dilate. Its near affinity to the genera *Dasypus* and *Tatusia* however is so obvious that there can be no doubt of the propriety of considering it as belonging to the same family of the order; whilst its relation to the mole can of course only be considered as one of analogy, in which respect it offers many interesting characters."

Fig. 38.

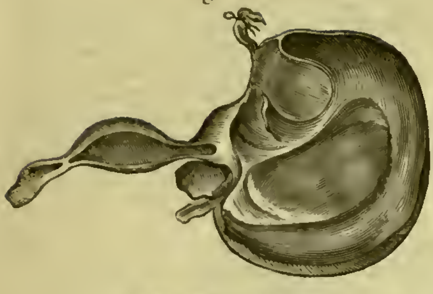
Skeleton of the Chlamyphorus truncatus.

Digestive organs.—In the character of these organs there is no less diversity between the *Tardigrada* and the *Edentata proper* than in the osteology already described. The former, essentially herbivorous, yet living principally upon the young succulent leaves which clothe the extremities of the branches, have the teeth formed for bruising this kind of nourishment, and an articulation of the lower jaw which allows of a degree of motion commensurate with the object. The teeth consist of a cylinder of bone enclosed within a simple case of enamel, but without any of the convolutions of these two substances which characterize the structure of these organs in the *Ruminantia* and other graminivorous animals. They are in fact the most simple which are found in any of the *Mammifera*. There is a single canine on each side above and below, both in the Unau, but none in the Aï.

In one form of the Armadillos, the genus *Dasypus* as now restricted, there are two incisive teeth in the upper and four in the lower jaw, and sixteen molares in each. In the allied genus *Tatusia* there are no incisive or canine teeth, and the molares are even rather more numerous, and in the *Priodonta Gigas* there are no less than fifty in the upper and forty-eight in the lower jaw. These are all simple, and formed for crushing insects.

The *stomach* in the Sloths is very remarkably formed. In the *Bradypus didactylus* (*fig.* 39) it is double. The first is large and rounded, contracted posteriorly, and produced into a conical appendix, which is doubled from the left to the right, and its cavity is separated from that

Fig. 39.



Stomach of the Sloth.

of the stomach by a semilunar fold. The cardia opens very far towards the right side, leaving a very large pouch, and enters a canal which proceeds along the right side of the first stomach, giving off from its right margin a broad process, which separates the pouch of the stomach from the other cavity, which lies between the pouch and the appendix before mentioned. Thus the first stomach is divided into three cavities. The canal already described turns from the left towards the right, and enters the second stomach by a narrow opening. The second stomach is of a slender form, much smaller than the former; its parietes are very thin for the first half of its length, but much thickened towards the pylorus; and the two portions are separated by a semilunar fold. Again, the first portion of this second stomach is itself partially divided by a beautifully indented fold, the dentated processes of which are directed towards the pylorus. There is also attached to the second stomach a small cul-de-sac, which lies between two similar ones connected with the first stomach, the internal surface of all of which appears to be glandular. In the Aï the appendix to the second stomach is much longer, and divided into three chambers by two membranous partitions.

The whole of this structure, and especially the canal which extends from the cardia to the second stomach, indicates a very remarkable relation to that of the ruminants, and is evidently intended for the digestion of vegetable substances only.

In the *Edentata proper* the stomach is, as may be expected, far more simple. In the *Myrmecophaga didactyla* it is of a globular form, and simple. In the *Manis pentadactyla* or Pangolin, it is internally divided by a fold into two cavities, of which the left, analogous to the paunch, is thin, and the pyloric, or true digestive portion, much thicker.

The intestinal canal does not present the same striking distinctions between the large and small intestines which are observed in most other mammifera. There are in the Ant-eaters two cœcal appendices, which may be considered as forming the boundary between the two portions, of which the posterior is very much shorter than the anterior. It is remarkable that the entrance to these small cœca is so contracted as wholly to prevent the passage of any fæces into them. In the *Manis longicauda* there is not the vestige of a cœcum. In the *Oryctcropus* it is short and oval. In the *Tardigrada*, the Aï for example, the large intestine is at once distinguished from the small by its sudden enlargement, and at their junction is found a slight fold, which partially separates them.

The liver offers but few peculiarities of consequence in a physiological point of view. In the Ant-eaters, the Armadillos, and the Orycterope, it consists of three lobes. In the former the hepatic duct joins the cystic at a considerable distance from the neck of the gall-bladder, and, as in the Armadillo, at a very acute angle.

Organs of circulation.—In a paper in the Philosophical Transactions, Sir A. Carlisle described a very remarkable peculiarity of the arrangement of the arteries of the limbs in several slow-moving animals, of which number were the *Bradypus tridactylus* and *Bradypus didactylus*. It appears that the axillary and iliac arteries, on entering the upper and lower limbs, are suddenly divided into a number of cylinders of equal size, which occasionally anastomose with each other. They are exclusively distributed in the muscles. Those of the other parts of the body, and even those of the limbs which supply the bones, &c. do not deviate from the usual mode of distribution. In the former species no less than forty-two of these cylinders were counted on the superficies of the brachial fasciculus, and there were probably not less than twenty concealed in the middle. In the second species they were less numerous, and deviated from the usual form. This difference in the two species is perfectly consistent with what is known of their habits; for there can be no doubt that the peculiarity has reference to the slowness of motion of these animals, in which character the Aï far exceeds the Unau. "The effect of this peculiar disposition of the arteries, in the limbs of these slow-moving quadrupeds, will be that of retarding the velocity of the blood. It is well known, and has been explained by various writers, that the blood moves quicker in the arteries near the heart than in the remote branches; and also, that fluids move more rapidly through tubes which branch off suddenly from large trunks than if they had been propelled for a considerable distance through small-sized cylinders; besides the frequent communications in the cylinders of the Bradypus tridactylus must produce eddies which will retard the progress of the fluid. From these and a variety of other facts, it will appear that one effect on the animal economy, connected with this arrangement of vessels, must be that of diminishing the velocity of blood passing into the muscles of the limbs. It may be difficult to determine whether the slow movement of the blood sent to these muscles be a subordinate convenience to other primary causes of their slow contraction, or whether it be of itself the immediate and principal cause."

The *integument* in the *Manis* as well as in the genera *Dasypus* and *Tatusia*, comprehending the Armadillos, and in *Chlamyphorus*, exhibits various modifications of a very extraordinary nature. The body of the *Manis* is covered with large imbricated scales, of a more or less rhomboidal form, of a horny consistence, and a reddish brown colour. The true structure of these scales is undoubtedly a congeries of hairs, as is evinced in the longitudinal lines with which they are all marked. They form a very firm and complete protection to the animal when rolled up in a ball, which is its ordinary means of escaping from danger. The scales cover the whole surface, excepting the inferior part of the head and tail, the axillæ, the middle of the belly, the inner surface of the thighs, and the soles of the feet, all of which parts, excepting the latter, are furnished with a few scattered hairs. In the Armadillos an osseous crust or shell envelopes the whole of the upper part of the head and the body, the outer part of the limbs, and the whole of the tail. The inferior parts of the body are not thus protected, but scantly covered with hair, intermixed with a kind of hard warts or scales. Their armour is composed of a helmet covering the upper part of the head, of a buckler over the shoulders, a similar one over the crupper, and the back has numerous imbricated bands, which move upon each other, varying in number in the different species; the tail is covered by rings, also allowing of motion. It is clear that this hard bony armour is capable of affording these animals the most complete protection when coiled up, which is the position usually assumed by them when in danger, or during repose. Although there is mutual motion only at the margins of the different pieces and at the commissures of the bands, there is considerable yielding at every portion of this coat of mail. Each of the larger pieces is composed of numerous adherent smaller ones, hexagonal, and perfectly tessellated; those of the shoulders are arranged in segments of concentric circles, the concavity being in front, so that the anterior series, which is the shortest, embraces the neck of the animal. The covering of the posterior part has a similar arrangement, but reversed, so that the short concave margin meets the origin of the tail. The cuirass of the *Chlamyphorus truncatus* differs in many respects from that of the Armadillos, and is thus described by Dr. Harlam in the only account which we have of the details of this singular animal, with the exception of the very interesting description of its osteology by Mr. Yarrell, in the third volume of the Zoological Journal.

"The shell which covers the body is of a consistence somewhat more dense and inflexible than sole leather of equal thickness. It is composed of a series of plates of a square, rhomboidal, or cubical form; each row separated by an epidermal or membranous production, which is reflected above and beneath, over the plates; the rows include from fifteen to twenty-two plates; the shell being broadest at its posterior half, extending about one-half round the body; this covering is loose throughout, excepting along the spine of the back and top of the head; being attached to the back immediately above the spine, by a loose articular production, and by two remarkable bony processes; on the top of the os frontis, by means of two large plates, which are nearly incorporated with the bone beneath; but for this attachment, and the tail being firmly curved beneath the belly, the covering would be very easily detached. The number of rows of plates on the back, counting from the vertex, (where they commence,) is twenty-four; at the twenty-fourth the shell curves suddenly downwards, so as to form a right angle with the body; this truncated surface is composed of plates nearly similar to those of the back; they are disposed in semicircular rows, five in number; the lower margin somewhat elliptical, presents a notch in its centre, in which is attached the free portion of tail, which makes an abrupt curvature, and runs beneath the belly parallel to the axis of the body; the free portion of the tail consists of fourteen caudal vertebræ, surrounded by as many plates, similar to those of the body; the extremity of the tail being depressed so as to form a paddle; the rest of the tail compressed. The caudal vertebræ extend up to the top of the back, beneath the truncated surface, where the sacrum is bent to meet the tail. The superior semicircular margin of the truncated surface, together with the lateral margins of the shell, are beautifully fringed with silky hair."

It is much to be regretted that but little is known of the generation of these animals. The dissections which have hitherto been made of the more interesting forms have been imperfectly performed, or the subjects themselves have been in such a condition as to allow of but very incomplete observations.

For BIBLIOGRAPHY, see that of MAMMALIA.

(T. Bell.)

ELASTICITY (Germ. *Springkraft, Federkraft*) is that property of natural bodies in virtue of which they admit of change either of size or form from the application of external force, resuming, upon the suspension of that force, their proper shape or volume.

Though elasticity is a purely physical property, its investigation is scarcely less interesting in physiological than in mechanical science. The most cursory examination of a living body is sufficient to convince us, that nature, in regulating its varied functions, has availed herself no less of physical than of vital laws. As it is the province of the physiologist to explain and analyze the several actions whose aggregate is life, to trace each to its proper source, and to distinguish those which are truly vital from those which are merely mechanical, it is plain that an acquaintance with the physical properties of the material elements of living bodies becomes one of the foundations of his knowledge. Hence, in a publication, the design of which is to present a complete view of the structure and functions of living beings, it would be improper to omit some notice of those properties of matter which are so frequently and so admirably employed in fitting them for their uses. In this article we shall offer, in the first place, some remarks upon elasticity generally, upon its laws, and upon the distinction between it and other forces; we shall next advert to its existence in the organized tissues of the animal machine; and, lastly, we shall point out some important actions in the living body where elasticity plays a principal part.

I. *General remarks on elasticity—its laws, &c.*—The degree of elasticity possessed by unorganized bodies is extremely variable; in some it is so great that they have obtained the name of perfectly elastic; while in others this property is so extremely small, that its very existence has been overlooked. Air is the most perfectly elastic substance with which we are acquainted; in experiments made upon atmospheric air a portion of it has been left for years subjected to a continued pressure, upon the removal of which under the same temperature and barometric altitude, it forthwith resumed its original volume. Amongst solid bodies, the most conspicuously elastic are certain metals and metallic alloys, glass, ivory, &c.; while other solids, such as moist clay, butter, wax, and many similar substances, possess elasticity in an almost imperceptible degree. Fluids have long been considered as completely inelastic; but though it is extremely difficult to demonstrate this property, yet the experiments of Canton would seem to indicate its existence; they place at least beyond all doubt their possession of another property, namely, compressibility, — a property somewhat allied to that we are now considering.

The laws which regulate the elastic force are not exactly the same in these three classes of natural bodies. In the gaseous or perfectly elastic bodies elasticity may be said to determine their volume: their particles having an incessant tendency to expand into a greater space are controuled merely by the surrounding pressure, and hence the bulk of gases is always inversely proportional to the compressing force. This law, at least in the case of atmospheric air, applies within all known degrees of condensation and rarefaction. By means of accumulated pressure, air may be so reduced in volume, that upon suddenly liberating it, as in the air-gun, it expands with amazing force; and in the receiver of the air-pump, even when reduced to one-thousandth part its original quantity, it has still elasticity enough to raise the valve. Another important law of elasticity in gases is that its power is increased by heat and diminished by cold, and this applies not only to the permanently elastic gases but to those likewise of another kind, such as the vapours of alcohol, mercury, nitric and muriatic acids, and water; the elastic vapours of the nitric and muriatic acids not unfrequently burst the vessels containing them; the vapours of mercury have broken through an iron box; and the vapours of alcohol have sometimes occasioned in distilleries the most terrible explosions: the elasticity of steam, and the fact that we can increase its power to any extent by means of heat, has enabled us to construct the steam-engine, and thus armed mankind with a physical power superior to every obstacle.

Solid bodies are never perfectly elastic; for although some, when acted upon by forces within a certain range, are as completely elastic as the gases themselves, yet if the disturbing force be carried beyond a certain degree, they will never resume their original condition. Thus, a harp-string gently drawn by the finger is thrown by its elasticity into vibratory motions, returning when these have ceased to its exact original state: this may be frequently repeated and always with the same effect, as proved by the same note being repeatedly obtained. If, however, it be once drawn with too great a force, it no longer returns to its original condition, a different tone is now produced by it: in other words, the solid substance of which it is composed exhibits a perfect elasticity, not, as the gases, under every degree of force, but only within a certain limit. Heat produces very different effects upon the elasticity of gaseous and solid bodies; we have just seen that we can increase the elastic power of the former to any extent by means of heat, but the elasticity of solids is, on the contrary, usually diminished by it; very high temperatures completely destroy it even in the most elastic metals. The design of this article does not permit us to enter more fully into the consideration of those laws, or of the experiments by which they are demonstrated. We must refer for the further investigation of this subject to works which treat expressly upon physics.

The various hypotheses which have been put forth to explain the nature of elasticity, though many of them extremely ingenious, do not however properly come within the province of the physical much less of the physiological enquirer. Indeed, while men directed their attention to such speculations little or no progress was made in real knowledge. The cause of elasticity, like that of life, is probably beyond the sphere of human understanding; and hence, in both sciences, the method of investigation should be the same—to study the laws or conditions under which the phenomena present themselves, and to lay aside all speculations as to their causes. But in abandoning these inquiries into the nature of elasticity we must particularly advert to the necessity of the physiologist possessing a clear and definite idea of this property of matter, so as to be enabled to recognize it under every circumstance, and to distinguish it from other physical and vital forces. Ignorance upon this point has been at all times a fruitful source of error in physiological investigations. The property with which it is especially liable to be confounded is contractility: when it is remembered that at one period of medical history these two properties were looked upon as identical; that even the illustrious Cullen has scarcely distinguished them, and that some of our most eminent living physiologists have fallen into manifest errors upon the same subject, it becomes plain that we cannot be too particular in familiarizing ourselves with the distinctions between these totally independent forces.

It is not enough to say that contractility is a vital and elasticity a physical property; for as we are ignorant alike of the nature of life and of elasticity, a distinction founded upon any such assumption must necessarily be futile. It is only by a diligent comparison of their respective laws that we can assign to each its proper limits. Let us then observe in contrasting them, first, that elasticity can never act as a prime mover; it is never a source of power, but merely the reaction of a force previously applied: thus, the elasticity of the spring will never of itself set the watch in motion unless some external force shall, in the first instance, have acted upon or bent it. But contractility can of itself originate motion, at least it is not essential that any mechanical force with which we are acquainted should precede its action. Again, the force of elasticity can never exceed that other power which has called it into existence; if, for instance, a weight of one pound be required to depress an elastic spring, the force of reaction upon the removal of that weight can never exceed the measure of a pound. But, in the case of muscular contraction, there is no such limit; there is no fixed ratio between the cause and the effect; the slightest touch of a sharp instrument will, in an irritable muscle, such as the heart, excite the most violent contractions. Elasticity cannot manifest itself except by the removal or suspension of the cause which has called it into action: muscularity requires no such suspension of its exciting cause. The exciting cause of elasticity is always of a physical nature; but many other causes no ways allied to physical ones may excite the muscular power. Lastly, elasticity is not destroyed by death nor affected by opium or other narcotics, while contractility presents a very striking contrast in both these respects.

These facts are quite conclusive in proving that muscular and elastic contraction are governed by distinct laws, and cannot consequently be referred to the same source. But if some physiologists have erred in overlooking the distinctions between these two properties, if they have not analysed with sufficient care, others have unquestionably erred in an opposite direction, and by pushing analysis too far, have attributed to imaginary forces effects which are the result of elasticity alone. We feel much diffidence in controverting any doctrine supported by the genius and authority of Bichat, but we confess that the distinction which that celebrated anatomist is so anxious throughout his various works to establish between what he terms "*contractility of tissue*" and elasticity, appears to us unfounded. Elasticity according to him is a purely physical property. Contractility of tissue, though not actually a vital one, is however found only in the animal tissues; it does not depend directly upon life, but results merely from the texture and organization of those particles which constitute the vital organs. The following passage from his work upon "*Life and Death*" may, perhaps, assist us in understanding his views upon this subject. "Most organs of our bodies are held in a state of tension by various causes; the voluntary muscles by their antagonists; the hollow muscles by the substances contained within them; the vessels by means of their circulating fluids; the skin of one portion of the body by that which covers the neighbouring part; the alveolar walls by the teeth contained within them. Now, upon the suspension of the distending causes, contraction takes place: divide a long muscle,—its antagonist becomes shortened; empty a hollow muscle, it shrinks upon itself: prevent the blood from entering an artery, the vessel becomes a ligament: cut through the integuments, the divided edges are separated from each other by the contraction of the adjoining skin: extract a tooth from its alveolus, that channel becomes obliterated. * * * In all these cases it is the removal of a tension naturally inherent in the tissue which determines its contraction:—in other instances it is the removal of a tension which does not naturally reside in the part. Thus we see the abdomen contract after parturition; the maxillary sinus after the extirpation of a fungous growth; the cellular tissue after the removal of an abscess; the tunica vaginalis after the operation for hydrocele; the integument of the scrotum after the removal of an enlarged testicle; the aneurismal sac upon the emptying of its fluid." He remarks in another place that motion when the result of elasticity is quick and sudden, and ceases as abruptly as it has been produced; but the motions which result from contractility of tissue are slow and imperceptible, lasting frequently for hours and even days, as are seen in the retraction of muscles after amputation. The distinction laid down in these passages appears to us totally unsupported: to say, for example, that even in a dead artery there are two principles of contraction which, though their mode of action is literally the same, should nevertheless be considered distinct and referred to different sources, appears contrary to every rule of philosophic reasoning. As to the distinction drawn from the comparative quickness of these motions, it is only necessary to say that upon this view of the subject even the movement of the watch-spring itself cannot be attributed to elasticity. We must then conclude that there are two and only two forces to which all the various movements of living bodies can be referred; the one a vital force regulated by its own proper laws, the other a general physical property, whose mode of action is essentially the same in organized and unorganized bodies: the phenomena above enumerated by Bichat are certainly not the result of vital action (for he admits that the contractility of tissue to which he ascribes them is not destroyed by death): they must then be owing to a physical force, and amongst the various physical agencies we are acquainted with, elasticity is the only one to which they can be referred.

The "*vis mortua*" of Haller appears likewise to differ little if at all from elasticity. Speaking of this force he observes, that, as indeed the very name implies, it is totally independent of life, and adds—"Hæc vis in partibus animalium perpetuo agere videtur, etiamsi non perpetuus effectus adparet. Videtur enim contractio cuique particulæ propriæ a contraria contractione duorum elementorum vicinorum impugnari et distrahi, ut quæ breviores fieri non possunt, quin mediam particulam distrahant. Id dum fit in omnibus, quies videtur, quæ est summa virium contrariarum se destruentium. Quam primum vero aliqua particula a sodalibus separatur, inflicto vulnere, tunc utique labium vulneris, nunc liberum, nec a contraria potestate retentum, se ad eam vicinam, a qua trahitur, integramque incisæ membranæ partem retrahit." The facts so accurately described in this passage are easily explained by the operation of elasticity. Why then multiply causes? Why assume the existence of another principle in order to account for them? The phenomena ascribed by Cullen and others to what he terms "*tonicity*," are also, at least in many instances, the effects of the same physical force. (See CONTRACTILITY.)

II. The tissues of the animal body are possessed of very various degrees of elasticity; some of them are but little inferior to the most highly elastic unorganized substances, while others are endowed with this property in so very trifling a degree, that in our physiological and pathological reasonings concerning them, we may almost consider it as absent. We shall endeavour to arrange the principal organic tissues in the order of their elasticity, and shall then proceed to offer a few remarks upon each.

1. *Yellow fibrous tissue.* 2. *Cartilage.* 3. *Fibro-cartilage.* 4. *Skin.* 5. *Cellular membrane.* 6. *Muscle.* 7. *Bone.* 8. *Mucous membrane.* 9. *Serous membrane.* 10. *Nervous matter.* 11. *Fibrous membrane.*

This view of the comparative elasticity of the different tissues must not be regarded as rigorously exact: owing to the impossibility of procuring each one perfectly separate from the others, the result of our experiments can be considered merely as approximate.

1. *The yellow fibrous system.*—The tissues composing this system are unquestionably the most highly elastic of all: the ligamenta subflava which unite the laminæ of the vertebræ to one another, and the ligamentum nuchæ which suspends the head in some of the larger quadrupeds, are scarcely inferior to caoutchouc in this respect. The middle coat of arteries is referred by Beclard to the yellow fibrous system, perhaps from its possessing in so high a degree this characteristic property. Its existence may be demonstrated by various experiments, and many of the physiological and pathological phenomena of the arterial tissue are modified or determined by its presence. The sudden expansion of an artery whether in the living or dead body upon the removal of a force pressing its sides together; the gradual contraction of a divided artery, by means of which hemorrhage is so frequently arrested; the contraction or obliteration of the vessel beyond the ligature, after it has been taken up in aneurism; the obliteration of the umbilical arteries and of the ductus arteriosus soon after birth; the gaping which occurs in longitudinal wounds of arteries owing to the recession of the divided edges; the power possessed by these vessels of accommodating their size to the quantity of circulating blood, (thus causing endless variations in the volume of the pulse even in the same individual);—all these facts have been accounted for by the transverse elasticity of the middle coat. The effects of this property in a longitudinal direction may be seen in the retraction of divided arteries during amputation; in the sort of locomotion which these vessels undergo from the impulse of the blood, and in the enlargement of a transverse arterial wound by the retraction of its edges. The proper coat of veins, though belonging likewise to this system, is however much less elastic than that of the arteries; but we cannot agree with those who deny this property to the venous tissue. The sudden flow of blood from a portion of vein included between two ligatures; the constantly varying size of the cutaneous veins according to the volume of their contents; the obliteration under certain circumstances of veins where circulation has been arrested, appear to us explicable only by attributing this property to them.

2. *Cartilage* is possessed of very great elasticity. On pressing the point of a scalpel into cartilage it is expelled upon the suspension of the force by the contraction of the surrounding substance. It may also be well demonstrated by twisting or bending the cartilages of the ribs, or those of the nose, eyelid, &c. The elasticity of cartilage in the adult is much greater than in the child or old person. We shall allude presently to the several important objects to which this property as connected with cartilage is applied.

3. *Fibro-cartilage.*—The elasticity of this tissue may be studied in the intervertebral fibro-cartilages, in which it contributes so remarkably to the obscure movements of the spinal column and to the security of the chord: it is remarkably displayed in restoring the substance to its proper condition, when pressure rather than twisting or bending has been the cause of derangement. The fibro-cartilaginous funnels through which the tendons are transmitted, possess likewise this property to a great extent. Bichat found, on removing a tendon in a living dog, that the funnel through which it had been transmitted became impervious, like an artery under similar circumstances.

4. *Skin.*—The great elasticity of the cutaneous tissue is exhibited in innumerable instances; the extension which it undergoes in pregnancy, in ascites, in cases of large fatty and other tumours, and the promptitude with which in these instances it returns to its proper state after the removal of the distending causes, are matters of every day observation, and are chiefly owing to its elasticity. The great retraction of the integuments in amputation depends likewise upon the same principle. There is perhaps no tissue in the body where elasticity is more impaired by advanced age: in the young or adult subject, when, owing to disease or other causes, the subcutaneous adipose matter has become suddenly absorbed, the skin, owing to its great elasticity, is enabled to contract, and thus accommodate itself to the diminished distention; while in old age, under the same circumstances, the power of contraction is lost, and hence it hangs in loose folds or wrinkles, so characteristic of that period of life. These remarks are meant to apply chiefly to the true skin or corion.

5. *Cellular tissue* ranks high among the elastic structures: many of the cases which we have just instanced as proving the elasticity of the cutaneous tissue, indicate likewise its existence in the cellular membrane; anasarca, œdema, and still more emphysema, can occur only in consequence of the distention of those filamentous threads which form the cells; and as recession occurs immediately upon the removal of the distending force, it is plain that elasticity is the principle to which the change must be attributed. We may likewise remark that there is no tissue whose elasticity is so frequently and perhaps so usefully employed as that which we are now considering; for it is by this property of cellular membrane that the motion of the several muscles is permitted and even assisted: thus upon elevating the arm the yielding cellular tissue of the axilla permits the member to be drawn upwards, and when the arm is again depressed the elasticity of the same tense filaments assists in some degree the muscles which bring it down.

6. *Muscle.*—Elasticity appears to belong to the muscular system in a very high degree; it is, however, extremely difficult to estimate its extent in the muscular fibre itself, partly owing to its being the seat of two other contractile forces, the vis insita and vis nervea, and partly to the great quantity of cellular and other tissues which enter into the structure of muscle, and thus impart to it their physical properties. There are however many instances in which we must concede elasticity to the muscular fibre; the contraction which occurs in the abdominal muscles even long after death, upon removing the accumulation of air or fluid contained within the peritoneum; and the recession of the cut edges which takes place upon dividing a muscle under the same circumstances, cannot be ascribed either to the vis nervea or to the vis insita, (for they have ceased to exist,) and the contraction is evidently too extensive to be attributed wholly to the cellular tissue. But we may observe the operation of this property even in the living muscles: on dividing the facial muscles of one side in a living animal the mouth is gradually drawn towards the opposite, and this takes place not by the effort, but solely by the elasticity of the uninjured muscles, which have now no counteracting force upon the other side to resist their contraction. So it is with all the other muscles during what is called their state of rest: the elasticity of one class is exactly balanced by the same property in their antagonists; and hence when the influence of the will is completely withdrawn, as in sleep, we may estimate the comparative quantity of elasticity which antagonizing muscles are possessed of: those of the face for example are exactly equal upon opposite sides in this respect, and accordingly the mouth retains its proper central position; but in the limbs, as the elasticity of the flexors exceeds that of the extensors, we usually find these parts of the body during sleep in a semiflexed position.

7. *Bone* possesses considerable elasticity, though its degree is frequently underrated by the superficial observer. It is not easily demonstrable in the larger bones, but upon cutting even these into thin plates its existence becomes at once evident. There are many phenomena both healthy and diseased which depend upon the elasticity of bone; the enlargement of the maxillary sinus from the growth of fungus within its cavity, and the collapse of its walls upon the removal of the distending matter; the obliteration of the alveolus after the extraction of a tooth; the narrowing of the optic hole which is found in cases of atrophy of the optic nerves, and of the carotid canal after tying the carotid artery; the diminution of the orbital cavity which gradually takes place upon extirpation of the eye—all these changes depend in a great degree upon the elastic qualities of bone. The great elasticity of the osseous system in the young subject, and the almost entire absence of it in the bones of old persons, is at once explained by the fact that elasticity resides in the cartilaginous and not in the earthy ingredient; the great proportion of the former in the young bone, and the accumulating deposition of earthy matter as age advances, are known to every observer.

8. *Mucous membrane.*—That this tissue is possessed of some degree of elasticity would appear from the well-known contraction which is found in the lower part of the intestinal canal after the establishment of an artificial anus; from the great variation of size which is observed in the stomach, and by means of which it can accomodate itself to the quantity of food contained within it; and from many other similar instances. But in these cases it is often difficult to determine how far contraction depends upon the mucous membrane, or upon the other tissues with which it is associated. We should also bear in mind that the contraction of the inner coat of the stomach is much less than might in the first instance be supposed;

the numerous folds or rugæ into which it is thrown seem destined to compensate for its imperfect elasticity.

9. *Serous membrane* is still lower in the scale. In those organs whose size is subjected to frequent variation, such as the stomach, intestines, urinary bladder, &c., we find an interesting provision to permit enlargement without at all stretching their serous envelope. The organ, instead of possessing a simple serous capsule, is inserted between two loosely adherent folds of peritoneum which permit its insinuation between them as soon as distension takes place. By this simple contrivance the possibility of rupture or even tension of the serous coat is completely obviated, even in cases of extreme enlargement. The tunica vaginalis testis would appear to possess more elasticity than other membranes of this class:—after the operation for hydrocele, a disease in which it is distended far beyond its proper limits, a sudden contraction of its tissue evidently occurs.

10. *Nervous matter.*—Upon the division of a nerve little or no retraction of the divided extremities takes place. The brain however possesses an obscure elasticity, as may be seen upon making a horizontal section of its substance: the numerous red points which there present themselves are owing to the blood forced from the divided vessels by the surrounding pressure.

11. *Fibrous membrane* is remarkable for its very low degree of elasticity; hence ligaments and tendons often give way rather than yield to a distending force. It is owing to the unyielding nature of the subcutaneous fascia in some situations that abscesses and other swellings occurring beneath, produce but little swelling upon the surface, and cause such severe pain to the patient; hence too upon dividing this fascia, no enlargement of the wound occurs as in other tissues by the elastic retraction of its edges. When the distending force however is slowly applied, there appears to exist some degree of elasticity even in fibrous membranes; thus in hydrops articuli the structures about the joint are frequently much distended by the accumulation of fluid within, upon the absorption of which they slowly resume their proper condition.

III. We shall now proceed to point out some instances in which elasticity plays an important part in the mechanism of organized beings; but it may be necessary to remark that in doing so we by no means profess to give an anatomical description of the various structures alluded to. We shall endeavour merely to bring into one general view some of the most interesting cases in which elasticity plays a prominent part, and thus enable the reader to refer to the separate articles in which these details are fully discussed.

Nature avails herself of this physical property in the construction of organized bodies, for several distinct ends. It is sometimes employed as a means of protecting certain delicate and important organs by bearing off or decomposing the forces to which they are exposed. It is often used to economise muscular contraction, not only in supporting depending parts, but likewise in effecting the movement of one portion of the body upon another. In some instances it is rendered subservient to the general movement of the body, or locomotion. By elasticity the proper patulous condition of certain canals and outlets is secured; and lastly, it very often serves to divide the power of particular muscles or sets of muscles, and thus to transfer the contractile force from one portion of an apparatus to another.

1. Elasticity is employed by nature as a means of protecting the body generally, or some of its organs more particularly, against external violence. The great elasticity of the various tissues in the young subject, and of the osseous system especially, affords at that period of life no inconsiderable security to the whole system: the bones themselves can yield in a very great degree to external impressions and thus prevent their bad effects. The frequent and apparently dangerous falls of children, and the perfect impunity with which they are encountered, are known to every one, and can easily be accounted for by the great elasticity of the tissues at that period of life. The opposite extreme of human existence, in which we meet with the reverse of these conditions, is equally illustrative of our subject; for then the bones, owing to the progressive accumulation of earthy matter, have almost lost their power of yielding, and hence a very slight force is sufficient to fracture them. But elasticity plays a still more important part in protecting certain organs, such as the spinal chord, whose structure is so delicate that it may be torn by the slightest violence, and whose function is frequently deranged even by mere concussion. The mechanism of the vertebral column exhibits at every step the most admirable application of elasticity to the protection of its contents. An unskilful mechanic who sought to afford the greatest security to this contained organ might naturally enough suppose that its safety would be proportionate to the strength and density of the material which he should employ in incasing it; he would probably have thrown around it a strong cylinder of solid bone, such as we see employed for a different object in the tibia or femur. But the condition of old age again affords us a complete refutation of such reasonings; the spinal column by the successive consolidation of its component parts is then in fact converted into one long cylinder of extraordinary strength; it has become literally a single bone; but now every touch upon the surface of the body, every application of the foot upon the ground, is conveyed by the solid and almost inelastic bones to the spinal cord, thus rendering even the movements of progression a source of pain; hence repose is the natural condition of this period of life, as restless activity is that of childhood. But looking at the spinal column in the active or adult age we perceive a totally different mechanism; it now consists of no less than twenty-four distinct bones piled one upon the other and connected by twenty-four layers of fibro-cartilage, a tissue, as we have al-

ready seen, possessed of extraordinary elasticity. The chord, instead of filling the whole cavity, is suspended within it by means of an elastic ligament; and thus this delicate cylinder of nervous matter is hung loosely upon a series of elastic springs which effectually break the many jolts and concussions incident to the frame in the various movements of active life. It is owing to this extreme elasticity of the spinal column, that even after very long-continued pressure, it soon recovers its proper condition. When, for instance, from long and severe exercise the fibro-cartilages have become somewhat pressed down by the superincumbent weight, a few hours' repose in the horizontal position is sufficient to restore the spine to its proper length. This fact has not escaped the shrewd practical observation of the lower classes; when admission into the army can be obtained only by persons of a certain stature, the candidate who apprehends he can spare nothing in that particular, usually presents himself after his night's repose. The delicate viscera of the thoracic cavity owe likewise their safety in a great degree to the same mechanism. The cartilages which connect the ribs and sternum, and which, as we shall presently find, are destined to modify the movements of the thorax, tend likewise to its security by permitting it to yield to external forces. The obscure elasticity of the ribs themselves and of the ligaments connecting them to the spine contribute to the same end; hence we seldom find the thoracic viscera ruptured even by the greatest violence applied against their walls. It is this elasticity, aided no doubt by other still more efficient causes, which enables the mountebank to receive with impunity the blows of the weightiest sledge on an anvil laid upon his chest.

2. Elasticity is often had recourse to as a substitute for muscular contraction. and, as it would appear, with a view to economize that more important property. We find, for example, that in most animals the abdominal viscera are supported in their position chiefly by the muscles of the abdomen, and that on being forced downwards in inspiration by the descent of the diaphragm, they are again pressed upwards by the contraction of these muscles. In the large ruminating quadrupeds whose abdominal viscera are of so great a size, and in whom, owing to the horizontal position of the trunk, these organs tend directly downwards, the quantity of muscular power requisite to support and move them should necessarily have been of great amount; but instead of increasing the quantity of muscle to such an extent, nature has effected her purposes by much more simple means. Beneath the abdominal integuments there exists a membrane of great strength and elasticity, which not only supports the viscera but also helps to elevate them after they have been forced downwards in inspiration. The elastic ligamentum nuchæ, which in these animals supports the very weighty head, is a simple but complete substitute for the great mass of muscle which should have existed on the back part of the neck, in order to effect the same end. So obviously in this instance is elasticity a substitute for muscularity, that upon comparing the structure in various animals we find the strength and elasticity of the ligament always proportionate to the weight of the head which it has to support. In the carnivora an interesting application of this property is seen in the retractile ligament passing between the claw and the phalangeal bone; as the claw in many genera is the chief weapon of attack, it must not be suffered to come into contact with the ground in progression, for otherwise it would become blunted, as seen in those which do not use it for the purposes mentioned; it is consequently suspended by the retractile ligament until drawn down at the will of the animal by means of the flexor muscles. Elasticity is here used as the means of suspension in order to save the effort of a constant muscular exertion. In the mollusca we see this property again employed to economize muscularity: the shell of the oyster admits of being opened as well as closed at the will of the animal; but muscularity is the source of the one action; elasticity residing in a strong ligament is the means of effecting the other.

3. Elasticity frequently preserves the patulous condition of certain outlets in the animal body, as, for example, those of the eyes and nostrils. This object is attained by the insertion of a rim of highly elastic cartilage into the soft parts which bound these openings. A material of greater rigidity, such as bone, would, it may be objected, have answered the purpose still better: but the rigidity of that substance would have greatly interfered with the free movements necessary for the functions of the lids, and in the nose would not only have increased the risk of injury from external violence, but would have prevented the approximation of the alæ which must take place in order to expel the nasal mucus. Neither would a soft and inelastic material have answered the purpose, for then the first effect of inspiration would be to approximate the edges of the opening, and thus to prevent the further entrance of air. The tracheal and bronchial canals are likewise preserved patulous by the same elastic material; and we again meet with it performing a like office in the Eustachian tube and the external meatus of the ear.

4. Elasticity is sometimes rendered subservient to locomotion, or the general movement of the body. The elastic pad placed beneath the foot of the dromedary and many other animals is no doubt intended to facilitate progression, and to compensate in some degree for the yielding looseness of the sands upon which they tread. The same apparatus is found in very great perfection in the feet of the carnivora, and must be of great use in enabling them to make those enormous bounds by which they spring upon their prey. But perhaps one of the most interesting examples of elasticity being rendered subservient to locomotion is met with in certain fish. The salmon, during its annual ascent to fresh-water streams for the

purpose of depositing its spawn, often encounters cataracts of great height, and which would seem to render farther progress impossible. By means, however, of a powerfully muscular tail and elastic spine it is enabled to surmount those obstacles; resting one side upon a solid fulcrum, it seizes its tail between its teeth, and thus draws itself into an arch of amazing tension; then suddenly letting go its hold, and thus freeing the elastic spring which its body represented, it is thrown into the air, often, as Twiss has seen in Ballyshannon in Ireland, to a height of twelve or fifteen feet, and falls beyond the obstacle which had opposed it.

5. Elasticity becomes occasionally in the animal machine a means of dividing muscular force, and thus transferring it from one portion of an apparatus to another. The muscles of inspiration are, if we may use the word, too strong for their opponents, and hence it becomes necessary to transfer a portion of their superfluous strength to the weaker set. This is effected by means of the elastic cartilages which connect the ribs and sternum. The inspiratory muscles in enlarging the thorax act with such a force that they not only elevate the ribs, but even stretch and twist the cartilages, and hence no sooner is inspiration completed than elasticity comes into play, tending to depress the ribs and thus to assist the weaker muscles. But we must not fall into the error of supposing that elasticity is in this case a substitute for muscularity, and much less that it is in itself a source of power. The only power exercised by it is that which it has just borrowed from the inspiratory muscles: had not the elasticity of the cartilages been set in action by this external agency, it would, like the elasticity of the watch-spring under the same circumstances, have remained for ever dormant. In those interesting discussions which have arisen of late years relative to what is termed the suction power of the heart, we apprehend that much error has arisen from overlooking this simple law of elasticity. That doctine will of course be fully stated and examined in its proper place; at present we shall merely observe that it was first regularly put forward in the admirable work of Dr. Wilson Philip, that it was followed up and explained by Dr. Carson, and that these views were regarded by Laennec with such respect that he pronounces their discovery the most important step made in this department of physiology since the time of Harvey. The heart, it is said, is not merely a forcing pump which by the contraction of its ventricle propels the blood throughout the arteries; it is likewise a suction pump, for by the expansion of the auricles it draws in the blood from the veins. Now this expansive force, if indeed it exist at all, is, we are quite satisfied, merely the effect of the heart's elasticity; for the reasonings of those who attempt to prove it of a specific nature are evidently insufficient. In this point of view the heart's expansion cannot be regarded as a new and independent power; if that organ be really elastic, then the muscular force of its systole must be greater than it would otherwise have been, for it has not only to propel the blood through the arterial system, but likewise to overcome the resisting elasticity of its own structure: this suction power of the heart is then merely the recoil of the surplus force; what is gained upon the one hand is lost upon the other; and hence elasticity in this instance cannot be regarded as an independent principle contributing to the blood's motion, but merely as a means of dividing muscular power and transferring a portion of it from the beginning of the arterial to the end of the venous system.

6. An interesting application of elasticity in the animal machine is to convert an occasional or intermitting force into a continued one. As human ingenuity has long since discovered the application of this principle, we may see it employed in many mechanical contrivances. In the common fire-engine, for instance, we observe that though it is worked by interrupted jerks, yet the water issues from its pipe, not per saltum as we should have expected, but in one uniform and continued stream. This is effected by causing the fluid to pass, in the first instance, into a hermetically sealed vessel containing a portion of atmospheric air: the accumulation of the water presses the air into a smaller space, but in doing so it is reacted upon by the elasticity of that gas, which may thus be considered as a powerfully elastic spring exerting upon the surface of the water an uniform and continual pressure. The very same principle is employed in the mechanism of the arterial system. Upon opening one of the small arteries we perceive that the blood does not flow per saltum as in those which are nearer to the heart, but issues in an uniform and uninterrupted stream. The intermitting action of the heart has in fact been converted into a continued one by means of the elasticity of the arterial tissue. We might indeed say with truth that the blood in these small arteries is not directly propelled by the heart at all; the force of that organ is expended in distending the larger elastic arteries, as the force in the fire-engine is expended in compressing the air. The immediate cause of motion is in the one case the reaction of the elastic air, and in the other the reaction of the elactic artery.

For the Bibliography of this article, see that of Fibrous Tissue and Muscle.

(John E. Brenan.)

ELBOW, REGION OF THE; fold or bend of the arm. (Fr. *pli du bras; coude.*) The region of the elbow is situated at the angular union of the arm with the fore-arm, and contains the humero-cubital articulation and the various organs which surround it: the extent of this region may be determined, superiorly by a circular line at a finger's breadth above the internal condyle, and inferiorly by a similar line at two fingers' breadth below that process: its greatest extent is in the transverse direction, and it forms an angle salient posteriorly and retiring in front, which cannot be effaced even in the utmost extension of the fore-arm. The anterior surface of this region when examined in the arm of a muscular man presents a triangular depression, in which is observed the confluence of several large subcutaneous veins; the base of this depression is above; the sides are formed by two prominences, of which the external is larger and more marked than the internal, and the apex of the triangle is formed inferiorly by the convergence of these prominences, which consist of the two masses of the muscles of the fore-arm which arise from the condyles of the humerus. This triangular depression is divided superiorly into two portions by a prominence formed by the tendon of the biceps; in the external or larger portion the median cephalic vein is situated, the internal is occupied by the oblique course of the median basilic vein and the trunk of the brachial artery, the pulsations of which can usually be felt and are even sometimes visible in this space: the superficial radial or cephalic vein and the two ulnar veins which contribute to form the basilic are also apparent in this region, being situated over the lateral muscular prominences. In the arm of a corpulent female, instead of the appearances here described, the front of the elbow presents a semilunar fold or depression, the concavity of which embraces the prominence formed by the biceps.

Laterally, the region of the elbow presents two prominences formed by the condyles of the humerus, of which the internal is more marked and higher than the external: in the arms of corpulent persons, on the contrary, two depressions like dimples are placed over the condyles.

Posteriorly, the olecranon forms a remarkable prominence, the situation of which varies in its relation to the condyles of the humerus according to the different motions of the fore-arm; in complete extension it is above the level of these processes, in semiflexion it is on the same level with them, and is below them when the elbow is flexed to a right angle.

On either side of the olecranon there is a depression of which that on the internal side is more marked; pressure here produces a painful sensation which is felt in the little finger and the inner side of the ring-finger; in the depression external to the olecranon the posterior edge of the head of the radius can be felt rotating immediately below the external condyle when pronation and supination of the fore-arm are performed. An accurate knowledge of the relations of these parts is essential to the forming an accurate diagnosis in cases of fractures and dislocations in this region.

Skin and subcutaneous tissue.—The skin covering this region is thin, smooth, and delicate in front; it is furnished with hairs over the lateral prominences, where it also contains sebaceous follicles in greater numbers than over the anterior depression. In consequence of being very vascular and plentifully supplied with nerves, the skin here is prone to inflammation, and is often the seat of small phlegmonous abscesses and of erysipelas. Posteriorly the skin is thicker, rough on the surface, and generally thrown into transverse folds above the olecranon, particularly in extension: it abounds more in sebaceous follicles and hairs here than on the anterior surface. The subcutaneous cellular tissue in front consists of two layers: one of these, more deep-seated, forms a sort of fascia, between the layers of which the subcutaneous veins and nerves are situated; the other, superficial, is principally composed of adipose tissue and varies very much in thickness. In lean persons this latter layer is often of extreme tenuity; while the other, on the contrary, is then thicker and more closely adherent to the skin. This deeper layer is considerably thicker over the anterior angular depression than on the lateral prominences: it sinks in between the pronator radii teres and supinator longus in company with the deep median vein, and is continuous with the cellular tissue between the muscles and around the articulation. Posteriorly the subcutaneous cellular membrane is more loose and lamellar: adipose tissue is almost always absent in it over the condyles of the humerus, and on the smooth posterior surface of the olecranon, there is merely a subcutaneous bursa mucosa between the skin and the periosteum.

The subcutaneous cellular tissue in front of the elbow contains some large veins, besides lymphatics and filaments of cutaneous nerves. As the subcutaneous veins in this region are those most frequently selected by surgeons for the operation of phlebotomy, and as untoward consequences sometimes result from a want of due care or of sufficient anatomical knowledge on the part of the operator, their situation and connexions should be carefully studied.

These veins are subject to much variety in their size, number, and situation: the following arrangement of them is that most uniformly adopted by authors as the normal one: three principal veins coming from the fore-arm enter the lower part of this region: 1st, the radial or cephalic on the external side courses along the external muscular prominence and ascends to the arm on the external side of the biceps; 2d, the ulnar or basilic ascends over the internal muscular prominence and the internal condyle of the humerus to the inner side of the biceps; 3d, the median vein ascending from the front of the fore-arm enters the apex of the triangular depression of the elbow, at which point it is usually augmented by a deep branch coming from the deep radial and ulnar veins, and immediately divides at an acute angle into two branches, one of which ascends on each side of the biceps; the internal of these, called median basilic, runs obliquely upwards and inwards over the course of the brachial artery, and joins the basilic vein above the internal condyle; its lower extremity is external to the brachial artery, which it crosses obliquely so as to get internal to it superiorly:

the other division of the median vein, called median cephalic, passes obliquely upwards and outwards, external to the prominence formed by the biceps, and joins the cephalic at an acute angle above the external condyle.

The cephalic, the basilic, and the two divisions of the median vein joining them, form a figure which somewhat resembles the Roman capital letter M.

The superficial lymphatic vessels follow the course of the veins; those on the internal side are larger and enter small ganglions, varying in number from two to five, which are situated in the subcutaneous cellular tissue, above and in front of the internal condyle, where they are sometimes seen swollen and inflamed in consequence of inflammatory affections of the hand or fore-arm.

The subcutaneous nerves are: branches of the internal cutaneous, usually three or four in number, the external cutaneous, and some twigs from the radial and ulnar nerves. The branches of the internal cutaneous pass down to the fore-arm, generally superficial to the basilic and median basilic veins, while the external cutaneous lies deeper than the cephalic and median cephalic, with the latter of which it is more intimately connected. Some twigs from both the internal and the external cutaneous nerves are distributed to the integuments behind the elbow.

Aponeurosis.—The aponeurosis of the region of the elbow is continuous with the brachial aponeurosis above, and with that of the fore-arm inferiorly; it is strong behind the elbow, where it receives an expansion from the tendon of the triceps, and has an intimate adhesion to the margin of the olecranon: on each side it is firmly attached to the condyles of the humerus, sending off several layers from its internal surface, which form septa between the origins of the muscles of the fore-arm which arise from these processes: anteriorly it is spread over the triangular depression, where its strength is considerably increased by expansions which it receives from the tendons of the biceps and the brachiæus anticus; the expansion from the brachiæus anticus comes forward on the external side of the tendon of the biceps, and is lost over the external muscular prominence of the fore-arm in front of the external condyle; the expansion from the biceps forms a narrow band about half an inch in breadth where it is first detached from the tendon of that muscle; it then descends obliquely to the inner side of the fore-arm, on the aponeurosis of which it is lost about two inches below the inner condyle. Superiorly this expansion crosses over the brachial artery, and its superior margin is defined by a lunated border to which the brachial aponeurosis is attached, while its inferior margin is confounded with the aponeurosis of the fore-arm.

From the above described attachments of the tendons of the biceps and brachiæus anticus to the aponeurosis of this region, it follows as a necessary consequence that the contractions of these muscles must have the effect of rendering it more tense.

The aponeurosis of the arm assumes the form of a very thin fascia as it approaches the superior margin of the expansion of the biceps; at this place it often appears to degenerate into cellular tissue which covers an oval space placed obliquely, the broader extremity of which is below, being bounded by the expansion of the biceps externally and inferiorly, and by a sort of defined border terminating the lower margin of the brachial aponeurosis superiorly and internally: in this oval space the brachial artery and the median nerve which lies to its inner side are more thinly covered than in any other part of their course. The aponeurosis is also very weak on the external side of the expansion of the biceps, where it is pierced by the deep branch of the median vein, and by the external cutaneous nerve which comes from beneath the aponeurosis at this place.

The brachial artery terminates by dividing into the radial and ulnar arteries in the triangular depression, which is bounded externally by the supinator longus and internally by the pronator radii teres.

This artery enters the region of the elbow on the internal side of the tendon of the biceps included in a common sheath with its two venæ comites, one of which lies on either side of it; it lies on the surface of the brachiæus anticus, and, becoming deeper as it descends, it divides into the radial and ulnar arteries at about an inch below the level of the internal condyle. The median nerve lies internal to it, separated from it at first by cellular tissue; lower down, where this nerve pierces the pronator teres, the external origin of that muscle arising from the coronoid process is interposed between it and the artery: the radial and ulnar arteries, while still in this region, give off their recurrent branches, which pass upwards, encircling the condyles of the humerus, to anastomose with the profundæ and anastomotic branches of the brachial, as described in the article Brachial Artery. The venæ comites of the brachial, radial, and ulnar arteries are double: these vessels are also accompanied by a deep set of lymphatics. The nerves which traverse this region beneath the aponeurosis are, the median on the internal side of the brachial artery; the radial, which, descending between the brachiæus anticus and the supinator radii longus, then between the biceps and extensor carpi radialis, divides into two branches, the posterior of which passes between the supinator brevis and extensor carpi radialis brevior to the muscles on the back part of the fore-arm, while the anterior branch or proper radial nerve descends in the fore-arm under the supinator radii longus. The trunk of the ulnar nerve passes behind the internal condyle, and entering between the two heads of the flexor carpi ulnaris follows that muscle down the fore-arm.

Development.—In early life the condyles of the humerus are not so well marked, nor is the olecranon so prominent, in consequence of which extension of the elbow can be carried farther than in the adult. At the same period the lesser sigmoid cavity of the ulna is proportionally smaller, and the annular ligament of the radius much more extensive.

Varieties.—When a high division of the brachial artery takes place, it often happens that the radial artery takes a superficial course, sometimes under and occasionally over the aponeurosis to its usual destination. The possibility of this occurrence should be constantly held in recollection in performing phlebotomy in this region, as it is evident that the vessel, when thus superficially situated, is exposed to be wounded by the lancet of the operator.

In considering the relative advantages presented by each of the superficial veins which may be selected for phlebotomy, it is necessary to remark that the operation may be performed on any of the veins at the bend of the arm; on the cephalic and basilic veins it is unattended with any danger; not so, however, when either the median basilic or median cephalic is the vessel selected. When bleeding in the median basilic vein about the middle of its course, if the lancet should transfix the vein, there is danger of the instrument wounding the brachial artery, an accident of serious consequence; the risk of this accident is not so great when the vein is opened near its lower part, as the brachial artery retires from it here towards the bottom of the triangular depression of the elbow; besides the occasional risk of wounding the radial artery, which, in consequence of a high bifurcation of the brachial, sometimes follows the superficial course already alluded to, the branches of the internal cutaneous nerve may be wholly or partially divided; in which latter case sharp pains are usually felt extending along the course of these nerves. Opening the median cephalic vein may be performed without apprehension of injury to the brachial artery; the external cutaneous nerve however, the trunk of which lies behind this vein, may suffer a puncture, in consequence of the lancet being pushed too deeply, the consequences following which have been in many instances a painful affection extending along the branches of this nerve to their terminations. In those unfortunate cases in which the brachial artery is punctured, should the wound in the artery not be closed and united by properly regulated pressure, the consequence likely to ensue may be one of the following: 1, the blood escaping from the wound in the artery may become diffused through the cellular membrane of the limb extending principally upwards towards the axilla along the sheath of the vessel, *(the diffused false aneurism;)* 2, the blood which escapes from the artery may be circumscribed within a limited space by the cellular membrane which surrounds it becoming condensed, *(the circumscribed false aneurism;)* 3, the wounded orifices of the artery and vein may remain in apposition, and adhere to each other, allowing the blood to pass from the artery directly into the vein, constituting the affection called *aneurismal varix*; 4, or a circumscribed sac may be formed between the artery and vein, having a communication with both vessels, *the varicose aneurism.*

(J. Hart.)

ELBOW (ARTICULATION OF THE), αγκων, cubitus; Fr. *coude*; Germ. *elbogen*; Ital. *gomito.* The elbow or humero-cubital articulation is an angular ginglymus formed by the inferior articular extremity of the os humeri and the superior articular extremities of the radius and ulna, the surfaces of which are, in the recent state, covered with a cartilaginous incrustation, and kept in apposition by an extensive synovial capsule, an anterior, a posterior, and two strong lateral ligaments.

The muscles which cover this articulation are, the brachiæus anticus, the inferior tendon of the triceps, and some of the muscles of the fore-arm anteriorly, the triceps and anconæus posteriorly, and the superior attachments of several of the muscles of the fore-arm laterally.

Bones.—The lower part of the humerus is flattened before and behind, and curved a little forwards: an obtuse longitudinal ridge, on a line corresponding to the lesser tuberosity at its superior extremity, divides it into two sloping surfaces anteriorly, while posteriorly it presents a broad, flat, triangular surface: a sharp ridge on each side terminates below in a rough tuberosity, called a condyle; the external condyle is the smaller of the two, and when the arm hangs loosely by the side, it is directed outwards and forwards: the internal condyle is much larger, more prominent, and directed inwards and backwards: a line let fall perpendicularly from the most prominent part of the greater tuberosity above would fall upon the external condyle; the internal condyle bears a similar relation to the centre of the superior articular head of the humerus. The inferior articular surface extends transversely, below and between the condyles, and presents a series of eminences and depressions; beginning at the external side, a small spheroidal eminence, the eminentia capitata or lesser head, situated on the front of the external condyle, directed forwards and received into the circular cavity on the head of the radius, internal to this is a small grooved depression which lodges the internal part of the border of that cavity: the remainder of this surface forms a sort of pulley, to which the greater sigmoid cavity of the ulna corresponds; this, which is called the trochlea, presents a large depression placed between two raised ridges: the depressed portion of the trochlea winds round the lower extremity of the humerus in an oblique direction from before backwards and a little outwards, being broader behind than in front; its external border forms a semicircular ridge, smooth in front and sharp behind, the anterior part of which corresponds to the division between the radius and ulna; its internal margin also forms a semicircular ridge, sharper and more prominent than the external, and which projects half an inch below the internal condyle, having between it and this latter process a sinuosity in which the ulnar nerve lies; it is the prominence of this ridge which determines the obliquity in the direction of the humerus, observable when its inferior articular extremity is placed on a horizontal surface.

Behind and above the trochlea a large triangular depression *(fossa posterior)* receives the olecranon in extension of the fore-arm; a similar depression of smaller size *(fossa anterior)* receives the coronoid process in flexion; these two fossæ are separated by a plate of bone, often so thin as to be diaphanous, and sometimes they communicate by an aperture, the longest diameter of which is transverse, as in the quadrumana, carnivora, glires, and pachydermata; Meckel is of opinion that the existence of this aperture in the human subject is more frequent in the Negro and Papuas than in the Caucasian race;* however it did not exist in any one of three Negroes and four Mulattoes which I dissected, while I possess two specimens of it, and have seen several others which occurred in Europeans: a second small fossa frequently exists above in front of the eminentia capitata, into which the head of the radius is received in complete flexion.

The superior extremity of the ulna presents anteriorly a deep cavity, *(the greater sigmoid cavity,)* which is concave from above downwards and convex in the transverse direction: it is bounded behind by the olecranon and in front by the coronoid process; the surface of this cavity is smooth and covered by cartilage, with the exception of a rough transverse notch which extends from the internal side nearly the whole way across it, and the inequalities of which are effaced in the recent state by a cushion of soft adipose tissue: on the external side of the coronoid process there is a small smooth lateral surface, oval in shape, *(the lesser sigmoid cavity,)* which is concave from before backwards; this depression is covered by an extension of the cartilage of the greater sigmoid cavity, and receives the internal side of the head of the radius.

The superior extremity of the radius forms a shallow circular depression which receives the lesser head of the humerus; this surface is covered by a cartilage which extends over its circumference on a circular surface applied to the lesser sigmuid cavity of the ulna internally, and embraced by the annular ligament in the rest of its extent: the articular head of the radius is supported on a cylindrical portion, called its neck, which is much smaller in its circumference, of about a finger's breadth long and curved a little outwards, its junction with the shaft of the bone being marked internally by a rough tuberosity, the tubercle of the radius, into the posterior side of which the tendon of the triceps is inserted.

Ligaments.—The fibrous ligaments of the elbow are four in number; 1st, the anterior ligament consists of oblique and perpendicular fibres arising superiorly from the front of the condyles and the part of the humerus immediately above the two anterior articular fossæ, and is inserted into the anterior edge of the coronoid process of the ulna inferiorly; 2d, the posterior ligament is less distinct than the anterior, consisting of transverse fibres extending from one condyle to the other, which become more evident when the elbow is flexed; 3d, the external lateral ligament arises from the anterior surface of the external condyle by a thick cord-like fasciculus of shining silvery fibres, and spreads out into a broad flat expansion, which is inserted into the whole length of the annular ligament of the radius and into the anterior and posterior margins of the lesser sigmoid cavity of the ulna; the tendons of origin of the supinator brevis and extensor muscles of the hand are intimately connected to the external surface of this ligament, but can be easily separated from it by careful dissection; 4th, the internal lateral ligament arises from the anterior surface of the internal condyle of the humerus, and passing over the internal side of the synovial capsule, divides into two portions, an anterior and a posterior, the former of which is inserted into the inner side of the coronoid process, and the latter into the internal side of the olecranon: this ligament presents more of a flattened form, and is more easily separated from the tendons of the muscles which cover it than the external lateral ligament.

The synovial capsule, having covered the articular surface of the humerus, ascends above this surface as high as an irregular continuous line, including the two anterior articular fossæ in front, the posterior articular fossa behind, and limited by the bases of the condyles laterally; at the level of this line the capsule is reflected from the humerus, and descends on the internal surfaces of the fibrous ligaments to be expanded over the articular surfaces of the radius and ulna, to the cartilaginous coverings of which it adheres in the same intimate manner as to that of the articular surface of the humerus; the portion of it corresponding to the radius descends within the annular ligament, below which it is reflected on the neck, and thence continued over the head of that bone; while it becomes attached to the ulna at the line which circumscribes the greater and lesser sigmoid cavities over the surfaces of which it is extended; this capsule, which is rather tense where it lines the lateral ligaments, is flaccid and sacculated anteriorly and posteriorly, so as not to interfere with the freedom of flexion and extension of the elbow: below the margin of the annular ligament and before it is attached to the neck of the radius, it forms a cul-de-sac so loose as to permit the rotatory motions of that bone to be executed without restraint.

Several masses of adipose cellular tissue are situated around the articulation external to the synovial capsule, more especially in the articular fossæ at the posterior margin of the olecranon: between the radius and ulna and in the

* Handbuch der menschlichen Anatomie, band ii.

notch on the internal side of the greater sigmoid cavity, there always occurs a mass of this substance from which a production extends over the rough groove described above, dividing the sigmoid cavity transversely.

The synovial capsule adheres closely to the fibrous ligaments, except where masses of adipose tissue are interposed, to which it is but loosely connected.

Motions.—The elbow is a joint remarkable for possessing great solidity, which is partly owing to the extent of its osseous surfaces and the manner in which they are locked into each other, and partly to the strong lateral ligaments and the muscles which surround it.

The motions enjoyed by the elbow-joint are flexion and extension.

Flexion may vary in degree so as to be complete or incomplete: in complete flexion the fore-arm is carried forwards and inwards in an oblique direction across the front of the thorax, so as to bring the hand towards the mouth; the direction of the fore-arm is determined in this movement by the obliquity of the trochlea of the humerus from behind forwards and inwards, as described above, and influenced by the clavicle preventing the falling inwards of the shoulder; were it not for the support of the clavicle, the hand in this movement, instead of being carried to the mouth, would be directed to the shoulder of the opposite side: when flexion of the elbow is carried to its greatest extent, the coronoid process and the head of the radius are received into the anterior articular fossæ of the humerus, displacing the adipose masses from these cavities, the olecranon is brought downwards on the trochlea so as to be placed below the level of the condyles of the humerus; the posterior part of the synovial capsule, the posterior ligament, and the triceps and anconæus muscles are made tense, and applied to the adipose mass in the posterior articular fossa and to the posterior part of the trochlea: the anterior part of the capsule and the anterior ligament are relaxed, as are also the lateral ligaments. A dislocation is rendered impossible in this state of the articulation, being effectually opposed by the hold which the coronoid process has on the front of the trochlea of the humerus.

In partial flexion or semiflexion, the several parts of the articulation are differently circumstanced; the coronoid process being carried down is no longer applied to the front of the humerus, the olecranon is on a plane with the condyles, and the lateral ligaments are on the stretch: in this state of the parts a powerful force applied to the olecranon from behind might have the effect of displacing the ulna forwards, were it not for the great mobility of the limb, owing to which a force thus applied is moderated or altogether expended in increasing the degree of flexion; hence a dislocation of the ulna forwards on the humerus is an accident which never happens.

In extension, the olecranon, ascending above the level of the condyles, is received into the posterior articular fossa, displacing the adipose substance which previously occupied that fossa, the radius is brought back on the lesser head of the humerus, over the anterior part of which and of the trochlea the capsule and the anterior ligament are stretched; the lateral ligaments, the tendon of the triceps, and the brachiæus anticus are also in a state of tension: the posterior part of the capsule and the posterior ligament are necessarily relaxed. It is when the elbow is in such a state of extension as here described that a dislocation of the fore-arm backwards usually occurs in consequence of a fall on the hand; the force producing the dislocation in this case operates in the following way, the fore-arm serving as a fixed point, the humerus becomes a lever of the first order, the fulcrum of which is the point of the olecranon applied to the posterior side of its lower extremity, the power is represented by the weight of the trunk of the body applied to its superior extremity in front, and acting with a force proportioned to its remoteness from the point of resistance formed by the ligaments and muscles which are found in a state of tension in front; when this force is such as to overcome the resistance, the ligaments in front are ruptured, the lower extremity of the humerus is then driven downwards in front of the bones of the fore-arm, the upper extremities of which are forced upwards behind the humerus, so that the coronoid process comes to occupy the normal situation of the olecranon in the posterior articular fossa.

Lateral motion. — Anatomists have been divided in opinion as to the possibility of any lateral motion being performed by the ulna on the humerus. Albinus, Boyer, Beclard, Cruveilhier, and others, have denied the occurrence of it; Monro and Bichat, however, have distinctly noticed it: they consider that this motion is possible only in the semifixed state of the elbow, when the lateral ligaments are most relaxed: in complete flexion, as well as in extension, the tense state of these ligaments effectually opposes any such movement. In my opinion it is easy to satisfy one's self as to the occurrence of this motion; it consists of a slight degree of rolling of the middle prominent part of the greater sigmoid cavity in the fossa of the trochlea, produced by those fibres of the lower part of the triceps which extend from the condyle on each side to the olecranon, and by the action of the anconæus externally,

(J. Hart.)

ELBOW-JOINT, ABNORMAL CONDITION OF.—Placed in the middle of the long lever which the upper extremity represents, the elbow-joint is of necessity exposed to numerous accidents, the most remarkable of which are fractures and luxations. These, reduced or unreduced, produce immediate and remote effects, to which it is our business in this place to advert. Congenital malformations sometimes, though very rarely, are to be met with affecting this articulation, and require some brief consideration.

The several structures too, which enter into the composition of the elbow-joint, are each and all occasionally affected by acute and chronic inflammations, the consequences of which we cannot omit to notice, and many of these have their reputed source either in struma or syphilis, while others are attributed to an arthritic or to a rheumatic diathesis.

I. *Accident.—Fractures.*—Fractures of the bones of the elbow-joint may be classed as to their situation and direction: first, as they affect the lower extremity of the humerus; and, secondly, as they engage the upper extremities of the bones of the fore-arm.

1. Simple fractures of the humerus near the elbow-joint may be transverse or oblique. When this bone is fractured *transversely* at its lower part immediately above its condyles, or in young subjects through its lower epiphysis, in either case the olecranon process is pulled backwards and upwards by the triceps, while the part of the humerus superior to the fracture, that is, almost the whole of the bone, is carried forwards, and forms such a projection below as much resembles a luxation forwards of the true articular extremity of the bone; the prominence in front is also considerably increased by the inclination forwards of the upper extremity of the lower short fragment, which is pulled in this direction by the supinators and pronators taking their fixed point below. The prominence forwards, formed by the angle of contact between the upper and lower fragments of the humerus, is covered in front by the brachialis anticus and biceps; and there is a projection behind formed by the olecranon process equally well marked; so that, in comparing the posterior aspects of the two articulations, we see the olecranon process at the affected side exceed by its projection backwards that of the uninjured arm an inch or more: when to all this we add the observation that the antero-posterior diameter of the arm is evidently augmented, we have here many of the signs which might lead one to suspect the existence of the luxation of the bones of the fore-arm backwards. There is this difference however, namely, that in fracture a crepitus can be felt, and the deformity is not accompanied with any changes of the normal relations existing between the olecranon and the condyles.

Oblique fractures near the elbow-joint are usually prolonged into the articulation, and may be either external or internal. The fracture may traverse in an oblique line from without inwards, and from above downwards; and then the external condyle and capitulum of the humerus will be detached from the shaft of that bone, and will constitute the external or inferior fragment; or the fracture may take place obliquely from above downwards, and from within outwards, so as to comprehend the trochlea of the humerus and internal condyle in the inner fragment. In the first case, or external fracture, the posterior muscles of the fore-arm will have a tendency to pull the condyle downwards and backwards; and in the second, the internal fragment with the trochlea will be drawn downwards and forwards by the pronator muscles.

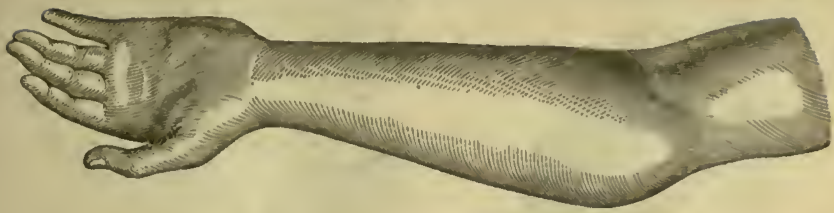
Oblique fractures, extending into the elbow-joint, detaching the *external* condyle of the os humeri, may be detected by the following symptoms. There is considerable swelling and pain upon pressure on the external condyle: and the motions of the elbow-joint, both of extension and flexion, are performed with pain; but the principal diagnostic sign is the crepitus produced by communicating a rotatory motion to the fore-arm. If the portion of the fractured condyle be large, it is drawn a little backwards, and it carries the radius with it; but if the portion be small, this circumstance does not occur; if the fracture of the external condyle take place immediately above it and within the synovial sac, it is stated by Sir A. Cooper that no union will take place except by means of ligament.* The oblique fracture of the external condyle is frequently met with in children; a fall on the hand forwards may cause it, the impulse being transmitted along the radius to the capitulum and outer condyle of the humerus. The connexion of the radius with the ulna at this period of life is so loose that no resistance is afforded to the forcible ascent of the radius when a sudden fall forwards on the palm of the hand occurs; and hence in the young subject particularly an oblique fracture of the outer condyle of the humerus can readily happen: at a late period of life, the connexions between the bones of the fore-arm are so strong and unyielding, that from a similar fall forwards on the hand, it is the lower extremity of the radius which would be obliquely fractured.

There is at this moment in the Richmond Hospital a young woman who met with this oblique fracture of the external condyle of the humerus near the elbow, when she was only five years of age. The outer condyle and capitulum of the humerus were detached obliquely from the shaft of the bone and thrown backwards, carrying with them the head and upper extremity of the radius; she now has very good use of her arm, but in consequence of the accident much deformity exists, particularly when she extends the fore-arm. The obtuse angle salient internally, which the fore-arm forms with the arm in the natural state when it is fully extended, and the hand supinated, does not exist. On the contrary, in this case the salient angle is external, and corresponds to the outer condyle and head of the radius, and the retiring angle is placed internally. (See *fig.* 40.)

The internal condyle of the humerus is frequently broken obliquely from the body of the bone, and the symptoms by which the accident is known are the following: when the fore-arm is extended on the arm, the ulna projects behind the humerus; the lower end of the humerus, too, advances on the ulna, so that it can be easily felt on the anterior part of the joint; on flexing the fore-arm on the arm, the ulna resumes its usual position; by grasping the condyles and bending and extending the fore-arm, a crepitus is perceived at the internal condyle: this accident usually occurs in youth,

* See plate xxvi. *fig.* 1, of Sir A. Cooper's work on Fractures and Dislocations.

Fig. 40.



Fracture and retraction of the outer condyle of the humerus.

although it may be seen in those advanced in life. It is an injury very likely to be mistaken for a dislocation.

2. Fractures which engage the upper extremity of the bones of the fore-arm are chiefly confined to the ulna, for the radius very seldom suffers. Sometimes the olecranon process at the ulna is broken off, and occasionally a fracture of the coronoid process occurs, the consequences of which last accident are sometimes very serious. Sir A. Cooper gives us the following history: "A gentleman came to London for the opinion of different surgeons upon an injury he had received in his elbow. He had fallen on his hand whilst in the act of running, and on rising he found his elbow incapable of being bent, nor could he entirely extend it; he applied to his surgeon in the country, who upon examination found that the ulna projected backwards when the arm was extended, but it was without much difficulty drawn forwards and bent, and the deformity was then removed. It was concluded that the coronoid process was detached from the ulna, and that thus during extension the ulna slipped back behind the inner condyle of the humerus."

A preparation of an accident, supposed to be similar, is preserved in the Museum of St. Thomas's Hospital; the coronoid process, which had been broken off within the joint, had united by ligament only, so as to move readily upon the ulna, and thus alter the sigmoid cavity of the ulna so much as to allow in extension that bone to glide backwards upon the condyles of the humerus.

Fracture of the olecranon.—This process of the ulna is not unfrequently broken off, and the accident is attended by symptoms which render the injury so evident that the nature of the case can hardly be mistaken. Pain is felt at the back of the elbow, and a soft swelling is soon produced there, through which the surgeon's finger readily sinks into the joint; the olecranon can be felt in a detached piece elevated sometimes to half an inch and sometimes to two inches above the portion of the ulna from which it has been broken. This elevated portion of bone moves readily from side to side, but it is with great difficulty drawn downwards; if the arm be bent, the separation between the ulna and olecranon becomes much greater.

The patient has scarcely any power to extend the fore-arm, and the attempt produces very considerable pain, but he bends it with facility, and if the limb be left undisturbed it is prone to remain in the semiflexed position. For several days after the injury has been sustained, much swelling of the elbow is produced, there is an appearance of ecchymosis to a considerable extent, and an effusion of fluid into the joint ensues; but the extent to which these symptoms proceed depends upon the violence which produced the accident. The rotation of the radius upon the ulna is still preserved; no crepitus is felt unless the separation of the bone is extremely slight. Fractures of the upper extremity of the ulna are sometimes very complicated. Thus Mr. Samuel Cooper informs us that there is a preparation in the Museum of the London University, illustrating a case in which the ulna is broken at the elbow, the posterior fragment being displaced backwards by the action of the triceps; the coronoid process is broken off; the upper head of the radius is also dislocated from the lesser sigmoid cavity of the ulna, and drawn upwards by the action of the biceps.

Luxations.—The bones of the fore-arm are liable to a great variety of luxations at the elbow-joint; the following arrangement will probably be found to comprehend most of those accidents as yet known and described.

1. Luxations of both bones backwards; 2. Luxations of both bones laterally, complete and incomplete; 3. Luxations of both bones laterally and posteriorly; 4. Luxation of the ulna alone backwards; 5. Luxation of the radius alone forward; 6. Luxation of the radius externally and superiorly; 7. Complete luxation of the radius backwards; 8. Sub-luxation of the radius backward; 9. Congenital luxation of the radius.

1. *Luxation of both bones of the fore-arm backwards.*—This luxation is the most frequent of all those to which the elbow-joint is liable; it is usually produced by a fall on the palm of the hand, the fore-arm being at the time extended on the arm, and carried forwards, as when a person falling forwards puts out his hand to save himself.

The patient suffers at the moment of the accident an acute pain in the elbow-joint, and is often conscious of something having given way in the joint. The fore-arm inclines to a state of supination (*fig.* 41); the whole extremity is manifestly shortened; the olecranon process rises very much above the level of the tuberosities; or, to speak more correctly, with reference to the position of the limb, which is always presented to

Fig. 41.

Luxation of both bones backwards.

us for examination more or less flexed, this process is placed much behind and somewhat below the plane of the condyles of the humerus. The tendon of the triceps carried back with the olecranon stands out in relief, as the tendo Achillis does from the malleoli. This part of the triceps thus standing out can be seized through the integuments by the fingers, and we perceive in front an interval between it and the back part of the humerus. Anteriorly, in the fold of the arm, through the thickness of the soft parts, we can feel a hard tumour, situated obliquely from without inwards and backwards, formed by the lower articular extremity of the humerus. The rounded head of the radius can be seen prominent below the external condyle, and we can occasionally even sink the end of the thumb into the hollow of its cup-like extremity, and if now a movement of pronation and supination be communicated to it, the nature of the case becomes very evident.

The patient himself feels the arm powerless, and we find we can communicate to it but little motion. When we make the attempt to rotate or flex the arm on the fore-arm, we find our efforts resisted, and that we give the patient pain; a little extension of the elbow-joint is allowed; and we have invariably found that a lateral movement of abduction and adduction could be given to the fore-arm, motions this joint does not enjoy in the natural state, but which we can account for being now permitted, when we recollect the complete laceration the lateral ligaments must suffer in this injury.

The transverse fracture of the lower extremity of the humerus, or a forcible separation of its lower epiphysis, are accidents most liable to be confounded with luxation of both bones backwards; but although the elbow projects much backwards, and there is a marked prominence in front, still the relative position of the condyles of the humerus and the olecranon process is not altered in the fracture, as they have already been described to be, in the luxation. Add to this, that in the fracture the surgeon can flex the patient's fore-arm on his arm, a movement which, in the luxation, the patient can neither himself fully perform, nor can it be communicated.

In the case of the transverse fracture also, notwithstanding the apparent similitude at first with the luxation, when a steady extension is made by pulling the hand forwards, while the arm is fixed, all the marks of luxation disappear, to return again very shortly, when the extending force is relaxed. In fracture, too, a characteristic crepitus may be felt just above the elbow-joint, by rotating the fore-arm on the humerus. It is very true that, in some cases of luxation, the dislocated bones are very readily restored to their place, and on the other hand, that a transverse fracture of the humerus may, after it is reduced, remain so for a little time, and thus we may perhaps account for the fact, that these accidents have been confounded with each other, and the mistake is a serious one. To guard against error in our diagnosis, it would be well, *after* the bones have been reduced, to try the experiment of pushing the fore-arm backwards, while the arm is steadily pressed forwards; if the accident has been a luxation, no change occurs, but if there has been a transverse fracture of the humerus, or of the coronoid process of the ulna, all appearances which erroneously induced a suspicion that the accident was one of luxation, are renewed, but not so the error of attributing these appearances to a luxation, for now the existence of a fracture can no longer be doubted. Lastly, after the bones, in a case of luxation, are apparently restored, it will be prudent to examine the head of the radius, and it will be right to be satisfied that this bone has also been replaced as well as the ulna, for, in the luxation of both bones backwards, the connexion of the radius with the ulna by means of the coronary and oblique ligaments, may have suffered, and under such circumstances, if care be not taken, the restoration of the radius to the lesser sigmoid cavity of the ulna and capitulum of the humerus may have been forgotten, as we have known to have happened in one instance.

When the luxation of both bones backwards is simple, and by mistake or neglect has been left unreduced, the case soon becomes irremediable; the patient for ever loses the power of fully flexing the fore-arm, and the muscles of the arm become more or less atrophied; the powers of pronation and supination also become impaired, but extension of the elbow-joint can be performed.

Sir A. Cooper had an opportunity of dissecting a compound luxation of the elbow-joint, in which the radius and ulna were thrown backwards, and the specimen is preserved in the Museum of St. Thomas's Hospital, and a representation given in his work on dislocations: see plate xxiii. fig. 2. The coronoid process of the ulna was thrown into the posterior fossa of the os humeri, and the olecranon projected at the back part of the elbow, above its natural situation, an inch and a half. The radius was placed behind the external condyle of the os humeri, and the humerus was thrown forwards on the anterior part of the fore-arm, where it formed a large projection. The capsular ligament was torn through anteriorly to a great extent; the coronary ligament remained entire. The biceps muscle was slightly put on the stretch by the radius receding, but the brachialis anticus was excessively stretched by the altered position of the coronoid process of the ulna.

This was a recent case; but it would appear from the dissections which have been made of cases which had been left for a long time unreduced, that a new bony cavity had been made on the front of the coronoid process of the ulna, while the brachialis anticus became the seat of ossific depositions. An interesting case of this kind is recorded by Cruveilhier, and figured by him in his Anat. Pathol. plate iv. fig. 1. Béclard also met with a similar case in dissection.

2. *Lateral dislocation of the bones of the fore-arm.*—Lateral dislocations of the elbow-joint are rare, and this circumstance is owing to the great transverse extent of the articular surfaces, to the inequalities which the corresponding surface of the humerus presents in the transverse direction, to the strength of the lateral ligaments, and the attachment to them of the tendons of those superficial muscles which pass to the anterior and posterior part of the fore-arm, which tendons almost identify themselves with the lateral ligaments, and must considerably strengthen and support the joint laterally. Again, the force which would have a tendency to luxate the bones laterally can very rarely be directed in such a manner as to produce the luxation we are now considering, nor are the muscles ever so directed as to produce them.

We find in authors circumstantial accounts of the symptoms of the complete luxation outwards and also of the complete luxation inwards; but we have not had any opportunities ourselves of witnessing these complete luxations as the immediate result of accidents. Indeed we can scarcely conceive any complete luxation outwards to correspond exactly to the description given; as we imagine that whenever the bones of the fore-arm are completely thrown outwards, these bones must be drawn

Fig. 42.

Luxation outwards of both bones of the fore-arm, consecutive to caries of the trochlea and great sigmoid cavity of the ulna.

immediately upward along the outer side of the arm. We can conceive it possible, however, that the bones of the fore-arm may be completely dislocated inwards from the trochlea of the humerus, and still be restrained from yielding to those forces which would draw them upwards and inwards, by the great projection inwards of the internal condyle of the humerus, which we know is so much more prominent than the external. We could scarcely mistake the case of complete lateral luxation of the fore-arm, whether it was inwards or outwards.

In the incomplete lateral luxations of the bones of the fore-arm at the elbow-joint, the articular surfaces of the bones are still in connexion, but the points of contact of their naturally corresponding surfaces are altered more or less as to their relative positions to each other. In these luxations the bones of the fore-arm may be thrown partially *outwards* or partially *inwards*. In the luxation *outwards*, the cavity of the superior extremity of the radius abandons the lesser head of the humerus, and its cup-like extremity may be felt beneath the skin, while the great sigmoid cavity of the ulna corresponds to the capitulum of the humerus from which the radius has been displaced. As to the anatomy of the parts under such circumstances, the ligaments must be all torn, the biceps and triceps muscles must be pulled outwards in the direction of the bones of the fore-arm, into which they are inserted, the supinator brevis muscle cannot escape laceration, and the musculo-spiral nerve must be more or less stretched. There must be danger of such a luxation being rendered complete or even compound.

One of the most remarkable of the external signs of this injury is an increase of breadth of the fore-arm in the line of the articulation. There is a considerable projection seen at the outer side of the arm formed by the head of the radius, and an angular depression immediately above this. On the inner side of the arm we see the prominence formed by the inner condyle of the humerus, and its lower extremity. The fore-arm is flexed, and the patient feels it impossible to move the joint. The deviation and curved direction outwards given to the biceps and triceps, and approximation of the olecranon to the outer condyle of the humerus, all taken together sufficiently characterize this rare accident.

In the incomplete luxation *inwards*, the cavity of the superior extremity of the radius, in abandoning the small head of the humerus, may be carried more or less inwards, and be placed under the internal border of the articular pulley or trochlea of this bone, while the inner edge of the great sigmoid cavity of the ulna and olecranon process must project inwards beneath the inner condyle of the humerus. The ligaments must be all torn as well as some of the muscles arising from the internal condyle of the humerus, the biceps and triceps are turned from their usual direction and are curved inwards, and the ulnar nerve must be more or less stretched. The external signs of incomplete luxation inwards are what the anatomy of the parts above described would lead us to expect; there is a remarkable increase of breadth across the line of the joint, permanent flexion of the fore-arm, and a powerless condition of the limb, all which were noticed in the former case. We must add to these a remarkable projection below and internal to the inner condyle of the humerus, formed by the internal edge of the great sigmoid cavity of the ulna. Our attention is also attracted by the approximation of the olecranon process and inner condyle of the humerus to each other, and the distance of the olecranon from the outer condyle of the humerus, which forms a remarkable projection externally.

3. Under the head of lateral luxations of the elbow-joint, Sir A. Cooper has described accidents which might perhaps be more correctly designated—*a*, complete luxation of the bones of the fore-arm at the elbow backwards and outwards; *b*, complete luxation of the bones of the fore-arm at the elbow backwards and inwards.

a. Luxation of the bones of the fore-arm backwards and outwards.—In this case the ulna, instead of being thrown into the posterior fossa of the os humeri, has its coronoid process situated on the back part of the external condyle of the humerus. The projection of the ulna backwards is greater in this than in the former luxation, and the radius forms a protuberance behind and on the outer side of the os humeri, so as to produce a depression above it. The rotation of the head of the radius can be distinctly felt by rolling the hand.

b. Luxation of the bones of the fore-arm backwards and inwards.—Sometimes the ulna is thrown on the internal condyle of the os humeri, but it still projects posteriorly, as in the external dislocation, and then the head of the radius is placed in the posterior fossa of the humerus. The external condyle of the humerus in this case projects very much outwards, and the usual prominence of the internal condyle is lost. The olecranon process approaches nearer than natural to the middle line of the body, and is pointed inwards, being thrown more posteriorly than in any other luxation.

4. *Luxation of the ulna alone directly backwards.*—The ulna is sometimes thrown back upon the os humeri, without being followed by the radius. The appearance of the limb is much deformed by the contortion inwards of the fore-arm and hand; the olecranon projects, and can be felt behind the os humeri. Extension of the arm is impracticable but by force, which will reduce the luxation, and it cannot be bent to more than a right angle. It is an accident somewhat difficult to detect, but its distinguishing marks are the projection of the ulna, and the twist of the fore-arm inwards. A specimen of this accident is preserved in the Museum of St. Thomas's Hospital; the luxation had existed for a length of time. The coronoid process of the ulna was thrown into the posterior fossa of the humerus, and the olecranon was found projecting behind the humerus much beyond its usual situation. The radius rested upon the external condyle, and had formed a small socket for its head, in which it was able to roll.* The coronary and oblique ligaments had been torn through, and also a small part of the interosseous ligament. The brachialis anticus was stretched round the trochlea of the humerus, and the triceps had been carried backwards with the olecranon.

5. *Luxations of the upper extremity of the radius from the humerus and ulna.*—When we look into the best books we possess for information on this subject, we must be struck with the remarkable discrepancy of the opinions we find expressed by the authors. Thus, upon the subject of luxation forwards of the radius, we find the celebrated Boyer stating that he doubts such a luxation can occur without being complicated with a fracture. Sanson states that this luxation forwards has never been observed, and moreover advances what he considers as anatomical and physiological explanations, to show the impossibility of such an occurrence. Sir A. Cooper, on the contrary, gives six examples of the luxation of the upper extremity of the radius forwards. The French writers state of the luxation of this extremity of the radius backwards, that although it is rare it has been many times witnessed, while Sir A. Cooper, alluding to this luxation backwards, says, " this is an accident which I have never seen in the living," but he gives an anatomical account of the appearances found in a subject, the history of which was unknown, brought into St. Thomas's Hospital for dissection. Having thus stated the different opinions of authors upon this subject, we shall proceed to give an account of—*a*, the luxation of the upper extremity of the radius forwards; *b*, of its luxation laterally and upwards; *c*, of its luxation backwards; *d*, of its sub-luxation; *e*, of its congenital luxation backwards.

* See plate xxiv. *fig.* 2, in Sir A. Cooper's work.

a. *Luxation of the radius at the elbow-joint forwards.*—The symptoms of this accident are as follows: the fore-arm is slightly bent, but cannot be brought to a right angle with the arm, nor can it be completely extended; when it is suddenly bent, the head of the radius strikes against the fore part of the humerus, and produces so sudden a stop to its motion as at once to convince the surgeon that one bone strikes against the other. The hand is placed in a prone position; but neither its pronation nor its supination can be completely performed, although its pronation may be nearly complete. The head of the radius may be felt on the front and upper part of the elbow-joint, and if rotation of the hand be attempted, the bone will be perceived to roll; this last circumstance and the sudden stop to the bending of the arm are the best diagnostic marks of this injury. In the dissection of this case, the head of the radius is found resting in the hollow above the external condyle of the os humeri. The ulna is in its natural position. The coronary and part of the capsular ligaments as well as the oblique and a portion of the interosseous ligaments are torn through. The laceration of the latter ligament allows of the separation of the two bones. The biceps muscle is shortened (*fig.* 43).

Fig. 43.

Luxation of the radius forwards.

We have known an instance in which this accident was produced in the following manner: the patient in endeavouring to protect his head from a blow aimed at him by a man who with both hands wielded a spade, received the force and weight of the spade on the edge of the ulna, which, at the same time that it produced a compound fracture of this bone, also dislocated the radius forwards. This latter complication not having been discovered in time, remained ever afterwards unreduced.

b. *Lateral dislocation of the upper extremity of the radius.*—This is an accident we find alluded to for the first time by Sir A. Cooper, in the appendix to the edition of his work on luxations. He does not adduce any recent case of it, but states that Mr. Freeman brought to his house a gentleman, aged twenty-five, whose pony having run away with him when he was twelve years old, he had struck his elbow against a tree, while his arm was bent and advanced before his head, in consequence of which the olecranon was broken, and the radius luxated upwards and outwards above the external condyle. When the arm was bent, the head of the radius passed the os humeri; he had a useful motion of the limb, but neither the flexion nor the extension was complete.

As the case here stated is the only one we are acquainted with on record of luxation of the radius upwards and outwards, we may be perhaps excused for exceeding our ordinary limits by relating the following case of this accident; the subject of it was a very intelligent medical student, about twenty-three years old, and we shall give the case nearly in his own words:—

He writes as follows: "When I was very young, a blow was aimed at my head by a person having a heavy boat-pole in his hands. I endeavoured to save my head by parrying the blow with my left arm. I received the pole on the middle and back part of the fore-arm with a force which knocked me down, and caused a wide lacerated wound where the pole came in contact with it. Whether a luxation of the radius occurred at this time or not was not known, but ever since the accident the arm has been weak, and about seven years ago the weakness increased, and it became liable to partial luxations forwards upon the slightest causes, which luxations I reduced myself by making extension with my right arm, until at length I got a severe fall, which dislocated it to such an extent, forwards and outwards, as to defy my attempts to restore it. The arm was locked in the flexed position, and the head of the radius was to be felt high up, and projecting slightly outside the external condyle of the humerus. The biceps muscle was contracted, and its tendon was very prominent, hard, and tense, like a bowstring. The hand was supinated. I suffered little pain, except when extension was attempted, when it became intense. Sir A. Cooper remarks, in his cases of luxation of the radius forwards, that the fore-arm is slightly bent, but cannot be bent to a right angle, nor completely extended. My arm was bent to an acute angle, and could not admit of the slightest extension. The luxation was reduced by extension, and in six weeks passive motion was begun; but I found it painful to use it, and the head of the radius would often catch in the ridge above the external condyle, but on extending the arm it returned with a noise into its place. A month, however, did not pass before I was one morning awakened in making some awkward movement in my bed, and my arm became luxated worse than ever. On this occasion the surgeon who heretofore had easily replaced the bone found it impracticable to effect it, and called in Mr. Colles to his assistance; but although much force was used it was in vain. From this time the head of the radius never was returned back to its proper situation, but habitually remained dislocated completely forwards in front of the external condyle. The ligaments seemed to have been so lacerated, and the joint felt so weak, that I was in constant terror lest the bone should be further luxated as formerly, and that it should again slip over the external condyle of the humerus. I could extend my arm, but not fully, and could rotate it, but could not flex it sufficiently to use my fork at dinner. In this state I remained for six years, and in the winter of 1834–5 the radius was again luxated laterally over the external condyle of the humerus by a fall from my bed. Now the difficulty experienced in bringing the bone back to the situation it had so long occupied in front of the external condyle, was extreme. I went to the hospital, and two surgeons, assisted by six of my brother pupils, could not, with all their force, reduce the bone. The pulleys were also now used, but without success. Dr. O'Beirne and the late Dr. M'Dowel were called into consultation; they placed me sitting on my bed, and fixing the hollow angle at the bend of the elbow against one of the bed-posts, they used great force to straighten it, in which they succeeded; that is to say, they replaced the bone, not into its original berth, but back to the new socket, which had been formed for it in front of the external condyle, where it had been lodged for six years previously to the last accident, and where it now remains. At this moment it presents all the characters assigned to the luxation of the radius forwards; the rounded head of this bone is quite prominent in front of the external condyle of the humerus, in which situation it seems to have worked for itself a socket, and behind the head of the radius a deep depression exists. The arm has a rounded appearance, and the fore-arm is much wasted."

This case seems to us important as proving three circumstances: 1. that a partial luxation forwards of the radius can exist from relaxation or elongation of ligaments; 2. that this partial luxation or weakness of the joint is readily convertible into the true luxation forwards; and, 3. that in the case of unreduced luxation of the radius forwards the patient is still in danger of further luxation of this bone laterally, or above the capitulum and outer condyle of the humerus.

c. Luxation of the upper extremity of the radius backwards.—This luxation would appear to be the most frequent the upper extremity of the radius is liable to, although it cannot be considered a common accident. When, however, we consider the functions of this joint and its form, we shall not be surprised to find the luxation backwards more usual than that forwards. The articulation is less sustained posteriorly by muscular parts than in front, when the fleshy bellies of the supinators cover and support it. There is also much latitude given to the movement of pronation, and the pronators are very powerful muscles. During a forced pronation, the radius becomes very oblique, and its upper extremity has a strong tendency to pass behind the axis of the humerus.

The motion of supination, on the contrary, is not so frequent, the muscles to effect it are not so powerful, and the oblique and interosseous ligaments, which afford no restraint in the motion of pronation, are, on the contrary, soon rendered tense, and oppose a forced supination, which is the movement most likely to be followed by the luxation forwards. We think, therefore, we have physiological grounds for our belief that the luxation of the radius backwards ought to be the most frequent luxation of the radius at the elbow-joint. When the luxation of the upper extremity of the radius backward has occurred, the patient feels at the moment a severe pain in the region of the joint. The fore-arm is flexed, and the hand remains fixed in a state of pronation. Supination cannot be effected either by the voluntary action of muscles or by force applied, and each effort, tending to produce this effect, is attended with a considerable augmentation of pain. The hand and fingers are held in a moderate state of flexion. Finally, the superior extremity of the radius forms a manifest prominence behind the capitulum or small head of the humerus.

When the bone is left unreduced, many of the motions of the fore-arm are rendered imperfect, particularly supination; but the shoulder articulation becomes somewhat more free, and in some degree this circumstance makes up for the deficiency.

Sir A. Cooper, who has not seen any example of this luxation of the radius backwards in the living subject, has given us an account of a dissection of this injury. He informs us that in the winter of 1821 a subject was brought for dissection into the theatre of St. Thomas's Hospital, in which was found this luxation, which had never been reduced. The head of the radius was thrown behind the external condyle of the humerus, and rather to the lower extremity of that bone. When the arm was extended, the head of the radius could be seen as well as felt behind the external condyle of the humerus. On dissecting the ligaments, the coronary ligament was found to be torn through at its fore part, and the oblique ligament had also given way. The capsular ligament was partially torn, and the head of the radius would have receded much more had it not been supported by the fascia which extends over the muscles of the fore-arm.

d. Sub-luxation of the upper extremity of the radius, with elongation of the coronary ligament.—While Boyer denies the possibility of any partial luxation of the upper extremity of the radius, he describes very clearly an abnormal condition of the radio-humeral joint, of which we have seen many examples, and which perhaps we may call a sub-luxation. The ligaments which connect the head of the radius to the ulna, in the cases above alluded to, undergo a gradual relaxation and elongation, so that whenever an unusual effort is made to produce a strong pronation of the fore-arm, the head of the radius is permitted to pass backwards, somewhat behind its natural situation; but as soon as the effort ceases, the radius resumes its natural position in the lesser sigmoid cavity of the ulna. A true luxation in these cases cannot be said to happen, unless the effort of pronation is sufficient to bring the superior extremity of the radius behind the small head of the humerus; whenever this has occurred, then the sub-luxation is converted into the complete luxation of the radius backwards, and presents all the characters of this accident, and it cannot be replaced without the assistance of art. It is known to anatomists that the radio-cubital joint is not advanced much in its development in infants; that the lesser sigmoid cavity is as yet small and shallow; and that the coronary ligament of the radius is proportionally longer and more yielding than it is destined to be in after life. This articulation, however, is fully equal, even at this earliest period of life, to sustain any efforts that its own pronator muscles can communicate to it; but it is by no means constructed so as to be able to resist those forced movements of pronation and stretching we see too frequently given to the fore-arms of infants of a tender age, by their attendants, who in lifting them from the ground usually seize them by the fore-arms, these being at the time in a full state of pronation. Thus we find that in delicate children the foundation is laid for that elongation of the coronary ligament, which ends in the condition of this joint we have denominated sub-luxation. We have usually observed that the subjects of this affection were delicate from their youth, and that sometimes only one, and that frequently both arms were affected; that in all cases the extremity was more or less deformed, having a bowed appearance, the convexity being external; that a very evident protuberance could be seen and felt in the situation of the head of the radius; and that the patient had nearly perfect use of the arm, although he could neither fully flex nor extend it. When the surgeon places his thumb on the external condyle of the humerus and head of the radius in one of these cases, and at the same time has the fore-arm supinated, the head of the radius is felt to rotate in its proper place, and on its axis, as in its perfect condition; but if now a forced movement of pronation be given to the head of the radius, the latter will be observed to slip backwards towards the olecranon process: every time the patient himself fully pronates the fore-arm, the sub-luxation occurs, and in supination the radius resumes its place again. This relaxation of the ligaments of the radio-cubital joint, no matter how produced, at all events predisposes those affected with it to the more complete luxation of the radius backwards.

e. Congenital or original luxation of the superior extremity of the radius backward.— Dupuytren is the first pathologist who has spoken of the congenital luxation of the radius; he met with a case of the kind in dissection, and described it in his lectures. He found that the superior extremity of each radius had abandoned its natural situation, and was found situated behind the inferior extremity of the humerus, having passed this *extremity an inch at least.* This disposition being absolutely the same on each side of the body, there existed no difference between these two luxations, which were probably congenital. It is also stated that Dupuytren had mentioned that about twenty or twenty-five years before he dissected the case now alluded to, he had seen a case nearly similar, but he was unwilling to speak positively on these cases, as the history was unknown, and accident or disease might have produced similar results.

Cruveilhier, in his very valuable work on Pathological Anatomy, quotes the above observations from Dupuytren's lectures, and seems to disagree entirely with the celebrated surgeon of the Hôtel-Dieu, advancing it as his opinion, that it would be much more natural to suppose that the cases described by Dupuytren were not congenital, but rather very old luxations, a long time left unreduced.

It is very true that Dupuytren speaks with hesitation about the matter, as he appears to have met with but two cases, nor can any one speak with certainty on this subject, until observation on the living, and anatomical investigations, shall be combined to elucidate the matter; but we think that already enough can be adduced to shew, that we have strong grounds for believing that such a congenital defect as luxation of the upper extremity of the radius backwards may be occasionally met with, and this is an opinion we think ourselves authorised to advance, because of the facts and reasons we can adduce to support it.

In the Museum of the Royal College of Surgeons in Ireland, there is a specimen, which the writer considers to be one of congenital luxation of the upper extremity of the left radius backwards; *fig.* 44 is a representation of it. The outer condyle of the humerus exists, but in front of it there is no rounded head or capitulum for the radius, or any trace of the usual convex articular surface ever having existed. The coronoid process and great sigmoid cavity of the ulna are unusually large transversely, and stretch almost the whole way across the lower articular extremity of the humerus, which is entirely formed into one single trochlea wider than natural. The head of the radius, which seems never to have been adequately developed, is situated behind the plane of the outer condyle of the humerus. The tubercle of the radius is much enlarged, and leans against the lesser sigmoid cavity of the ulna, while the neck of the radius, directed somewhat backward, is twice its natural length, and instead of reaching merely to the level of the lesser sigmoid cavity of the ulna, stretches as high up along the ulna as to reach near to the level of the summit of the olecranon process, while the carpal extremities of the radius and ulna are, in their natural state, on an even line with each other. There is scarcely any interosseous interval, the bones seem so closely connected with each other. Indeed, from the inspection of this preparation, we may justly infer that the fore-arm during life had remained much in a state of semiflexion on the arm, and of rigid pronation, and that the movement of supination was nearly impracticable. This defective formation, or atrophy of the capitulum and increased developement of the trochlea of the humerus, which was so formed to accommodate itself to the unusual breadth acquired by the coronoid process and the whole of the ulna, must not be considered unprecedented. We find, by referring to the beautiful work of Sandifort, (the Museum Anatomicum, table ciii. fig. 3,) a case similar to the above delineated (*fig.* 45). In referring to it, the author states that the bones of the fore-arm were anchylosed, that the form of the capitulum was lost, that the head of the radius was luxated completely backwards, and that the ulna alone remained in articulation with the humerus; the parallelism between these two cases will be still more fully seen, when, speaking of the lower articular extremity of the humerus, we find that he says, "Figura ergo capituli periit. Rotula unica, sed major formatur;" and of the ulna, "insignem acquisivit amplitudinem et totam inferiorem ossis humeri partem admittere potuit."

Fig. 44.

Congenital luxation of the radius backwards.

Fig. 45.

Congenital malformation of right humerus — trochlea enlarged — no capitulum.

In examining very lately the splendid collection of morbid specimens contained in the Museum of Guy's Hospital, the writer's attention was caught by observing a preparation of the radius and ulna, belonging, he is certain, to the same class of diseases now under consideration, namely, congenital luxations of the radius. In this preparation there is a very oblique relative position of the bones of the fore-arm to each other. While their carpal extremities are exactly upon a line with each other below, the neck of the radius is elongated upwards, and the head of this bone is displaced much backwards, and is situated behind and below the outer condyle of the humerus, and reaches nearly to the summit of the olecranon. The coronoid process and great sigmoid cavity of the ulna have acquired much breadth, and what is remarkable in this case, and in which it differs from any other we have seen, is, that a process of caries had been going on in the articulation. Cruveilhier has given four drawings of two cases of complete luxation backward of the radius, which he however does not consider to be congenital. Nor is it in our power absolutely to prove that they are specimens of congenital luxations backwards, although we feel persuaded that all the cases we have referred to, these inclusive, are very curious specimens of this congenital deformity of the radio-humeral articulation.

The previous history of all the cases we have collected is totally unknown; it is recorded of them all, that the arm was remarkable for its deficient development, that the fore-arm was in a state of demi-pronation and demi-flexion, that the movement of extension was incomplete, and of supination impossible. Cruveilhier, in the account he has given of both his cases, states that the superior extremity of the radius was at the level of the summit of the olecranon process (*fig.* 46), and that the inferior or carpal extremity of the two bones of the fore-arm were on the same precise line below, and that no deformity here existed. The head of the radius and tubercle were deformed, or rather imperfectly developed, while there was an elongation of the neck of the radius upwards for more than an inch. Cruveilhier cannot concur with those who consider these cases as examples of congenital luxations, but looks upon them as old luxations, which had been left unreduced.

Fig. 46.

Malformation of the radius, in which it was found as long as the ulna.

For our part we cannot see in these pathological observations any thing to convince us that any one of the cases alluded to was an old luxation originally produced by accident or disease. Suppose, for argument sake, it be admitted that, from long disease, the form of the capitulum was altogether lost, when the radius was no longer in contact with it, and that the acquired breadth of the sigmoid cavity of the ulna was the result of a natural effort to compensate for the loss of strength the joint suffered from the dislocation of the radius. Still, supposing it possible that the surface of the capitulum of the humerus could be so completely removed, under such circumstances, as we find it was in the cases of which *figs.* 44 and 45 are delineations, we may ask, is it likely, from accident or disease, that both elbow-joints should be similarly affected, as they were in Dupuytren's cases. Another circumstance in our mind cannot be accounted for, unless by supposing these cases congenital, namely, the alteration and great elongation of the neck of the radius. "L'extremité supérieure de chaque radius avait abandonné sa situation naturelle, se trouvait placé derrière l'extremité inférieure de l'humerus, et depassait cette extremité d'un pouce au moins. Cette disposition était absolument la même de chaque côté du corps." We know of no process which could take place in the head and neck of the radius after it had been dislocated, which could satisfactorily account for the elongation of the radius, which has been remarked in these cases. While looking on them as congenital, we need not be surprised at it; for we have known the neck of the femur elongated and atrophied, in the case of congenital luxation of the femur, and have very frequently seen the lower extremity of the ulna exceed in length by half an inch the corresponding extremity of the radius; and these were cases in which no doubt could be entertained that they were congenital.

Disease.—Acute and chronic inflammation produces effects on the membranes, cartilages, and bones entering into the composition of the elbow-joint, which will be found nearly analogous to those which the same morbid action produces on similar structures in other articulations. A few local peculiarities, if we may so call them, when the elbow is the seat of the acute or chronic disease, should alone occupy our attention here.

Synovitis of the elbow-joint, uncombined with any affection of the other structures, is rare; it may, however, present itself either in the acute or subacute form. Increased effusion of fluid into the joint, accompanied with the usual local and sympathetic phenomena of inflammation, is the result. Two well-marked oblong swellings at each side of the olecranon process in these cases first present themselves, which after a time, if the disease proceeds, join and form one swelling, which extends up the back of the arm, occupying the cellular interval existing between the back part of the humerus and the front of the triceps muscle, opposite to the outer condyle of the humerus and head of the radius; the supinators arising here are, in severe cases, occasionally elevated and thrown out from the bones by a soft tumour, which, upon examination, conveys to the fingers a distinct feeling of a fluid contained beneath. The nature of the accumulated fluid will, when the joint is cut into, be found to vary. When the effusion has followed an acute attack of inflammation of the membrane, it will be generally found to be purulent, though sometimes we have observed the quality of the synovia but little altered, except that it was more or less turbid. When the contents of the synovial sac have been washed away, the membrane will be seen to be highly vascular, and the vessels of the subsynovial tissue congested with blood, and its cells infiltrated with serum; while, if fine injection, coloured with vermillion, is thrown into the vascular system of these parts, the unusual redness the membranes assume can only be compared in height of colouring to the membrane of the eye in acute conjunctivitis. With this intense redness of the surrounding membranes is strongly contrasted the appearance of the cartilages of the joint; these, but little altered from their natural colour, are seldom in this articulation found covered with vascular membranes, and even when the surrounding structures are minutely injected, the fluid cannot be made to penetrate the synovial investment of the cartilages.

Cartilage.—When acute inflammation has existed in the synovial membrane or bones of the elbow-joint, the articular cartilages covering these will very frequently be found to have assumed, in patches, a dull yellow colour; in the latter discoloured points the cartilage is softened, and a blunt probe slightly pressed will sink into its structure, and its subjacent surface will be found to be detached. A new vascular membrane having been interposed between the cartilage and the cancellous structure of the bone, this elevation and partial detachment of the articular cartilages from the heads of the bone, and interposition of a new organized membrane, are probably the usual preludes to those other changes we notice. Thus sometimes a leaf or flap of the articular cartilage, adherent only by an edge, hangs into the cavity of the joint, and again fragments of this structure completely detached are found loose in the interior of the articulation. In these instances there is reason to conjecture that the diseased action which detached the cartilage began on the surface of this structure contiguous to the bone. We have occasionally, however, evidence of ulcerative absorption having commenced on the free surface of the cartilage. The peculiar worm-eaten appearance which the surfaces of cartilages next the cavity of the joint occasionally present, and which, wherever it exists, is considered by many pathologists to be the result of a process of ulceration which had begun on the free surfaces of the articular cartilages, has been occasionally though rarely seen in the elbow-joint; much more frequently in examining elbow-joints which have been the seat of disease, the articular surfaces of the bones have been found extensively divested of their cartilages; a few patches of them alone here and there remain; and these, though apparently thinner than natural, are of their ordinary texture, and are firmly adherent to bone.

Such extensive removal of cartilage, which has exposed the cancelli of the heads of the bones, has generally been the result of some very violent attack of inflammation, which, no matter in what situation it had originated, ultimately we find had not spared any of the tissues entering into the formation of the articulation.

Bone.—The elastic white swelling (which is one of the usual external signs of this articular caries when the bones of the elbow-joint are the seat of the affection) is always situated posteriorly, and gives a characteristic appearance and a rounded form to the back part of the elbow-joint, which cannot be mistaken nor misunderstood. The wasted appearance of the arm above and of the fore-arm below makes this swelling more conspicuous, and the whole limb remains habitually in the semiflexed position, with the fore-arm somewhat prone; every movement of the articulation causes the patient much pain. The disease, thus arrived at its second or third stage, may remain stationary for a time or terminate in an anchylosis of the bones; commonly, however, the morbid process goes on. Luxation of one or both bones of the fore-arm occurs, symptomatic abscesses present themselves, and these after a time make their way to the surface, and discharge their contents through openings, sometimes near, and frequently at a distance from the joint; and thus, at length, we see formed direct outlets as well as sinuses and fistulous canals, which give exit to exhausting discharges. The pain and irritation attendant on the disease itself, added to all these, give rise to hectic fever, which too frequently nothing but the desperate measure of amputation will arrest. The disease, which produces such serious consequences, often begins very insidiously, either in the head of the radius and external condyle of the humerus, or in the trochlea of this bone and the great sigmoid cavity of the ulna. When the disease begins at the radial side, the pain runs along the course of the musculo-spiral nerve, and there is a manifest swelling externally in the situation of the radio-humeral articulation: although there is even now a marked tendency in the fore-arm to remain in a semiflexed position, still gentle flexion and limited extension are admissible; but when the radius is pressed against the humerus, and a movement of rotation at the same time is given to the fore-arm, much pain is complained of. The disease may go on, confining itself chiefly to the radial side of the elbow-joint through its first stage of pain and swelling; through its second of effusion of fluids and relaxation of the coronary and external lateral ligament; and, thirdly, to dislocation backwards of the head of the radius, and even to suppuration and discharge of matter through an ulceration or slough of the integuments.

When the caries has commenced in one of the opposed surfaces of the trochlea of the humerus or great sigmoid cavity of the ulna, the swelling and effusion are first noticed internally at the side of the olecranon and internal condyle. The pain extends to the wrist along the course of the ulnar nerve; the fore-arm is in this case also in a state of semiflexion, and any attempt to extend or increase the degree of flexion causes very severe pain, while, on the contrary, a movement of rotation of the fore-arm is permitted. If the disease proceeds, the great sigmoid cavity of the ulna becomes wider and deeper, and the humerus advances on the coronoid process; the internal lateral ligaments are relaxed, and the triceps drags back the fore-arm, so that the olecranon process projects somewhat posteriorly, and there is a tendency to a displacement backwards.

Whether the disease has originated on the radial or ulnar side of the joint, it very generally spreads so as to involve the articular surfaces of the three bones, and now the disease, termed scrophulous white swelling, becomes fully established, and is easily recognized by the usual signs. Besides dislocation backwards, either of the radius or of the ulna singly, or of both these bones together, lateral displacements of the bones of the fore-arm at the elbow have been noticed as a consequence of caries; nor need we be surprised at such variety of position being assumed by the bones, when inflammation has softened the strong lateral ligaments and caused their ulceration. While the patient is confined to bed or to the horizontal posture, the mere position which is given to the fore-arm on the pillow will influence the direction of the displacement that will occur. We have seen, under such circumstances, complete lateral displacement of both bones of the fore-arm outwards. The internal condyle of the humerus pressing against the integuments covering it had caused a round slough, through which the internal condyle of this bone protruded, while the rounded head of the radius had on the outer side caused a similar slough and ulceration of the integuments, through which the upper cup-like extremity of this bone had protruded.

This lateral displacement of both bones of the fore-arm outwards, whether occurring suddenly from accident, or slowly from the effects of articular caries, if it be complete, must always (we imagine) be followed by a consecutive dislocation upwards. In this case of caries above alluded to, we found the whole extremity somewhat shortened, that the hand remained habitually prone, and that the fore-arm (in a state of semiflexion as to the arm) was directed with considerable obliquity inwards. It was plain that the causes of all these external signs were, that both bones of the fore-arm having their normal relation to each other, were first carried completely outside the inferior extremity of the humerus, and were then drawn upwards above the level of the outer condyle of this bone. The olecranon process was not thrown at all backwards, but was situated immediately above and outside the external condyle of the humerus; the coronoid process was in front of this bone; the inner semilunar edge of the great sigmoid cavity therefore corresponded to the convexity of the outer side of the humerus, and seemed, as it were, to embrace this bone here so as to forbid any further retraction of the fore-arm. When we proceed to examine an elbow-joint which has been the seat of a scrophulous white swelling that had presented the usual characters of this disease in its advanced form, we usually notice the surface of the skin studded over here and there with the orifices of fistulous canals; these are found generally to have proceeded by a winding course, either from the cavity of the elbow-joint or from the cancellous structure of the bones, or from both these sources. When a section is made of the bones in this advanced period of the disease, they will generally be found to be softened in the interior, and to contain a fatty or yellowish cheese-like matter in their cells; when examined in an earlier stage of this scrophulous caries, these organs are generally found to be preternaturally red and vascular, and with much less proportion of earthy matter than natural, so that they admit not only of being cut with a knife without turning its edge, but yield and are crushed under very slight pressure.

We have also occasionally opportunities of examining the joint when the process of caries would appear to have been arrested and to have given place to a new growth of bony vegetations around the joint; under such circumstances, conical granulations, several lines in length, shoot out like stalactites around the trochlea of the humerus and from the olecranon and coronoid processes of the ulna; the bones are, however, in these specimens remarkably light, porous, and friable. In some cases, however, the caries of the bone has altogether ceased, and a process of anchylosis has been established, and the fore-arm is flexed on the arm: a section through the elbow-joint longitudinally will in such cases frequently exhibit a complete continuation of the cancelli through the joint from the cells of the humerus to those of the radius and ulna.

Rheumatism.—The elbow-joint, like all the other articulations, is liable to attacks of acute rheumatic inflammation, the external signs of which differ but little from those which we observe to attend an ordinary case of acute synovitis. The disease, however, seldom fixes itself for any time upon this or any one joint in particular and usually terminates favourably, so that opportunities seldom occur of ascertaining by anatomical examination the effects of this species of inflammation in the different structures of the elbow-joint. But this articulation is, in the adult and in those advanced in life, affected by a disease which, for want of a better name, is termed chronic rheumatism, the anatomical characters of which are very remarkable, yet they never have received from pathologists that attention they appear to us to deserve. In these cases the elbow-joint becomes enlarged and deformed; its ordinary movements, whether of flexion, extension, or rotation, become restricted within very narrow limits; and when we communicate to the joint any of these motions, the patient complains of much pain, and a very remarkable crepitation of rough rubbing surfaces is perceived: a careful external examination of the joint will in such circumstances enable us to detect foreign bodies in the articulation. Some of them are small, but others occasionally are met with of a very large size, and can easily be felt through the integuments. Sometimes the synovial membrane of the joint itself is much distended with fluid, and the bursa of the olecranon is likewise affected, in which small foreign bodies are also to be detected: sometimes, however, there would appear to exist in the interior of the joint even less synovia than natural. The muscles of the arm and fore-arm for want of use are more or less wasted and atrophied. As the external appearances vary, so also do we find the anatomical characters of the disease to present varieties, some of which deserve notice. We have found the most general abnormal appearance to be that the cartilages are removed from the heads of the bones which are greatly enlarged, and that these articular surfaces are covered by a smooth porcelain-like deposit, and after a time attain the polish and smoothness of ivory: the trochlea of the humerus, also, and corresponding surface of the great sigmoid cavity of the ulna are also marked with narrow parallel sulci or grooves in the direction of flexion and extension. In these cases the radio-humeral joint is likewise affected, the head of the radius becomes greatly enlarged, and it assumes quite a globular form, while the anterior and outer part of the lower extremity of the humerus will have its capitulum or convex head not only removed, but here the humerus will be found to be even excavated to receive the head of the radius, and to accommodate itself to the new form it has acquired from disease. In many cases where the radius had become thus enlarged and of a globular form, the writer has found the cartilage removed altogether and its place occupied by an ivory-like enamel. In two examples he has seen a depression or dimple in this rounded head of the radius, similar to what naturally exists in the head of the femur, and in these two cases, strange to relate, a distinct bundle of ligamentous fibres analogous to a round ligament passed from the dimple or depression alluded to, connecting this head of the radius to the back part of the sigmoid cavity of the ulna. In some few cases, when the external signs of this chronic disease in the elbow-joint were present, we have found the bones of this articulation enlarged, hard, and presenting a rough porous appearance, while the cartilage was entirely removed; but in these specimens no ivory deposit was formed. These were cases in which the same disease existed locally, and the same disposition prevailed in the constitution; but from the bones having been kept in a state of quietude, the rough surfaces of the articular extremities had not been smoothed by the effects of friction, nor an ivory-like enamel formed. We believe that in such cases, were life prolonged, anchyloses would be established: in other instances the head of the radius has not been found enlarged as above described, but otherwise altered from its natural form. The superior articular extremity of this bone has been found excavated from before backwards, its outline not being circular nor exactly oval but ovoidal, accurately representing on a small scale the glenoid cavity of the scapula.

It may be remarked that one of our patients, a man, aged sixty, in the surgical wards of the House of Industry, who had for many years suffered from the severest forms of chronic rheumatism in all the articulations, got diarrhœa and died. The writer had previously noted in particular the condition of the right elbow-joint; the motions of flexion and extension were very limited, attended with much crepitation, and caused to the patient very great pain. The exact condition of the bones described in the preceding paragraph existed, and the loss of the circular outline of the radius fully accounted for what we had in this case previously noted, viz. that to remove the hand from the state of pronation in which it habitually remained, or to communicate any movement of rotation to the radius was nearly impracticable; the glenoid-shaped surface for the head of the radius allowed of flexion and extension in the radio-humeral articulation, but any except the perfect circular form was ill-suited to permit any rotatory movement of the radius on the ulna. This then is a peculiar disease which causes a complete removal of the articular cartilage from the head of the bones of the elbow-joint, so that the porous substance of the bones becomes exposed: they do not become carious, but on the contrary they are enlarged, hard, and their surfaces seem to expand. If the joint be much used, the effects of friction become evident; if kept at rest, they are rough, and anchylosis may take place.

From the phenomena we observe in the variety of cases that present themselves, we may infer that, when this disease affects the elbow-joint, in whichever bone most vitality exists and most active nutrition is going on, enlargement would appear to take place, while in the bone which is softer and in which the process of nutrition is least, the effects of friction become of course most manifest. Thus, in some cases, as already mentioned, we have found the head of the radius greatly enlarged and of a globular form, and the outer condyle of the humerus excavated to adapt itself to this convexity, while on the contrary, in other cases the outer condyle of the humerus seemed to have been the seat of active nutrition, and the head of the radius to have been rendered soft and to have yielded to the effects of friction. In all these cases, there seems to be a very active circulation of blood in the capillary vessels of the bones and other structures of the joint. Much of the synovial membrane may be removed with the cartilages; but the synovial folds and fimbriæ (as they are called) which encircle the neck of the radius, and occupy the different fossæ in front and behind the trochlea of the humerus, become unusually vascular and enlarged.

In most of the cases we have examined, we have discovered what are called foreign bodies in the cavity of the joint. These we have found of all sizes, from that of a pea to that of a walnut. Some were seen hanging into the cavity of the articulation, being suspended by white slender membranous threads which seemed to be productions from the synovial sac; and some were loose in the joint: while, as to their structure, some were cartilaginous and bony. The number of these foreign bodies we have seen in the cavity of the elbow-joint we confess has astonished us, amounting in one case to twenty, in another to forty-five. In all these cases the vessels of the synovial fimbriæ of the joint were in a highly congested state. The co-existence, therefore, of foreign bodies with such a condition of the membranes and their capillary vessels as these dissections elicited, cannot be too fully impressed on the mind of the practical surgeon, who is sometimes solicited to undertake an apparently simple operation for their removal. Lastly, instead of the few scattered fibres external to the synovial sac, which, in this joint, when in a normal state, can scarcely be said to resemble even the rudiment of a capsule, we have found in these morbid specimens the thickness and number of ligamentous fibres so considerable, that the joint seemed to possess almost a complete capsular ligament.

In Cruveilhier's Pathological Anatomy, Livraison No. 9, Plate 6, Figure 1, there is a graphic delineation of an elbow, illustrating many of the points here alluded to: he denominates the disease *usure des cartilages*, but it is quite sufficient to look at one of these cases, either in the living or the dead, to be satisfied that the disease does not confine itself to the cartilages of the joint, but that the articular heads of the bones are also engaged; indeed, in many of our specimens, the bones of the elbow-joint are so much enlarged as to resemble at first sight the knee-joint; the shafts also of the ulna and radius are heavier and harder than natural, and their cancellated structure no longer exists, the cells being so densely penetrated with phosphate of lime that the sections of these bones in several parts present the appearance of ivory. This account of the state of the elbow-joint produced by that slow disease called chronic rheumatism, is the result of many observations and dissections made specially by ourselves. We may also add that Mr. Smith, the able curator of the Museum of the Richmond Hospital, who has given equal attention to such investigations, has examined and preserved several specimens which verify the account here given of the anatomical characters of this disease; while, under the writer's own immediate charge in the House of Industry, are numerous living examples of, and sufferers from, this chronic disease, affecting the elbow-joint. In most of these cases, however, some of the other articulations are equally engaged.*

(R. Adams.)

* [Since the preceding article was put to press, the Editor has been favoured with the following communication from the Author, which is too interesting to be omitted: "Within these three days I met with a very singular case of congenital deformity of both elbows in a girl about eleven years of age. The radius could be felt to press forwards and backwards for the extent of an inch when it was rotated either in pronation or supination. These movements did not consist in a simple rotation of the radius on its longitu-

ELECTRICITY, ANIMAL.—A power, or imponderable agent, possessed by and evolved from certain living animals, which enables them, independently of the operations of external agents on their structures, to produce several of the phenomena exhibited by common and voltaic electricity, generated in inorganic matter.

The animals so endowed, with which we are at present acquainted, are all fishes; and the effect by which their power is most sensibly made known to us is the feeling of a shock, or momentary stunning, which is experienced in the hand that touches their surface.

It is still doubtful whether the agent which produces this effect be absolutely identical with those which produce the various phenomena of common and voltaic electricity, thermo-electricity, &c.; but the most recent researches on the subject render it probable that it is the same in its nature, although different in intensity.

When Galvani discovered the possibility of exciting muscular contraction by establishing an external communication between the nerves and muscles by means of metals, he imagined that the contraction was produced by the stimulus of a peculiar agent (or fluid) existing in the nerves in a state of accumulation, which, being attracted by the metals, passed along them to the external surface of the muscles. The agent, which was supposed to remain latent in the nerves, was called by some "the nervous fluid," as it was imagined to be identical with that power which animates the nerves during life. Galvani seems to have entertained this notion. Other philosophers, avoiding a name derived from a theory, denominated the agent *Galvanism*. Afterwards it was called *Animal Electricity*. These views were supported by Valli, Carradori, Aldini, and Fowler. But, since Volta and others demonstrated that the contractions of the muscles in Galvani's experiments were owing to electricity developed by the contact of the metals employed, and not to any fluid pre-existent in the nerves, the term *Animal Electricity* has had its meaning changed. At present, most physiologists use it in the sense which is implied in the definition given above.

That is *not* called *Animal Electricity* which is generated by the friction of animal substances one upon the other, or by the mere contact of animal tissues of dissimilar natures. The phenomena so developed have their source in common and voltaic electricity. They are phenomena exhibited by animals in common with inorganic matter. As the study of these, however, may ultimately lead to the elucidation of some points connected with the electricity of living fishes, they shall be noticed in the course of the following article.

It is in the mode of its development that the chief peculiarity of *Animal Electricity* consists. None of the usual excitants of electricity are concerned in it. There is no chemical action, no friction, no alterations of temperature, no pressure, no change of form. The exercise of the animal's will, and the integrity of the nervous system, as well as of certain peculiar organs which exist in all the animals endowed with electrical power, seem to be alone sufficient for its evolution.

The following are the systematic names of the electrical fishes at present known:—

Torpedo narke.
——— *unimaculata.* *Risso.*
——— *marmorata.* *Ditto.*
——— *Galvanii.* *Ditto.*
Gymnotus electricus.
Trichiurus electricus.
Malapterurus electricus.
Tetraodon electricus.

The four species of Torpedo inhabit various parts of the Atlantic and Mediterranean. They were formerly regarded as constituting one species, (Raia Torpedo, of Linnæus;) and now Dr. John Davy proposes to reduce them to two; having satisfied himself (and in this he is supported by the opinions of Cuvier and of Rudolphi) that the T. marmorata and T. Galvanii are merely varieties of the same species, for which he suggests the name of T. diversicolor. It is known in Italy by the name of the Tremola. The other species (the Occhiatella of the Italians) Dr. Davy thinks would be better named T. oculata. Both pass in Malta under the term Haddayla. The first of these species (T. vulgaris, of Fleming,) occurs on the south coast of England, where it sometimes attains a great size. Pennant mentions one which measured four feet in length and two and a half in breadth, and weighed fifty-three pounds. And Mr. Walsh describes another which was four feet six inches in length, and of the weight of seventy-three pounds.*

dinal axis, but a real change of place of the upper extremity of the radius on the outer condyle of the humerus. The elbow was but slightly deformed, and all its motions were perfect except extension, which was not complete, but the girl had perfect use of both arms and fore-arms, which were exactly similarly formed. The radius seemed principally in fault, and the motions of the upper head corresponded much to the description given of the subluxation. (Vide p. 74.) I was afforded an opportunity of examining the joints in consequence of the child having died of scarlet fever. Both joints were exactly alike. The radius was large, the great sigmoid cavity of the ulna was not half its usual size, and the coronoid process did not exist. The trochlea on the humerus, corresponding to the diminished sigmoid cavity, was one-half less than its natural size so that the lower extremity of the humerus bore so striking a resemblance to the cundyles of the femur, when viewed posteriorly from the popliteal space, that nobody could look at it without observing the striking resemblance in miniature of the humerus to the femur. There were fibrous bands representing the crucial ligaments, and all the fibres around were yellow and stronger than natural. The annular ligament of the head of the radius was wider than natural but much stronger, and accounted for the passing to and fro of this head in pronation and supination. That the deformity was congenital no one can doubt: the appearance—the history—the existence of the same malformation on both sides, all prove it." Dec. 12, 1836.]

* Phil. Trans. 1774.

Both species (Ναρκη of Aristotle and Oppian) are abundant in some parts of the Mediterranean, and are frequently brought to the market of Rome. Off the west coasts of France, in Table-bay at the Cape of Good Hope, in the Persian Gulf and in the Pacific Ocean, the same, or at least nearly similar species are plentiful. They frequently form an article of food amongst the poorer class in the coast towns between the Loire and the Garonne; but the electrical organs are carefully avoided, as they are supposed to possess some poisonous properties. The Gymnotus is found in several of the rivers of South America; it was met with by Humboldt in the Guarapiche, the Oronoco, the Colorado, and the Amazon. The Malapterurus (Silurus, of Linnæus) occurs in the Niger, the Senegal, and the Nile; the Trichiurus in the Indian Seas; the Tetraodon has been met with only on the shores of Johanna, one of the Comoro Isles. According to Margrav* there is a kind of ray-shark on the coasts of Brazil, which possesses the power of giving shocks. He described the fish under the name of Paraque.† It is the Rhinobatus electricus of Schneider and other modern ichthyologists. But in an examination which Rudolphi made of the fish in question, he found no structure resembling that peculiar organ which exists in all the well-known electrical fishes. No other naturalist has made the same observation as Margrav, so that the electrical power of this fish cannot be regarded as satisfactorily ascertained. In Maxwell's Observations on Congo, mention is made of a large fish " like a cod," possessed of electrical powers, which was taken in the Atlantic Ocean. No such animal has yet come under the notice of any scientific observer. Certain insects seem to be possessed of some power resembling animal electricity in its effects, but few observations have hitherto been made on these. *Reduvius serratus* is one of the insects so endowed; with regard to which an intelligent naturalist reports, that, on placing a living individual on the palm of his hand, he felt a kind of shock, which extended even to his shoulder; and that, immediately afterwards, he perceived on his hand red spots at the places whereon the six feet of the insect had rested.‡ Margrav described a species of Mantis, a native of Brazil, which, on being touched, gave a shock felt through the whole body. According to the report of Molina§ and Vidaure,‖ when the Sepia hexapodia is seized with the naked hand, a degree of numbness is felt, which continues for a few seconds. Alcyonium bursa, a native of the German Ocean, is said to have communicated to the hand a sensation like that of an electrical shock.¶

It must be regarded as an extremely interesting fact that the electric fishes belong to genera widely removed from one another in structure and habits, and yet that their own structure is not so peculiar as to prevent them from being arranged along with many other fishes possessing no degree of the same power and no vestige of a structure analogous to their own.

As the fishes enumerated above have not all been examined with the same degree of attention, we are ignorant of the extent to which they exhibit phenomena exactly resembling one another. But it is well ascertained that they all agree in possessing the power of communicating a sudden shock to the hand which touches them. This shock causes a certain degree of temporary numbness not only in the finger which immediately touches the fish, but also in the hand, and sometimes even in the arm. The sensation produced has been compared by different experimenters to the shock felt on the discharge of a Leyden phial, differing from it only in force. Hence the shock caused by an electrical fish is said to be produced by *a discharge* of its electricity. The numerous facts relating to the phenomena which accompany or are connected with this discharge, which have been collected by the industry of the many observers of the last and the present age, who have devoted their attention to the subject,* may be conveniently arranged under the following heads: 1. the circumstances under which the discharge takes place: 2. the motions of the fish in the act of discharging: 3. physiological effects of the discharge: 4. magnetical effects of the discharge: 5. chemical effects of the discharge: 6. results of experiments on the transmission of the discharge through various conducting bodies: 7. the production of a spark and evolution of heat: 8. results of experiments in which the nerves, electrical organs, and other parts, were mutilated: 9. descriptions of the electrical organs in the several fishes which have been anatomized.

I. *Circumstances under which the discharge takes place.*—Electrical fishes exert their peculiar power only occasionally, at irregular intervals, and chiefly when excited by the approach of some animal, or by the irritation of their surface by some foreign body. The discharge, both with regard to time and intensity, seems to be dependent on an exertion of the will. They discharge both in water and in air. Sometimes the discharge is repeated several times in close succession; at other times, particularly when the fish is languid, only one discharge follows each irritation. The intensity of the torpedo's discharge is generally greater when the fish is vigorous, becomes gradually less as its strength fails, and is wholly imperceptible shortly before death takes place; but Dr. Davy has met with some languid and dying fish which exerted considerable electrical

* Hist. rerum Nat. Brasil. 1648.

† The name *Puraqua* is used by Condamine in reference to the Gymnotus.

‡ Kirby and Spence's Entomol. vol. i. 110.

§ Naturgesch. von Chili. S. 175.

‖ Gesch. des Königr. Chili. S. 63.

¶ Treviranus, Biologie. V. 144.

* Redi, Réaumur, Walsh, Ingenhousz, John Hunter, Cavendish, Bancroft, Spallanzani, Williamson, Humboldt, Gay Lussac, Geoffroy, J. T. Todd, and Dr. John Davy, have all laboured in the same field of inquiry.

power. No irritation has ever produced a discharge after death. The intensity of the electrical power seems to bear no relation to the size of the fish, at least after it has attained mature age; small fish are almost always actively electrical.

The torpedo sometimes bears great irritation, even the firm grasp of a hand, without discharging. In these circumstances it writhes and twists itself about for some time, using strong efforts to escape, before it emits its electricity. In a few instances it has been found impossible by any means to excite even vigorous torpedos to discharge. Both Lacépède and Réaumur handled and irritated the most lively torpedos, even while yet in their native element, without experiencing any shock. But generally the shocks are stronger when the skin of the fish is in any way irritated. All electrical fishes soon become exhausted and die, even in sea-water, when they are excited to give a continued succession of discharges. But fishes much exhausted by frequent discharges recover their electrical energy after a few hours' rest. The torpedo seems to possess electrical power even in the earliest periods of its existence. Spallanzani relates that he found within a female torpedo two living fœtuses, which gave distinct shocks on being removed from their coverings. Dr. Davy, also, once received a sharp although not a strong shock, in extracting fœtal fish from the uterine cavities of a dying torpedo.

When the Gymnotus is grasped by the hand, the intensity of the discharge is moderate at first, but is increased if the pressure be continued. The torpedo discharges whenever it is taken out of the water; and Walsh found that a vigorous fish repeats the discharge as often as it is lifted out, and again on being re-immersed; also that it gives more violent shocks in air than in water. Spallanzani found the shock to be more severe when the fish was laid on a plate of glass. The following observation, reported by Walsh, seems to prove that the Gymnotus can distinguish at some distance between substances capable of receiving and conducting its discharge, and those which cannot conduct; and that (excepting when it is much irritated) it discharges only when conducting bodies are presented to it. Two wires were put into the water of the vessel in which a Gymnotus was swimming; these wires were of some length, and stretched; they terminated in two glasses filled with water placed at a considerable distance from each other. Whilst the apparatus remained in this state, and the circulation was of course interrupted, the animal did not prepare to exercise his power, but whenever any conducting substance filled the interval, and rendered the circle complete, it instantly approached the wires, arranged itself, and gave the shock.

The same fish, according to the observations of Messrs. Humboldt and Bonpland, appears to have the power of transmitting its discharge in any direction it pleases, or towards the point where it is most sharply irritated; and further, it seems to be able to discharge, sometimes rom a single point, at other times from the whole of its surface. Dr. Davy has satisfied himself that the Torpedo also has the power of discharging its electricity in any direction it chooses.

The shock produced by the discharge of the Gymnotus is most severely felt when one hand seizes the head and the other the tail. When two persons take hold of a Gymnotus, the one by the head or by the middle of the body, and the other by the tail, both standing on the ground, shocks are felt, sometimes by one alone, sometimes by both. It has been observed that when metals are placed in the vessel or pond containing a Gymnotus, the fish appears much agitated, and discharges very frequently.

II. *Motions of the fish in the act of discharging.*—These have been particularly observed only in the Torpedo and Gymnotus. At the time of discharging, according to some observers, the Torpedo generally becomes somewhat tumid anterior to the lateral fins, retracts its eyes within their orbits, and moves its lateral fins in a convulsive manner. When the fish begins to lose its plumpness, after having given frequent shocks, "a little transient agitation" is perceptible along the cartilages which surround the electrical organs at the time of the discharge. Dr. Davy, however, states that he has never seen the Torpedo of the Mediterranean retract its eyes at the time of discharging; and that he has not been able to associate any apparent movement of the fish with the electrical discharge.

The Gymnotus sometimes emits the strongest discharges without moving any part of its surface in the slightest perceptible degree. But, at other times, it seems to arrange itself so as to bring the side of its body into a parallel with the object of its attack before discharging. When a small fish is brought near a Gymnotus, it swims directly up to it, as if about to seize it; on approaching close, however, it halts, seems to view the fish for a few seconds, and then, without making the smallest movement discoverable by the eye, emits its discharge; should the small fish not be killed by the first, the Gymnotus gives a second, and a third shock, until its object is accomplished. It continues to kill a large number in close succession, if they be supplied to it, but it eats very few.

III. *Physiological effects of the discharge.*—The effects of the discharge on man vary according to its intensity and the extent of the surface of the fish which is touched. A vigorous torpedo causes a momentary shock, which is felt through the arm even as far as the shoulder, and leaves a degree of painful numbness in the finger and hand, continuing for a few seconds, and then going off entirely. Some observers have compared the sensation produced to that felt in the arm when the elbow is struck so as to compress strongly the ulnar nerve; and others (even such as have been much accustomed to receive electric shocks) have declared the sensation to be extremely painful; Gay Lussac and Humboldt say that it is more so than the shock produced by the Leyden phial; and Configliachi compares it to that caused by the contact of two poles of the voltaic pile. Ingenhousz thus describes his sensations under the discharge of the torpedo. "I took a torpedo in my hand, so that my thumbs pressed gently on the upper surface of the lateral fin, whilst my forefingers pressed the opposite side. About one or two minutes after I felt a sudden trembling in my thumbs, which extended no further than my hands; this lasted about two or three seconds. After some seconds more, the same trembling was felt again. Sometimes it did not return in several minutes, and then came again at very different intervals. Sometimes I felt the trembling both in my fingers and my thumb. These tremors gave me the same sensations as if a great number of very small electrical bottles were discharged through my hand very quickly one after the other. Sometimes the shock was very weak, at other times so strong that I was very near being obliged to quit my hold of the animal."* Walsh ascertained that the same torpedo has the power of discharging in two different manners, so as to produce at one time the effect described by Ingenhousz as a trembling, and at another time a sharp instantaneous shock closely resembling that produced by the discharge of a Leyden phial.† According to Sir H. Davy, "whoever has felt the shocks both of the voltaic battery and of the torpedo must have been convinced, as far as sensation is concerned, of their strict analogy."‡

Sometimes the torpedo buries itself in the sand left dry at ebb-tide; and it has occasionally happened, according to some naturalists, that persons walking across the sand, and treading upon the spot beneath which the electrical fish lay concealed, have received his discharge so fully as to be thrown down.§

The effects produced by the discharge of the Gymnotus are more severe. When it is touched with one hand, a smart shock is generally felt in the hand and fore-arm; and, when both hands are applied, the shock passes through the breast. The discharges of large fish (they grow to the length of twenty feet in their native rivers) sometimes prove sufficient to deprive men, while bathing, of sense and motion. Fermin found that a strong one had power to give a shock to fourteen persons at the same time; and other experimenters have seen twenty-seven persons simultaneously receive its shock. Humboldt states that, having placed his feet on a fresh Gymnotus, he experienced a more dreadful shock than he ever received from a Leyden phial, and that it left a severe pain in his knees and in other parts of his body, which continued for several hours. Sometimes the discharge occasions strong contractions of the flexor muscles of the hand which grasps the fish, so that it cannot be immediately let go; and then, the shock being repeated still more severely, painful sensations are experienced thoughout the whole body, and headache with soreness of the legs remains for some time after.* Paralytic affections, as well as giddiness and dimness of sight, are said sometimes to have followed the reception of strong discharges.† It is stated by some observers that there are men who are as insusceptible of the shocks of electrical fishes as others are of those from the Leyden phial; and that women affected with nervous diseases are seldom conscious of receiving the discharge. Kæmpfer asserted‡ that, by suppressing respiration for a short time, any man may render himself insensible to the torpedo's discharge; but this has been disproved by Walsh and other observers.

Regarding the effects of the discharges of the other electrical fishes, we know very little. The shock given by the Malapterurus of the Nile and Niger (Silurus, *Linn.*) is said to be more feeble than that of the Torpedo, and yet very painful, attended with trembling, and followed by soreness of the limbs. In attempting to take an individual of Tetraodon electricus in his hand, Lieutenant Paterson (its discoverer) received so severe an electrical shock that he was obliged to quit his hold.

The effects of the discharge of the Gymnotus on the larger animals cannot be better illustrated then by the account which Humboldt has given of the method of capturing the fish adopted by the South American Indians. This method consists in irritating the fish by driving horses into the pools which it inhabits. It directs its electricity in repeated discharges against these horses until it becomes exhausted, when it falls an easy and harmless prey into the hands of the fishermen. Humboldt saw about thirty wild horses and mules forced into a pool containing numerous Gymnoti. The Indians surrounded the banks closely, and being armed with harpoons and long reeds, effectually prevented the escape of the horses. The fishes were aroused by their trampling, and, coming to the surface, directed their electrical discharges against the bellies of the intruders. Several horses were quickly stunned, and disappeared beneath the surface of the water. Others, exhibiting signs of dreadful agony, hurried to the bank, with bristled mane and haggard eye, but

* Phil. Trans. 1775, 2.
† Phil. Trans. 1773, 467.
‡ Phil. Trans. 1829, 15.
§ The experience of Dr. Davy would lead us to call in question the possibility of such an occurrence; for he has always found it necessary to touch the opposite surfaces of the electrical organs or organ to receive the torpedo's shock. He has irritated torpedos very frequently by pressing with the finger on different parts of the back, but however much the fish were irritated he never had any sensation referrible to the passage of the electricity. In corroboration of his opinion that the fish cannot give a shock excepting the two opposite surfaces of its electrical organs be connected by conductors, Dr. D. states that when one surface only is touched and irritated, the fish themselves appear to make an effort to bring, by muscular contraction, the border of the other surface into contact with the offending body. This is done even by fœtal fish. Phil. Trans. 1834.

* Bryant, Trans. Amer. Soc. ii. 167.
† Flagg, do. ii. 170.
‡ Amœn. Exot. 514.

there they were met by the wild cries and violent menaces of the Indians, which forced them again to enter the water. And when, at last, the survivors were permitted to leave the pool, they came out enfeebled to the last degree, and their benumbed limbs being unable to support them, they stretched themselves out upon the sand completely exhausted. In the course of five minutes two horses were drowned. By degrees, the discharges from the Gymnoti becoming less intense, the horses no longer manifested the same signs of agony, and the wearied fishes approached the margin of the pool, almost lifeless; and then they were easily captured by means of small harpoons attached to long cords. The fishes left in a pool thus disturbed were found scarcely able to give even weak shocks at the end of two days from the time of their combat with the horses. Humboldt concluded from what he saw and heard, that the horses which are lost in the course of this singular fishery are not killed, but merely stunned, by the discharge. Their death is occasioned by the consequent submersion.

In this way many mules are destroyed in attempting to ford rivers inhabited by the Gymnotus. So great a number of mules were thus lost within the last few years at a ford near Uritucu, that the road by it was entirely abandoned. When small fishes receive the discharge of a Gymnotus, they are immediately stunned, turn upon their backs, and remain motionless. They however, for the most part, recover after being removed to another vessel. Reaumur reports that he once saw a duck killed by the repeated discharges of a torpedo; but both Ingenhousz and Dr. John Davy kept small fishes in the same vessel with torpedos, without observing that the former showed any symptoms of suffering from the shock of the latter. Humboldt saw one Gymnotus receive the discharge of another without giving any evidence of feeling it. Galvani, having placed some frogs' thighs, skinned, on the back of a torpedo, saw them convulsed when the fish was excited to discharge.

It is said that the discharge of the torpedo is used medicinally by the Arabians of the present day, particularly in fevers. The patient is placed naked on a table, and the fish applied to all the members of the body in succession, so that each should receive, at least, one shock. This treatment causes rather severe suffering, but enjoys the reputation of being febrifuge.

IV. *Magnetical effects of the discharge.*—Schilling asserted that he had seen the magnetic needle set in motion by the discharge of a Gymnotus;* also, that the fish was attracted by a magnet, and adhered to it; and that it became so languid when detached from the magnet, that it gave no shock when irritated. Ingenhousz, Spallanzani, Flagg, Humboldt, and Bonpland obtained no such results in repeating the experiments of Schilling. Professor Hahn of Leyden suggests that the fish examined by Schilling may have been coated with particles of ferruginous sand, which frequently forms the beds of the American rivers inhabited by the Gymnotus; and that these, adhering to its glutinous skin, may have given rise to the phenomena observed by Schilling. In quoting the contradictory statements of the above-mentioned observers, Treviranus remarks,* "it is a striking circumstance that so good an observer as Schilling was should have been convinced that he saw such magnetic phenomena in connexion with the fish, and still more remarkable is it that Humboldt and Bonpland should have found a belief in the possession of magnetic properties by the Gymnotus prevalent amongst the inhabitants of the Savannas of Caraccas."

Sir Humphry Davy passed many strong discharges from a torpedo through the circuit of an extremely delicate magnetic electrometer, without perceiving the slightest deviation of, or effect on, the needle. He explained this negative result by supposing, that the motion of the electricity in the organ of the torpedo is in no measurable time, and that a current of some continuance is necessary to produce the deviation of the magnetic needle.† Under more favourable circumstances than those in which Sir H. Davy investigated the properties of the electricity of the torpedo, Dr. John Davy resumed the enquiry at Malta, and ascertained, in the most satisfactory manner, that animal electricity *is* capable of producing magnetic effects. He not only saw the needle of a magnetic electrometer very much affected by the discharge of a torpedo, but he found needles, previously free from magnetism, converted into magnets by the same. In one experiment, he placed eight needles within a spiral, formed of fine copper wire, one inch and a half long, and one tenth of an inch in diameter, containing about one hundred and eighty convolutions, and weighing four grains and a half. A single discharge from a torpedo, six inches long, having been passed through this, the contained needles were all converted into magnets, each one as strong as if only one had been used. It was found that the ends of the needles which were nearest the ventral surface of the fish had received southern polarity, and of course the other extremities northern polarity. The discharges from fish, only four hours after they were taken from the uterine cavities of their mother, were sufficiently strong to magnetize needles through the medium of a spiral, although but feebly. The same kind of result was obtained with the multiplier; the needle of which, when subjected to a torpedo's discharge, indicated that the electricity of the dorsal surface corresponded with that of the copperplate of the voltaic pile, and the electricity of the ventral surface with that of the zinc plate.

In 1827, before Dr. Davy performed his experiments, similar magnetic effects were observed by means of the multiplier, by MM. De Blainville and Fleuriau, at La Rochelle. They

* Mém. de l'Acad. de Berlin, 1770.

* Biologie, v. 145.

† Phil. Trans. 1829. 16. Similar experiments were made with the discharge of the Gymnotus by Messrs. Rittenhouse and Kinnersly with the same results. They saw no effect produced on the electrometer. Philadelphia Med. and Phys. Journal, i. 15.

thrust into the electrical organ of a torpedo the two needles which terminate the wires of Schweigger's multiplier, and immediately saw the magnetic needle describe more than half a revolution.*

V. *Chemical effects of the discharge.*—It does not appear that any observer before Sir H. Davy attempted to ascertain what chemical effects the discharge from electrical fishes is capable of producing. But Sir Humphry obtained only negative results. He passed the shocks of the torpedo through the unterrupted circuit made by the silver wire through water, without being able to perceive the slightest decomposition of the water.† Dr. John Davy, however, has obtained decisive evidence of chemical agency being exerted by animal electricity. The fishes which he made use of in his experiments were more recently taken from the sea, and were, consequently, more vigorous than those which were the subjects of Sir Humphry's observations; and it was, probably, owing to this circumstance that the results which he obtained were different from those of his brother's experiments.

By means of golden wires, one of which was applied to the upper surface of the fish, and the other to its under surface, Dr. Davy passed the discharge from a torpedo through solutions of nitrate of silver, common salt, and superacetate of lead, and found that all were decomposed. The decomposition of the superacetate of lead was effected only when the fish seemed to put forth all its energy, after being much irritated.‡ From the solution of nitrate of silver, the metal was precipitated only on the wire connected with the ventral surface of the fish. When platina wires were used, and plunged into nitric acid, gas was given off only from that in connexion with the dorsal surface. A solution of iodide of potassium and starch having been subjected to the discharge conveyed along the platina wires, had the iodine in combination with the starch precipitated from it on the wire from the upper surface.§ By the same discharges which produced these chemical effects, the needle in the galvanometer was moved, the spirit in the air-thermometer was raised, and needles in the spiral were magnetized.

VI. *Results of experiments on the transmission of the discharge through various conducting bodies.*—Almost all bodies which are conductors of common and voltaic electricity conduct also the discharge of electrical fishes; and those which are non-conductors with regard to the former are the same with regard to the latter. But the discharge of the torpedo, when feeble, does not pass along even good conductors; and this circumstance has given rise to some discrepancy between the statements of different observers. Walsh received the torpedo's discharge through iron bolts and wet hempen cords. The French fishermen declare that they sometimes receive shocks through nets, while the fish is twelve feet distant from their hands. But Humboldt and Gay Lussac state that they received no shock when they touched the fish with a key or any other conducting body;* further, that when they placed the fish upon a metallic plate, so that the inferior surface of its electric organ touched the metal, the hand which supported it felt no shock: and they concluded from their experiments that the torpedo could not transmit its discharge through even a thin layer of water; although they found that when two persons applied each one hand to the fish, and completed a circuit through their own bodies by means of a pointed piece of metal held in the other hand, and plunged into a little water placed upon an insulating body, both felt the shock. In one instance Dr. Davy received the torpedo's shock through water, but his hand was within a very short distance of the fish. Walsh transmitted the torpedo's discharge through a chain of eight persons, who communicated with one another only by water contained in basins, in which their hands were immersed. And the same observer also found that when a torpedo was touched with a single finger of one hand, while the other hand was held in the water at some distance, shocks were distinctly felt in both hands. Numerous observations made on the Gymnotus leave no doubt with regard to the passage of its discharge through water. If a person hold his finger in the water several inches (some say even ten feet) distant from the fish, and another person touch it, both receive shocks equally severe. Dr. Williamson found that a person holding his finger in a stream of water, running from a hole made in the bottom of a wooden vessel in which a Gymnotus was swimming, very distinctly felt all the discharges given by the fish. The discharge from the Gymnotus passes through a chain of ten persons, so that they all seem to feel the shock in the same degree. It is conducted by iron rods several feet in length. It does not pass through air, interposed between metallic conductors, until these are brought within about one-hundredth of an inch of each other.

So far as they have been examined, the phenomena presented by the discharge of the Silurus have been found to be nearly the same as those just detailed.

VII. *The production of a spark, and evolution of heat.*—No observer has hitherto seen light emitted from the body of any electrical fish at the time of the discharge; but, by artificial arrangements, some have succeeded in producing sparks in the course of the circuit described by the discharge. In 1792, Gardini saw a spark from a torpedo's discharge, in the course of his repeating some of Walsh's experiments. And in 1797, Galvani obtained a small spark, visible only with the aid of a lens, from a torpedo; but it does not appear that any other observer has been equally successful with regard to this fish. Very recently, Dr. Davy has directed his attention particularly to this point, and, although he used active fish, and took

* Pouillet, Elem. de Phys. i. 773.
† Phil. Trans. 1829.
‡ Phil. Trans. 1832.
§ Phil. Trans. 1834.

* Ann. de Chimie, t. lxv. 15.

every possible precaution, he could neither, in the light, detect the slightest indications of the passage of electricity through even very small intervals of air, nor observe a spark in the dark. He was equally unsuccessful in using an electroscope formed on the principle of Coulomb's, which displayed sparks when touched either with a small rod of glass slightly excited, or of sealing-wax. He varied the trials, using highly rarefied air at ordinary temperatures, and also condensed air deprived of moisture, with the same negative result. He insulated the fish on a plate of glass, wiped its margin dry, and besmeared it with oil, but no spark could be procured.

Dr. Davy was more successful in obtaining indications of the evolution of heat during the torpedo's discharge. He used Harris's electrometer, and saw proof of an elevation of temperature in the motions of the fluid in the air-thermometer; thus corroborating the prediction of Dr. Faraday, who was previously convinced that, by means of this instrument, the evolution of heat by animal electricity would be made evident. Dr. Davy made several experiments with the view of ascertaining whether very fine platina wire might not be ignited in the passage of the electricity of the torpedo, but never witnessed the expected effect. Upon this he remarks, "This want of ignition may, at first view, seem contrary to the effect on the thermometer; but perhaps it ought not to be considered so, taking into account the rapid manner in which the heat evolved in the fine platina wire must be carried off by the adjoining compound wire of platina and silver."*

From the discharge of the Gymnotus, Walsh, Fahlberg, Guisan, and other observers of the last century, obtained sparks. Walsh attached a thin sheet of pewter to a plate of glass, cut a very fine slit in it, and then passed the discharge along the metallic sheet, the fish being at the time out of the water. A spark was very distinctly seen at the margins of the slit. Fahlberg of Stockholm used the same kind of apparatus, but with gold leaves instead of pewter, and placed the margins of these about *a line* apart. Dr. Williamson fixed two brass rods in a frame, and brought their points to within one-hundredth of an inch of each other, but, although the discharge of the gymnotus passed from one rod to the other through the intervening air, there was *no spark*. Humboldt watched an active Gymnotus for a long time during the night, and irritated it so as to obtain from it many sharp discharges, but he saw no spark.

VIII. *Results of experiments in which the nerves, electrical organs, and other parts were mutilated.*—The general result of these experiments is, that destruction of the communications between the electrical organs and the nervous centres is followed by annihilation of the power of discharging.

According to Mr. Todd, (whose experiments were made on the torpedo at the Cape of Good Hope,) it is necessary to cut through *all* the nerves going to the electrical organs to destroy

* Phil. Trans. 1834.

their peculiar powers. He cut through all on one side, and some on the other, but still shocks were given. He also lacerated the organs themselves extensively, without destroying the discharging power. Mr. Todd found that fishes in which all the electrical nerves had been cut appeared more vivacious after the operation than before it, and actually lived longer than others not so injured, but which were excited to discharge frequently.*

In repeating Mr. Todd's experiments, Dr. Davy obtained very similar results; but he mentions that "when a small portion of brain was accidentally left, contiguous to the electrical nerves of one side, and with which they were connected, the fish, on being irritated, gave a shock to an assistant, who grasped the corresponding electrical organ."†

Spallanzani found that the torpedo loses its power of giving shocks after the aponeurotic covering of the electrical organs is removed; but that the cutting out of the heart does not lessen this power until the animal life begins to suffer from the loss of blood.

Humboldt cut a Gymnotus through the middle of the body transversely, and found that the anterior portion alone continued to give shocks.

Experiments of this kind have not yet been performed on the Silurus; but, judging from the structure of the organs in this fish, we have every reason to expect that the results of such experiments on it would be the same. While we would not be understood to sanction the *wanton* repetition of experiments such as these, which cannot but be productive of much suffering to the subjects of them, we must yet repeat here the suggestion recently made by Professor Müller of Berlin with regard to future experiments on the Gymnotus and Silurus. He points out how very desirable it is to ascertain whether the double organs of these fishes act as opposite electromotors, which might be determined by cutting out one organ from either side, and then exciting the fish to discharge. The same distinguished physiologist remarks that if he had an opportunity of experimenting on the torpedo, his first experiment should be, after having cut through the nerves going to the electrical organs, to irritate their cut extremities, still in connexion with the organs, with mechanical and galvanic stimulants, with the view of discovering whether these would excite the organs to discharge their electricity.‡

IX. *Anatomy of the electrical organs.*—The experiments referred to in the former section sufficiently demonstrate that the manifestation of the peculiar power possessed by electrical fishes depends on the integrity of the connexion between their nervous centres and certain organs of a peculiar structure, which have been named the electrical organs. These have been particularly examined in the Torpedo, Gymnotus, and Silurus, by several anatomists, and no doubt is entertained that they, together

* Phil. Trans. 1816.

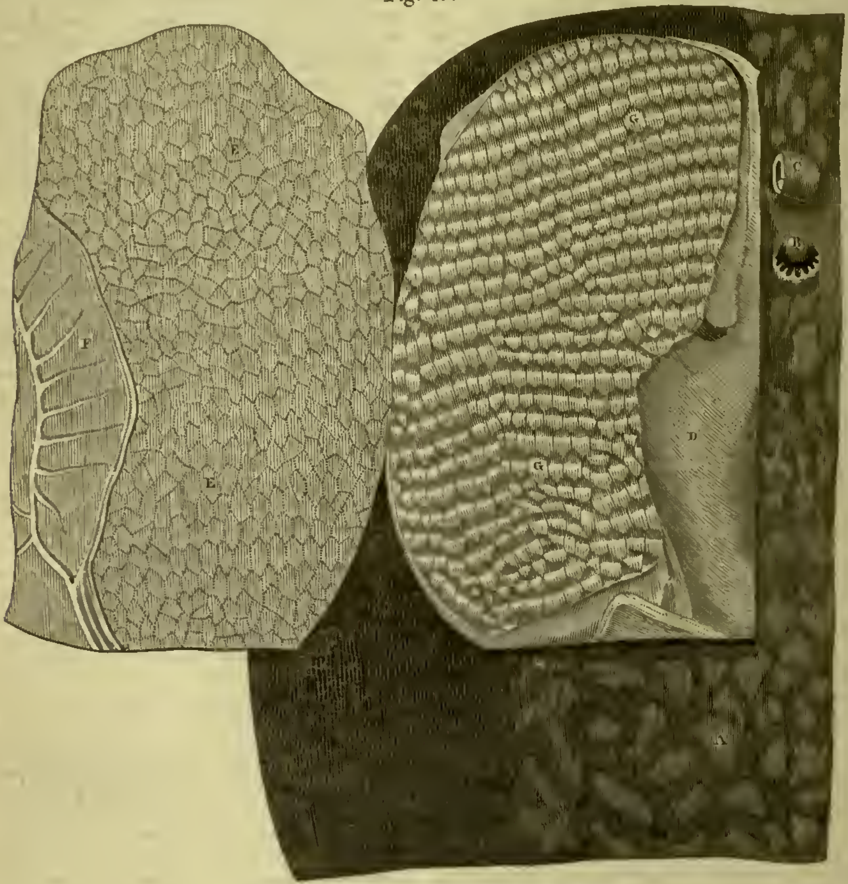
† Phil. Trans. 1834. 120.

‡ Handbuch der Physiol. des Menschen. Coblenz. 1833.

with their large nerves, are the sole means employed in bringing this mysterious agent under the control of the animal's volition. They are therefore well worthy of an attentive examination.

1. *The electrical organs in the torpedo.*—The torpedo is a flat fish, possessing the same general appearance and structure as the rays, and classed along with them in zoological systems. The electrical organs occupy a large part of the broad expansions of the body, which in the other allied fishes are formed only by the lateral fins. They form two separate masses, one on either side of the head and gills, extending outwardly to the cartilaginous margins of the great fins; and, posteriorly, to the cartilage which separates the thoracic from the abdominal cavity. Their form and the honey-comb embossments of their surfaces can be distinguished through the skin both of the dorsal and ventral aspects. The common integuments being removed, two strong fascial coverings are discovered investing the electrical organs. The outer one has longitudinal fibres, which are rather loosely adherent, and, around the margins of the organs, seem to inosculate with the skin. The inner fascia is of considerable density, forms the immediate tunic of the electric columns, and sends processes down between them to form their partitions. Throughout their whole extent, the essential part of the electrical organs is formed by a whitish soft pulp, divided into numerous pentagonal prisms by the fascial processes just mentioned. These lie close together, parallel with one another, and perpendicularly between the dorsal and ventral surfaces of the fish, so that their extremities are separated from these surfaces only by their fascial and the common integuments. When these are removed, the columns present something of the appearance of a honey-comb. The columns are longest next to the head and gills, and thence gradually diminish outwardly, until, on the external margin, they are only

Fig. 47.



Upper surface of electrical organ of left side.

A, common integuments. B, branchial opening. C, eye. D, situation of the gills. E E, skin dissected off from the electrical organ, and turned outwards. F, part of the skin which covered the gills. G G, the upper surface of electrical organ.

about one-sixth of the length of the internal ones. In a fish described by John Hunter,* of which the whole electrical organ was about five inches in length, the longest column was about one inch and a half, and the shortest about one-fourth of an inch in length. In the same fish the average diameter of each column was about two-tenths of an inch. In a fish from the Mediterranean, thirteen inches and a half in length, and about seven inches in breadth, (which, through the kindness of Dr. Allen Thomson, we have had an opportunity of examining in detail,) the length of the longest columns is one inch, and that of the shortest about three-tenths of an inch. Most of these columns are either irregular pentagons, or irregular hexagons; a few are nearly tetragonal. They are united to one another by short but strong fibres, and by a reticular expansion of tendinous threads spread through them. Their number varies considerably according to the age of the fish. Hunter conjectured that a few new columns are added every year to the circumference of the organ. In one of the largest fish that has yet been particularly examined, which was four feet and a half in length, the number of columns in one electrical organ was 1182. Mr. Hunter found 470 in each organ in a fish of ordinary size. Mr. Hunter described each column as being divided into numerous distinct compartments by delicate membranous partitions, placed horizontally, at very short distances from each other. The interstices between them appeared to him to contain a fluid. He found the partitions in several places adhering to one another by bloodvessels; and all, throughout their whole extent, attached to the inside of the column by a fine cellular membrane. In a column of one inch in length, he reckoned 150 partitions, and it appeared to him that their number is the same within the same space in all the columns.† Hence, he thought it likely that "the increase in the length of a column, during the growth of the animal, does not enlarge the distance between each partition in proportion to that growth, but that new partitions are formed and added to the extremity of the column from the fascia."

The partitions are covered with fine network of arteries, veins, and nerves. According to Hunter, "they are very vascular." He described the numerous arterial branches which ramify on the walls of the columns as "sending inwards from the circumference all around, on each partition, small arteries which anastomose upon it, and passing also from one to the other, unite with the vessels of the adjacent partitions." The partitions themselves are so delicate as not to admit of being satisfactorily examined in the fresh fish: (all Hunter's observations were made upon fish that had been preserved in spirits, by which, doubtless, the delicate membranes were rendered more opaque, and therefore more easily visible.) In point

* Phil. Trans. 1773, 481.

† Desmoulins and Majendie say that they found only seven or eight partitions in each column. Anat. des Syst. Nerv. ii. 378.

of fact, Dr. Davy has never seen them in the course of the numerous dissections which he has made of the electrical organs in fish recently taken; whereas, in specimens sent hither by him, preserved in spirits, Dr. Allen Thomson and the writer of this article have satisfactorily ascertained their existence and structure as described by Hunter. Dr. Davy says, "when I have examined with a single lens, which magnifies more than 200 times, a column of the electrical organs, it has not exhibited any regular structure; it has appeared as a homogeneous mass, with a few fibres passing into it in irregular directions, which were probably nervous fibres."* However, after having immersed the organs in boiling water, Dr. Davy has occasionally seen something like a laminated structure within the column. Rudolphi satisfied himself of the division of the columns by membranous partitions, and further, that each partition is supplied with a distinct nerve.† In a memoir on the comparative anatomy of the Torpedo, Gymnotus, and Silurus, Geoffroy described ‡ the columns as being filled with a semifluid matter composed of gelatine and albumen.

A large quantity of fluid enters into the composition of the general mass of the electrical organs. Dr. Davy has found that they lose more by drying than any other part of the fish—nearly 93 per cent.; while the soft parts in general, including the electrical organs, lose only 84.5 per cent.§ He believes that the fluids of the organs hold various substances in solution, but the exact nature and proportions of them have not been ascertained. We are indebted to the same indefatigable observer for an account of the specific gravity of the electrical organs. He found it to be very low compared with that of the truly muscular parts of the fish,—namely, 1.026, to water as 1.000, while that of a part of the abdominal muscles of the same full-grown fish was 1.058, and of the dorsal muscles 1.065. In a fish eight inches long, five inches across the widest part, and which weighed 2065 grains entire, the electric organs together weighed 302 grains, the liver only 105 grains.

No contraction has ever been seen in the electrical organs of living fish under the stimulus of the strongest excitants, not even under that of galvanism; so that, although what appear to be tendinous threads are spread amongst and over the columns, we have no reason to suppose that any muscular tissue enters into their composition. But, in all directions, they are exposed to the pressure of

* Phil. Trans. 1832. 259.

† Abhandl. der Acad. der Wissensch. in Berlin. 1820. 224.

‡ Ann. du Mus. No. 5.

§ The smallest torpedo employed by Dr. Davy in his experiments weighed 410 grains, and contained only 48 grains of solid matter; its electrical organs weighed 150 grains, and contained only 14 grains of solid matter; yet this small mass gave sharp shocks, converted needles into magnets, affected distinctly the multiplier, and acted as a chemical agent. "A priori, how inconceivable that these effects could be so produced!"

strong muscles, such as are plainly designed to compress them. Some of these are inserted into the marginal cartilages of the fins; and there is a set of very powerful ones, arranged in a cruciform manner on the ventral surface, so placed as to compress the electrical organs most strongly during their contraction. Dr. Davy remarks, "It is only necessary to compare these muscles as they exist in the torpedo with the same in any other species of ray to be convinced that they are adequate to, and designed for, the compression of the batteries."

Some observers, as John Hunter, state that a large proportion of blood circulates through the electrical organs. Girardi found the torpedo much more full of blood than the other rays.* But Dr. Davy says, that there are very few vessels containing red blood in the organs themselves; although their tegumentary coverings and the adjoining mucous system are highly vascular. The arteries of the organs are branches from the arteries of the gills; their veins run between the gills direct to the auricle. The temperature of the electrical organs is not at all higher than that of other parts of the fish.

All anatomists who have examined the torpedo have had their attention much arrested by the great size of the nerves distributed to the electrical organs. These consist of three principal trunks, all arising immediately from the cerebro-spinal system. The two anterior trunks are regarded by Desmoulins and Majendie † as portions of the fifth pair of nerves, and the third as a branch of the eighth pair. But the first electrical nerve seems to have an origin altogether distinct from the root of what is unquestionably the main portion of the fifth pair, although it certainly is in very close proximity with it, and, in passing out of the cranium, the two nerves seem to be in some degree united for a short space. Immediately beyond this point of union, the electrical nerve sends a soft twig to a small cavity within the adjoining cartilage, (which Dr. Davy thinks is the ear,) and then divides into three small branches, and two large ones. One of the small branches goes to the gills, another to the neighbouring muscles, and the third to the mouth. The first of the large branches runs along the outer margin of the electrical organ, advancing first anteriorly, then going round to the posterior part of its circumference, and losing itself in the mucous glands of the tegumentary system, without sending a single twig into the electrical organ itself. The other great branch is inferior to the former in position, but much more voluminous; it enters the electrical organ, and is ramified through its anterior third part, passing between its columns, and giving off numerous twigs for the supply of the walls of the columns, and the partitions, on which it terminates; some of which pass even into the gelatinous matter with which the columns are filled. This branch, from its very origin, has all its fibres separated, isolated, and parallel, held together only by cellular tissue, which also forms a kind of membranous sheath around the nerve. Just as it reaches the organ, it is divided horizontally into two portions, one of which runs near the upper surface, the other on the plane between the lower and middle thirds of the thickness of the organ.

When examined with a high magnifying power, the minute branches of the electrical nerves present a dotted appearance, showing as if the medullary substance were arranged within the sheath, not in a continuous line, but in a succession of small portions with a little space between each.*

The second electrical nerve rises a little behind the former. After leaving the cranium, it divides into two large branches, which, with the exception of a few twigs which go to the gills, are wholly distributed in the middle third of the electrical organs, in the same manner as the first pair.

The third electrical nerve arises from the brain close to the second, from which, however, it is separated by a thin cartilaginous plate. The greater portion of it goes to the electrical organ, and is distributed through its posterior third. It also supplies part of the gills, the gullet, the stomach, and the tail. Dr. Davy says it appeared to him that the branch of this nerve which goes to the stomach is the principal nerve of that organ: it is spread over its great arch.† The same observer also points out as deserving of particular attention, a very large plexus of nerves formed by a union of the anterior and posterior cervical nerves, of the former of which there are seventeen on either side, and only fourteen of the latter. This plexus presents itself as a single trunk just below the transverse cartilage that divides the thoracic from the abdominal cavity. It sends a recurrent branch to the muscles and skin of the under surface of the thorax; but the larger portion is distributed upon the pectoral fin and the neighbouring parts. The motive and sentient powers of the muscles and integuments connected with the electrical organs seem to depend on this plexus.

The only other peculiarity of structure in the torpedo which can be supposed to be in any way connected with its electrical power, is in the system of mucous ducts, which is much more fully developed in it than in any other ray with which we are acquainted. It consists of numerous groups of glands arranged chiefly around the electrical orgaos; and of tubes connected with these, having strong and dense coats, filled with a thick mucus secreted by the glands. The tubes open chiefly on the dorsal surface of the skin, and pour out the mucus,

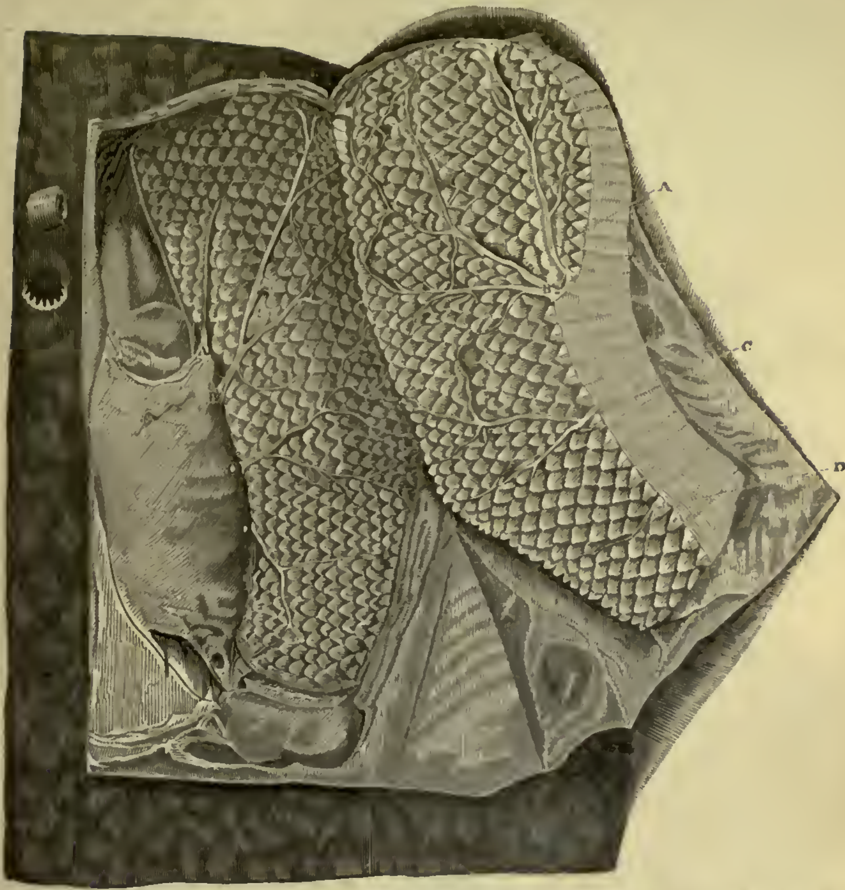
* Mem. della Soc. Ital. iii. 553.

† Anat. Comp. des Syst. nerv.

* Dr. John Davy, Phil. Trans. 1834.

† On this subject, Dr. Davy remarks—"It is an interesting fact that the nerves of the stomach are derived from those supplying the electrical organs. Perhaps superfluous electricity, when not required for the defence of the animal, may be directed to this organ to promote digestion. In the instance of a fish which I had in my possession alive many days, and which was frequently excited to give shocks, digestion appeared to have been completely arrested; when it died, a small fish was found in its stomach, much in the same state as when it was swallowed—no portion of it had been dissolved."

Fig. 48.



The right electrical organ divided horizontally at the place where the nerves enter, the upper half being turned outwards.

A A, The first or anterior electrical nerve.
B B, The second or middle nerve arising behind the gill.
C C, The anterior branch of the third nerve arising behind the second gill.
D D, The posterior branch of the third nerve arising behind the third gill.

which, probably, serves as a medium of communication between the electrical organs; being, apparently, a better conductor of electricity than either the naked skin or salt water.*

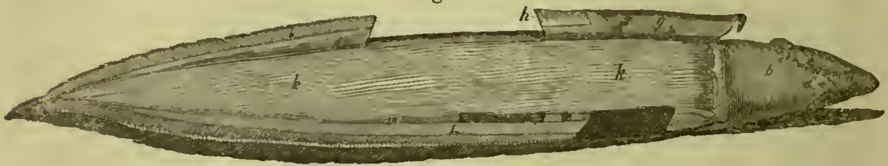
With regard to the development of the electrical organs, it appears that, in the earliest stages of fœtal growth, they cannot be seen. In a fœtus of about seven-tenths of an inch in length, Dr. Davy found neither electrical organs nor fins. In another, more than one inch long, the organs were beginning to appear, and the roots of the electrical nerves were visible, although the brain could not be seen. In this stage, the external branchial filaments were about six-tenths of an inch in length, and presented a very remarkable appearance. In a fœtus of two inches and a half long, the electrical organs were distinctly formed, and the branchial filaments still long. These filaments Dr. Davy supposes to be destined to absorb matter for the formation of the electrical organs, and, perhaps, the gills and adjoining mucous glands. They are most numerous and of greatest length while the electrical organs are forming, appearing just before these organs begin to be developed, and being removed when they are tolerably complete.—In no other allied fishes is there the same "elaborate apparatus of filaments;" where they do exist, they are less numerous and very much shorter.

2. *The electrical organs in the Gymnotus.*—This fish has a general resemblance in form to the common eel. Its electrical organs occupy nearly one-third of its whole bulk. They are formed by two series of tendinous membranes; one of which consists of horizontal plates, run-

* Davy, Phil. Trans. 1832. Also Annales du Mus. no. v., in which E. Geoffroy endeavoured to show that the common mucous system of rays is absent in the torpedo, and that its place is supplied by the columns of the electrical organs, which he believed to be analogous to the mucous ducts.

ning from the abdominal cavity towards the tail, placed one above another with short distances between them; the other of perpendicular plates, forming, along with the other series, small quadrangular cells, which are filled with a semi-gelatinous transparent substance. This structure is divided longitudinally into two pairs of distinct organs, one considerably larger than the other. The greater pair (*k k*, *fig.* 49) lies above the other, and immediately beneath the long muscles of the tail. They are separated from one another by part of these muscles, by the air-bladder, and by a central membranous partition. They occupy a large portion of the lower and lateral parts of the body, and are covered externally only by the common integuments. The smaller pair are covered also by the muscles of the caudal fin. Both pairs of organs are somewhat angular in their transverse section, truncated anteriorly, tapering towards the tail. In the Gymnotus dissected by John Hunter,* which was about two feet four inches long, the large

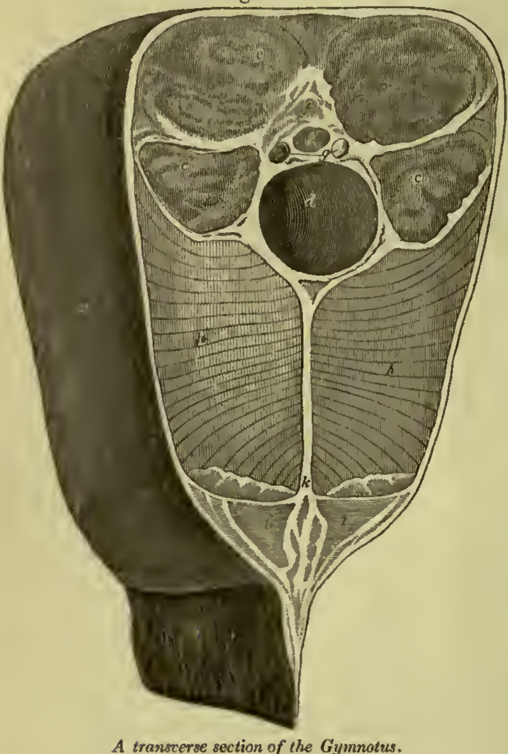
Fig. 49.



The surface of the electrical organs of the Gymnotus, on the right side, after removal of the integuments.

a, the lower jaw. *b*, the abdomen. *c*, anus. *d*, pectoral fin. *e*, dorsal surface of fish. *f f*, anal fin. *g g*, skin turned back. *h h*, lateral muscles of the anal fin turned back with the skin, to expose the small electrical organ. *i*, part of this muscle left in its place. *k k*, the large electrical organ. *l l*, the small electrical organ. *m m*, the substance which divides the large organ from the small. *n*, a space from which the partition is removed.

Fig. 50.



A transverse section of the Gymnotus.

a, the surface of the side of the fish. *b*, the anal fin. *c c*, cut ends of the dorsal muscles. *d*, cavity of the air-bladder. *e*, body of the spine. *f*, spinal marrow. *g*, aorta and vena cava. *h h*, cut ends of the two large electrical organs. *i i*, cut ends of the two small organs. *k*, partition between the two organs.

organ of one side was about one inch and one quarter in breadth at its thickest part, and in this space there were thirty-four longitudinal septa. (In a specimen examined by Dr. Knox, there were thirty-one of these septa.†) The smaller organ in the same fish was about half an inch in breadth, and contained fourteen septa, which were slightly waved. The perpendicular or transverse membranes are placed much more closely together than those of the other series. John Hunter and Dr. Knox counted two hundred and forty of them in an inch. They are of a softer texture than the longitudinal plates. It appears probable (as Hunter suggested) that these septa, longitudinal and transverse, answer the same purpose as the columns in the torpedo. Lacepède calculated that the discharging surface of these organs in a fish four feet in length is, at least, one hundred and twenty-three square feet in extent; while in a torpedo of ordinary size, the discharging surface is only about fifty-eight feet square.

The nerves of the electrical organs of the Gymnotus are derived from the spinal marrow alone. They are very large and numerous, and are divided into very fine twigs on the cells of the organs. Dr. Knox counted fifteen nervous branches distributed to each inch of the organ. He describes them as being flattened like the ciliary nerves of Mammalia. Each

* Phil. Trans. lxv. 1775.

† Edin. Journ. of Science, i. 96. 1824.

nerve is, for the most part, divided into five distinct branches before entering the electrical organs; and these are again subdivided into, at least, as many branches as there are longitudinal septa. Rudolphi describes a nerve formed from branches of the fifth pair and sympathetic, which runs beneath the lateral line, over the surface of the electrical organs, but does not enter them. This has, by some, been supposed to be an electrical nerve, but without sufficient reason.*

3. *The electrical organs in the Silurus.*—The only organ that can be regarded as connected with the electrical function in this fish is a thick layer of dense cellular tissue, which completely surrounds the body immediately beneath the integuments. So compact is it that, at first sight, it might be mistaken for a deposit of fatty matter. But, under the microscope, it appears to be composed of tendinous fibres, closely interwoven, the meshes of which are filled with a gelatinous substance. This organ is divided by a strong aponeurotic membrane into two circular layers, one outer, lying immediately beneath the corion, the other internal, placed above the muscles. Both organs are isolated from the surrounding parts by a dense fascia, excepting where the nerves and bloodvessels enter. The cells or meshes in the outer organ, formed by its reticulated fibres, are rhombic in shape, and very minute, so as to require a lens to see them well. The component tissue of the inner organ is somewhat flaky, and also cellular.

The nerves of the outer organ are branches of the fifth pair, which runs beneath the *lateral* line and above the aponeurotic covering of the organ. This aponeurosis is pierced by many holes for the transmission of the nerves, which are lost within the cellular tissue of the organ. The intercostals supply the inner organ: their electrical branches are numerous and remarkably fine.†

The organs of the other known electrical fishes have not yet come under the notice of any anatomist.

In taking a general view of these interesting organs, we are struck with the existence of a certain degree of analogy amongst them, and yet we fail to discover such resemblances as might be expected, and such as exist between the structures of other organs performing the same functions in different animals. Here we have tendinous membranes variously arranged, yet all so as to form a series of separate cells filled with a gelatinous matter. But how great is the difference between the large columnar cell in the torpedo full of delicate partitions, and the minute rhombic cells of the Silurus! All, however, are equally supplied with nerves of very great size, larger than any others in the same animals; and, indeed, we may venture to say, larger than any nerve in any other animal of like bulk.

The organs vary in different fishes; *first*, in situation relatively to other organs. They bound the sides of the head in the torpedo; run along the tail of the Gymnotus, and surround the body of the Silurus; *secondly*, in having different sources of nervous energy; and, *thirdly*, in the form of the cells. No other fishes have aponeuroses so extensive, or such an accumulation of gelatine and albumen in any cellular organ. Broussonet remarked that "all the electrical fishes at present known to us, although all belonging to different classes, have yet certain characters in common. All, for instance, have the skin smooth, without scales, thick, and pierced with small holes, most numerous about the head, and which pour out a peculiar fluid. Their fins are formed of soft and flexible rays, united by means of dense membranes. Neither the Gymnotus nor torpedo has any dorsal fin; the Silurus has only a small one, without rays, situated near the tail. All have small eyes."*

X. *Analogies of animal electricity.*—Setting aside the vague hypotheses of the older philosophers, (some of whom attributed the phenomena produced by the peculiar power of electrical fishes entirely to the mechanical effect of certain rapid motions of their surface, and others to the influence of currents of minute corpuscules flowing from the body of the fish in the act of discharging,) we can have no difficulty in referring this very remarkable series of phenomena to the agency of some power very analogous to common or voltaic electricity, which seems to stand in the same relation to these as they do to electricity derived from other sources.†

It was by Muschenbroek that the effects of the torpedo's discharge were first referred to electricity. He was led to imagine that the agent producing the shock was truly electrical from the similarity of its effects to those of the discharge of the Leyden jar. Succeeding observations, however, as we have seen, have shewn that certain differences exist between the phenomena produced by Animal Electricity and those observed in connexion with the discharge of the Leyden jar: the chief of these are—its passage through air only to a very small distance; its producing only very slight igniting effects even when considerably accumulated; and its manifesting but feebly the phenomena of attraction and repulsion. Further, it affects the multiplier more strongly than common electricity does under ordinary circumstances, and its chemical effects are more distinct. From voltaic electricity it is distinguished by the comparative feebleness of its power of decomposing water; by the greater sharpness of the shock caused by the discharge, and by the weakness of its magnetizing power.

Only four of the eight experimental effects enumerated by Dr. Faraday‡ as characteristic

* Abhandl. der Acad. v. Berlin, 1820-21. 229, and Blainville, Princ. d'Anat. Comp. i. 232.

† Rudolphi, (Abhandl. der Acad. v. Berlin. 1824.) 140.

* Mém. de l'Acad. de Paris, 1782. 693.

† It is interesting to know that the Arabic name of the torpedo (Rausch) means also *lightning*.

‡ Philos. Trans. 1833.

of common and voltaic electricity are produced by animal electricity; which appears to be sufficient to prove that the latter is as much a peculiar power distinct from these as are the agents called *magneto-electricity* and *thermo-electricity*. Perhaps, however, what we at present regard as so many powers differing from one another in their natures, may be merely modifications of the same power, varied in its sensible properties by changes in the circumstances under which they are manifested. This latter view is that taken by Dr. Wilson Philip, who holds that Animal Electricity is just common electricity modified in its properties by those of life, under the influence of which it operates in the living animal.

Sir Humphry Davy thought he saw a stronger analogy between common and animal electricity, than between voltaic and animal electricity, but concluded that the latter would be found by more extended researches than he was able to make to be "of a distinctive and peculiar kind."* Cavendish, on the other hand, believed that there is a complete identity between common electricity and that of fishes. And this he laboured to prove by imitating several of the peculiarities of the discharge of the torpedo by a particular arrangement of small Leyden jars, forming a battery, from which the electricity was discharged in large quantity but of low intensity.† Others, again, have attempted to trace a certain resemblance between the structure of the electrical organs of the torpedo and the formation of the voltaic pile, "inasmuch as they are formed of alternate layers of moistened conductors of different natures, to wit, of membranous partitions, and of gelatinous and albuminous fluid." (Tiedemann.) They suppose that the nerves, being spread over one side of the transverse partitions of the cells, produce opposite states of electrical tension on the two sides of the partition. In the present imperfect state of electrical science, all such hypotheses are unsatisfactory.

The only conclusions which, in our opinion, can be legitimately drawn from the accumulated facts on the subject are—that the shock given by electrical fishes is caused by an agent closely allied in its nature to common electricity and other like powers;‡ and that the developement and discharge of this agent are strictly dependent on the integrity of the nervous communication between certain peculiar organs and the great nervous centres.

It is evident that the nervous system plays a very important part in the electrical function. But whether its influence merely stimulates the electrical organs to do what their organic structure renders them capable of doing, or really supplies them with a stream of the imponderable agent which they accumulate, and then, under voluntary impulses, discharge, is still a point for further investigation. In the structure of the electrical organs, we do not see any arrangement such as researches in electricity artificially developed lead us to believe *fitted* either to produce or to accumulate electricity. But this is in itself no reason why we should conclude that the organs have not such powers. It seems more in accordance with what we know of the actions of other parts of the animal frame, to believe that they do possess such powers. But—if the electrical organs, by their organic structure, be fitted to develope and to discharge electricity under the nervous influence, just as a gland secretes its peculiar fluid and its ducts eject it, why (it may be asked) are the nerves going to these organs of so very great a size compared with the same parts in other organs of similar bulk and very energetic action? Is their subjection to the *will* of the animal sufficient to account for the difference? or does it indicate, as some physiologists maintain, that the nervous influence does more in this case than merely supply the vital stimulus such as is received by all other organs in common? In other words—is the agent discharged by the fish as electricity first developed in the nervous centres, and only accumulated in the electrical organs; and is this agent *identical* with common nervism? To these questions we cannot yet give a satisfactory reply. They point the way to some very interesting and important fields of investigation, and cheer us with the hope of considerably extending our acquaintance with the physiology of the nerves, on the supposition that the phenomena of animal electricity shall one day be proved to be owing to an accumulation and discharge of the very same agent that causes contraction of muscles, &c. Such a view appears to have been taken of this subject by Sir H. Davy when he remarked,* "there seems a gleam of light worth pursuing in the peculiarities of animal electricity,—its connexion with so large a nervous system,—its dependence on the will of the animal,—and the instantaneous nature of its transfer, which may lead, when pursued by adequate inquirers, to results very important for physiology." Treviranus, in 1818, suggested the likelihood of the power concerned in the manifestation of electrical phenomena by animals, being one of those on which continuance of life in general depends. "Perhaps," said he,† "it is the same power which enables the torpedo to give electric shocks that is the immediate cause of the contraction of muscular fibres." The same hypothesis is thus expressed by Carus.‡ "Numerous nerves are distributed upon the cells of the electrical organs, and as it is through the agency of

* Philos. Trans. 1829. 16.

† Philos. Trans. 1776. 196.

‡ The latest experiments on the subject, with which we are acquainted, are those of Messrs. Becquerel and Breschet, reported to the Academy of Sciences in October, 1835, (Ann. des Sciences Nat. n. s. iv. 253,) which seem to have been performed with great care. The experimenters completely satisfied themselves that the shock of the torpedo is the result of *an electrical discharge*.

* Philos. Trans. 1828.

† Biologie. v. 141.

‡ Traité element. d'anat. comp. 2d edit. i. 392. (French translation by Jourdan.)

these nerves that the organs act, it is not impossible that the nervous influence itself is accumulated in these cells as in condensers, and that it is discharged at will, just as this influence is accumulated in the muscular tissue to produce contraction of its fibres." It was reflection on the phenomena of animal electricity that led Dr. Wollaston to form the hypothesis, which he supported with so much ability, of secretion in general being dependant on electricity, conveyed by the nerves, and acting on the secerning organs.* Dr. Wilson Philip, also, thinks that the circumstances under which electrical action is manifested by fishes go to the support of his theory of the nervous influence being identical with common and voltaic electricity. Dr. Faraday says that, from the time that it was shewn that electricity could perform the functions of the nervous influence, he has had no doubt of their very close relation, and probably as effects of one common cause. To the numerous list of learned observers who have speculated on this interesting subject, we have to add the respected name of Sir John Herschel, who imagines that the present state of electrical science warrants the conjecture, that the brain and spinal marrow form an electric organ, which is spontaneously discharged along the nerves, at brief intervals, " when the tension of the electricity reaches a certain point."† Meissner, again, supposes that the blood becomes charged with electricity in the lungs, during the chemical process of respiration; that the electricity immediately traverses the nerves of the lungs, and then the other parts of the ganglionic system ; that hence the central organs of the nervous system become charged ; and that the brain, on and through which the will acts, being charged, excites the several organs to activity through the medium of their respective nerves, along which electric currents are passed.‡ The facts, (in addition to those which have chiefly engaged our attention in this article,) upon which such theories are built are,— (1) that the muscles of an animal recently dead contract when common electricity passes through them, just as they do when they are subject to the animal's will; (2) that voltaic electricity acts upon secreting organs, so as to enable them in some degree to carry on their functions after their proper nerves have been cut; and (3) that the same agent appears to influence powerfully the capillary circulation. But, although these facts, taken along with what we know of the phenomena of the electricity of fishes, certainly do appear to favour the views to which we have just alluded, there are yet other facts which are so hostile to them as to make it probable that they do not express the truth. For instance, the most carefully conducted experiments have failed to demonstrate the existence of electric currents through muscles during their contraction; which, from all that is known of the phenomena exhibited by electricity in other circumstances, it may be presumed would not have been the case had it been the immediate stimulant of muscular contraction. M. Person has applied the poles of a galvanometer to the spinal marrow without obtaining any indications of the existence of electrical currents through its substance. The subjects of Person's experiments were cats, dogs, rabbits, eels, and frogs. The spinal canal having been opened, the piles of the galvanometer were placed in communication with the anterior and posterior columns of the cord. This was done at different parts, after the roots of the nerves had been cut. Small plates of platina, with which the wires of the instrument were armed, were thrust into the cerebellum and into several of the largest nerves. These experiments were repeated after the animals had been placed under the influence of strychnia. But there was no certain indication of electricity obtained, although the most delicate instruments were used.* Person's experiments have been repeated by Müller with the same results. Messrs. Prevost and Dumas, however, state that, having armed the branches of their galvanometer with two wires of platina, exactly alike, and having plunged one of them into the muscles of a frog's leg, while, with the other, heated to redness, they touched its nerves, they saw considerable deviations of the needle of the instrument follow the contractions of the muscles.† But seeing that the electricity made manifest in this experiment may have been developed rather by the contact of the hot wire and the nerves than by the nervous actions, we cannot admit that it is sufficient to prove the existence of electrical currents in muscles during their contraction. Dr. Faraday, also, has lately experimented on living muscles with the very delicate galvanometer invented by himself, but has entirely failed to obtain indications of moving electricity. Negative results such as these, obtained by so many practised observers, are sufficient to induce us to withhold our assent from those theories which make nervism identical with electricity, until the whole subject shall have been more fully investigated.

As in some degree illustrative of the phenomena of animal electricity, properly so called, we must here take notice of *the manifestation of common electricity in animal substances and in living animals.*

The mere contact of heterogeneous bodies is

* Phil. Mag. xxxiii. 488.

† Discourse on the Study of Nat. Phil. 343.

‡ Syst. der Heilkunde. Wien. 1832. If hypotheses such as these should hereafter be proved to express the true state of the case, the electrical fishes will become objects of great interest to the physiologist, as presenting him with opportunities, such as no other animals afford, of studying *in accumulation* the properties of that wonderful agent, which is *the moving power* of the animal organization, and a very important link in the chain of causes and effects by which life is manifested.

* Journal de Physiol. x. 217. Some years ago M. Pouillet announced that he had witnessed electrical phenomena during the operation of the acupuncture of muscles; but he has since confessed that he was deceived.

† Edwards, De l'influence des agens physiques sur la Vie, in Appendix.

sufficient for the development of electricity; and animal tissues of dissimilar natures, both living and dead, obey the same law as other substances in this respect. For instance, a kind of voltaic pile has been formed by building up layers of muscle and nerve placed one above the other alternately; (Buntzen:) also by placing one upon another alternate layers of muscular fibre and brain, separated by a porous substance, soaked in salt-water. (Lagrave.) Another such has been made with plates of one kind of metal, fresh muscle, and salt-water, or blood, which acted on the galvanometer. When the conductors of a galvanometer (Schweigger's) are armed with plates of platina, on one of which a piece of muscle of a few ounces in weight is placed, and the conductors are then plunged in blood or in a weak solution of salt, a deviation of the magnetic needle of the instrument is perceptible. (Prevost and Dumas.) The same happens when to one conductor is applied a plate of platina moistened with muriate of antimony or nitric acid, to the other a piece of nerve, muscle, or brain, and both are brought into contact. (Majendie.) Dry piles of considerable electrical power may be formed of organic materials alone, without the intervention of metals. If concentrated extracts of organic bodies (animal or vegetable) be spread upon thin paper, and piles be built up of discs cut from this paper, so that two dissimilar layers be separated by two thicknesses of the paper, so much electricity is developed that the electrometer is affected. (Kœmtz.) When two persons, both insulated, join hands, electricity is developed sufficiently to affect Coulomb's electroscope. And, if the contraction of muscles, the nervous connexion of which with the living body has been destroyed, be considered as a proof that they are subject to the influence of electricity, there are numerous experiments on record tending to prove that electricity is evolved by the mere contact of two dissimilar animal substances. Galvani, Volta, Humboldt, Aldini, Kellie, and Müller, have all found that when the muscles and the great nerves of a frog's limb are touched synchronously with a piece of the muscle of a warm-blooded animal, weak contractions of the frog's muscles ensue; and that, when the crural muscles are cut and folded back so as to touch the lumbar nerves, muscular contractions are perceived in the lower part of the limb. Aldini excited most powerful contractions by bringing the nerves of a warm-blooded animal into contact with the muscles of a cold-blooded animal, and *vice versa*. And Müller has further found that contractions are excited by touching the moistened skin of the leg with the nerves of the thigh dissected out and turned down upon them; the nerves being held by means of an insulating rod.*

Tiedemann thus states the general results of experiments such as these. "1. The nerves of the muscles in which it is proposed to excite convulsions must make part of the chain. 2. The nerve or portion of nerve which is to make part of the chain must be isolated as completely as may be, and no other conductor must produce derivation in this portion of the chain, so as to oblige the electric current, when developed in the chain, to take a course through the nerves. 3. *Cæteris paribus*, the convulsions are so much stronger, and are manifested over a greater extent, as the nervous portion, acting as a conductor, enters into the chain. 4. The convulsions are so much more powerful, and last the longer, as the chain is quickly formed, and the surface with which the parts constituting it are in contact is extensive."* And lastly, we now know that even the evaporation of fluids, and changes in the molecular constitution of both solids and fluids are always accompanied by electrical excitation.

Applying these facts to our knowledge of the various processes of the animal œconomy, we cannot but conclude that, in the course of the many interchanges that are constantly taking place amongst the component particles of all living organs, electricity (perhaps modified by the organic forces) must be developed altogether independently of nervous influence. It is certain, however, that electricity flowing from this source is very feebly manifested; at least it affects our best electrometers in a very inconsiderable degree. Saussure frequently examined the electricity of his own body by means of Volta's electrometer, used along with a condenser, but always failed to perceive any indications of free electricity while he was entirely naked. It was also imperceptible while he perspired freely, and when his clothing was cold. Under other circumstances, he found the electricity of his body sometimes positive, and at other times negative; but he could not determine the causes of these variations. Similar observations were made by Hemmer of Mannheim in 1786, both on the electricity of his own body, and on that of many other individuals placed in various circumstances. He obtained the following results. 1. Electricity is developed in all men, but varies in intensity and in nature in different individuals. 2. The character and intensity of the electricity frequently varies in the same person. In 2422 experiments, it was 1252 times positive, 771 negative, and 399 times imperceptible. 3. When the body is at rest and warm, its electricity is always positive. 4. When the surface is much cooled, the electricity becomes negative. 5. It is also negative when the muscular vigour is diminished. More recently this subject has been investigated by Messrs. Pfaff and Ahrens.† They used a gold-leaf electrometer; and the subjects of their observations were insulated. The collecting plate screwed on the electrometer was touched by the person experimented upon. The upper plate of the same was placed in communication with the ground by means of conductors. The results which they thus procured were as follows:—1. The electricity of healthy men is generally positive. 2. Irritable men of sanguine temperament have more free

* Handbuch der Physiol. des Menschen. Berlin, 1833.

* Physiol. transl. by Drs. Gully and Lane, 276.
† Meckel's Archiv. iii. 161.

electricity than those of a phlegmatic temperament. 3. An increased accumulation of electricity takes place in the evening. 4. Spirituous drinks augment its intensity. 5. The electricity of women is more frequently negative than that of men. 6. In winter, while the body is very cold, no electricity is manifested, but it gradually reappears as the body is warmed. 7. The whole body naked, as well as every part of it, shews the same phenomena. 8. During the existence of rheumatism, the electricity is greatly diminished in intensity, but as the disease declines it again increases. Gardini found that the electricity of women during menstruation and pregnancy is negative.

Some individuals exhibit electrical phenomena much more readily than others. Some persons, for instance, hardly ever pull off articles of dress worn next the skin without sparks and a crackling noise being produced. It is related of a certain monk that sparks were always emitted from his hair when it was stroked backwards; and of an Italian lady that her skin, when rubbed with a linen cloth, gave out sparks, attended with a crackling noise. The same phenomenon, as exhibited by the cat, and by other animals covered with a soft fur, is daily observed. But it has been stated that the cat's electricity may be accumulated in its own body and given off suddenly, so as to produce a shock. Romer says,* "If one take a cat in his lap, in dry weather, and apply the left hand to its breast, while with the right he strokes its back, at first he obtains only a few sparks from the hair; but, after continuing to stroke for some time, he receives a sharp shock, which is often felt above the wrists of both arms. At the same moment, the animal runs off with expressions of terror, and will seldom submit itself to a second experiment." In repeating this experiment, we have obtained the like result.

We are not aware of any other observer having met with any thing resembling an accumulation of electricity in quadrupeds, excepting Cotugno, who asserted that, in dissecting a living mouse, he felt an electric shock when its tail touched his finger.†

XI. *Uses of animal electricity.*—The purpose which the electrical function is fitted to serve in the animal economy is probably not single. It is very evident that the discharge from the organs frequently strikes terror into the enemies of their possessors, and thus it may be regarded as a means of defence; while, in certain circumstances, it may be useful in enabling the fish more easily to secure its prey. But this, probably, is not all. It is very likely, as Dr. Roget has suggested,‡ that the electrical organs communicate to the fish perceptions of electrical states and changes in surrounding bodies, (very different from any that we can feel,) in the same way as other organs of sense convey perceptions with regard to light and sound. Such perceptions we can conceive to be very useful and pleasurable to animals living in the dark abysses of the waters.

Some of Dr. John Davy's observations make it very doubtful whether the electrical function is ever subservient to that of prehension of food. He kept young torpedos for a period of five months or more, in large jars of salt water, during which time *they ate nothing*, although very small fishes, both dead and alive, were put into the water. Yet they grew, and their electrical energies and general activity increased.* The small fishes seemed to have no dread of the torpedos. On one occasion, however, when a lively torpedo was placed in a small vessel along with a smelt, and excited to discharge, the smelt was evidently alarmed, and once or twice, when exposed to the shock, leaped nearly out of the vessel, but it was not injured by the electricity. It has also been frequently observed of the gymnotus that it eats very few of the fishes that it kills by its discharge.

The electrical power of the young fish is proportionally very much greater than that of the old, and can be exerted without exhaustion and loss of life much more frequently. After a few shocks, most of the old fish which Dr. Davy has endeavoured to keep alive have become languid, and died in a few hours, whilst young ones, from three to six inches long, remained active during ten or fifteen days, and sometimes lived as many weeks. Hence Dr. Davy concludes that the chief use of the electrical function is to guard the fish from its enemies, rather than to enable it to destroy its prey, and so provide itself with food. He further conjectures that, besides its defensive use, the electrical function may serve also to assist in respiration by effecting the decomposition of the surrounding water, and so supplying the gills with air when the fish is lying covered with mud or sand, in which it is easy to conceive that pure air may be deficient. And Dr. Davy has often imagined that he saw something of this kind going on. After repeated discharges, he has observed, all around the margin of the pectoral fins, an appearance as if very minute bubbles of air were generated in it and confined. That this may be one purpose which the electrical function is designed to serve, is rendered still more probable by the circumstance, that the gills (in the torpedo at least) are largely supplied with twigs of the electrical nerves. In fishes in which he had cut the electrical nerves, Dr. Davy found the secretion of the cutaneous mucus considerably diminished or altogether arrested; and hence he supposes that the electricity assists in the production of this fluid.

Lastly, it has been conjectured that the electrical function is subservient to that of digestion. This idea was started by Mr. J. Couch some years ago.† He says, "Without denying that the torpedo may devour that which it disables by the shock, I conceive that the principal use of this power has a reference to the functions of

* Gilbert's Ann. der Phys. B. xvii.

† Humboldt. Ueber die gereizte Muskel-und-Nervenfaser. Berlin, 1793. i. 30.

‡ Bridgewater Treatise, i. 31.

* Phil. Trans. 1835.

† Linn. Trans. xiv. 89.

digestion. It is well known that an effect of lightning or the electric shock is to deprive animated bodies very suddenly of their irritability; and that thereby they are rendered more readily disposed to pass into a state of dissolution than they would otherwise be; in which condition the digestive powers of the stomach can be much more speedily and effectually exerted on them. If any creature may seem to require such a preparation of the food more than another, it is the torpedo, the whole intestinal canal of which is not more than half as long as the stomach."

These views receive some support from the fact that the nerves of the stomach are derived from those supplying the electrical organs; and perhaps also from the fact, reported by Dr. Davy regarding a torpedo, in which, after it had been frequently excited to give shocks, digestion seemed to be completely arrested.

The only conclusion to which, in the present state of our knowledge, we can come on this point is, that although the electrical organs form a very efficient means of defence from their enemies for the fishes which possess them, this is not the only purpose they are intended to serve; what, however, their other uses are is at present only matter of conjecture.

There remains yet unentered upon a large field of enquiry connected with the physiology of those wonderful organs, which, we doubt not, will yield to future ages very striking examples of that nice and close adaptation of means to ends which so clearly proves to us the existence and continued exercise of Wisdom Supreme, "upholding all things by the word of his power," making the smallest of his works "very good," and "to be thought upon."

Bibliography.—*Volta*, Memorie sull' elettricita animali, 1782. *Galvani*, Dell' uso e dell' attivita dell' arco conduttore nelle contrazioni dei moscoli. Bologna, 1794. *Ejus*. Memorie sull' elettricita animale, Bologn. 1797. *Fowler*, Experiments and Observations relative to the influence called animal electricity. Lond. 1793. *Aldini*, Essai Theorique et experimental sur le Galvanisme, et in Bulletin des sciences, an xi. No. 68. *Pfaff*, Ueber thierische Elettricität und Reizburkeit. Leipzig, 1795. *Humboldt*, Versuche über die gereizte Muskel und Nervenfaser. Berlin, 1797. *Treviranus*, Biologie. *Tiedemann*, Physiologie. *Müller*, Physiologie. *Carus*, Anat. Comp. French ed. t. i. *Lorenzini*, Osservazioni interno alle torpedini, Flor. 1678. *Walsh*, Phil. Trans. 1774. *Pringle* on the Torpedo, Lond. 1783. *Ingenhousz*, Phil. Trans. 1775. *Hunter*, Phil. Trans. t. lxiii. et lxv. *Geoffroy Saint Hilaire*, Ann. du Mus. t. i. *Humboldt*, Recueil d'observ. de zoologie et d'anat. comp. *Knox*, Edin. Journal of Science, 1824. *Todd*, Phil. Trans. 1816. *Davy*, Phil. Trans. 1834. *Majendie* and *Desmoulins*, Anat. des Systemes Nerv. t. ii. *Rudolphi*, Abhandl. der Acad. der Wissenschaft in Berlin, 1820. *Becquerel*, Traité d'Electricité et Galvanism, t. iv. Par. 1836.

(John Coldstream.)

ENCEPHALON. In order to lay before the reader a connected view of the Anatomy of the Encephalon in conjunction with that of the Medulla Spinalis, the Anatomy of both these organs will be given under the article "Nervous Centres."

ENDOSMOSIS, (ἐνδον, intus, ωσμος, impulsus).—Accident having made me acquainted with the fact that a small animal bladder, containing an organic fluid, became considerably distended by remaining for some time plunged in water, and that the water even expelled the thicker fluid contained within the bladder, when there was a hole by which it could escape, I bethought me of the probable cause of this phenomenon, and soon came to the conclusion that it depended on the difference of density between the included or interior fluid, and the water or exterior fluid. I found that the cœca of fowls filled with milk, thin syrup, &c. and secured with a ligature, became turgid and even excessively distended when treated in the same way. I now discovered that the fluids contained in the cœca permeated their coats, and were diffused in the surrounding water. I saw, further, that two opposite currents were established through the parietes of the cœca; the first and stronger formed by the exterior water flowing towards the fluid contained in the cœca; the second and weaker, by the thick included fluid flowing towards the water. To the first of these currents I gave the name of *Endosmosis*, and to the second that of *Exosmosis*. These titles, I must allow, are objectionable, and perhaps badly chosen. The first conveys the idea of an entrance and the second of an exit. Now, the phenomenon, regarded in its proper point of view, consists in a double permeation of fluids, abstracted from any idea of entrance or exit. Besides, the current of endosmosis, which, etymologically speaking, expresses an in-going current, may nevertheless be, experimentally speaking, an out-going current; this, for example, happens when a hollow membranous organ, containing water, comes to be placed in contact exteriorly with a fluid more dense than water. There is then a current of *endosmosis* which goes out of the bladder, and a current of *exosmosis* which enters it. Thus facts are found in contradiction to the terms, and these I should not have hesitated to change, if their general adoption did not render this change very difficult, and subject to great inconvenience. I have, therefore, resolved to retain them, wishing it to be understood by naturalists that no attention is here paid to their etymological signification.

To estimate the amount of endosmosis I contrived an apparatus to which I gave the name of *endosmometer;* it consists of a small bottle, the bottom of which is taken out, and replaced by a piece of bladder. Into this bottle I pour some dense fluid, and close the neck with a cork, through which a glass tube, fixed upon a graduated scale, is passed. I then plunge the bottle, which I entitle the *reservoir of the endosmometer*, into pure water, which, by endosmosis, penetrates the bottle in various quantities through the membrane closing its bottom. The dense fluid in the bottle, increased in quantity by this addition, rises in the tube fitted to its neck, and the velocity of its ascent becomes the measure of the velocity of the endosmosis.

To measure the strength of endosmosis, I have made use of an endosmometer in which the tube was twice bent upon itself, the ascending branch containing a column of mercury, which was raised by the interior fluid of the endosmometer in proportion as the endosmosis increased the volume of this fluid.* By means of these two instruments I have found that the velocity and strength of endosmosis follow exactly the same law. Both are in relation to the quantities which express, in two comparative experiments, the excess of density of two dense fluids contained in the endosmometer, above the density of water, which in these two experiments is exterior to the instrument. Thus, for example, in putting successively into the same endosmometer, syrup of which the density is 1.1, and syrup of which the density is 1.2, and in plunging in both cases the reservoir of the endosmometer into pure water, you obtain in the first case an endosmosis, of which the strength and velocity are represented by 1, and in the second case an endosmosis, of which the strength and velocity are represented by 2; that is to say, by the numbers relative to the fractionals 0.1 and 0.2, which express the excesses of density of the two solutions of sugar above the density of water, which is 1. I have ascertained by experiment that the strength of endosmosis is such that, with syrup of which the density is 1.11, and an endosmometer, the opening of which is closed by three pieces of bladder, one over the other, you obtain an endosmosis which raises the mercury to 1 metre 238 millimetres, or 45 inches 9 lines, which is equivalent to an elevation of water of 16 metres 77 centimetres, or 51 feet 8 inches. It follows from this, that in employing syrup, of which the density was 1.33, (its ordinary density,) you would obtain an endosmosis, the strength of which would be capable of raising water more than 150 feet.

Fluids of a different nature have, with reference to endosmosis, properties which are in no way in proportion to their respective densities. Thus sugar-water and gum-water of the same density, being put successively into the same endosmometer, which is plunged into pure water, the former produces the endosmosis with a velocity as 17, and the latter with a velocity as 8 only. I have seen, in the same manner, a solution of hydrochlorate of soda and a solution of sulphate of soda of the same density, put successively in the same endosmometer surrounded with pure water; the velocity of the endosmosis produced by the solution of sulphate of soda is exactly double that of the endosmosis produced by the solution of hydrochlorate of soda. These results are invariable, and I am persuaded that if I have ever obtained a different result, the experiment has been defective.

I have made several experiments since with gelatinous and albuminous waters placed successively in the same endosmometer, surrounded with pure water, which produced endosmosis severally in the proportion of 1 to 4; so that the albumen had four times more power of endosmosis than the gelatine. I have seen by another experiment that the power of endosmosis of syrup is to the power of endosmosis of albuminous water of the same density, as 11 is to 12.

All alkalies and soluble salts produce endosmosis; so do all acids, but each with special phenomena, which will be noticed by and by. These chemical agents in general occasion an endosmosis of short duration only, when the endosmometer is closed with a portion of an animal membrane. Organic fluids alone, which are not very sensibly either acid or alkaline, or salt, produce lasting endosmosis, which, indeed, does not stop until the fluids are altered by putrefaction, when they become charged with sulphuretted hydrogen. I have shown that when an endosmometer is closed with a thin plate of baked clay instead of the animal membrane, the endosmosis which a saline solution produces, and which would have stopped in a few hours with the animal membrane, continues to go on indefinitely with the baked clay.

The property of destroying endosmosis may be considered as belonging to all chemical reagents, but merely on account of their susceptibility to enter into combination with the permeable partition of the endosmometer. Thus all acids, alkalies, soluble salts, alcohol, &c. being disposed to combine with the elements of organic membranes, destroy endosmosis, although they had induced it before their complete combination with the elements of the membrane had taken place; and it is not until this combination is complete that endosmosis ceases. Organic fluids, which have no chemical action upon the elements of the membrane of the endosmometer, ought not, consequently, to tend to the destruction of endosmosis, unless some change should take place which should give them a chemical action, such as they usually acquire by decomposition, when they usually become charged with sulphuretted hydrogen.

My earlier experiments tended to show that carbonate of lime (*chaux carbonatée*) reduced to thin laminæ, and employed to close an endosmometer, is totally without the power of producing endosmosis; my latter experiments have somewhat modified this conclusion. After having vainly employed laminæ of carbonate of lime of greater or less thickness, I finished by making use of one of white marble, two millimetres in thickness, but with no better success. Without carrying my experiments further, I concluded that porous carbonate of lime was totally unapt to excite endosmosis. This conclusion having, notwithstanding, left some doubts in my mind, I again took the same plate of marble with the intention of measuring its permeability to water, compared with the various degrees of thickness which I could give it, and of renewing, at the same time, my attempts to make it produce endosmosis. Having closed an endosmometer with this plate of marble, I filled the reservoir and the tube of the instrument with pure water, and suspended it over a vessel filled with water, in which the plate of marble only was immersed. If the marble had been permeable to water, the fluid contained in the endosmometer would have flowed

* See my work entitled, Nouvelles Recherches sur l'endosmose et l'exosmose, &c. 8vo. Paris, 1828.

through the capillary conduits of the plate, and this flow would have become perceptible by the sinking of the water in the tube, the interior of which was only two millimeters in diameter.

The result of this experiment was that the plate of marble, which was four centimeters in diameter, did not lose by filtration, in one day, more than the small quantity of water capable, by its subtraction, of lowering its level one millimeter and a half in the tube. I next tried syrup in this endosmometer, the reservoir being plunged into pure water; but no endosmosis was induced. I now reduced the thickness of the plate of marble to one millimeter and a half; in this state it lost by filtration, in the course of a day, eleven millimeters of water measured by the tube. The permeability of this plate was, as may be perceived, very sensibly increased: still the endosmometer which it closed when filled with syrup showed no indications of endosmosis. I reduced the thickness of the plate of marble to one millimeter. In this state it lost by filtration, in the space of a day, twenty-one millimeters of water measured in the tube. I put into the endosmometer, which this plate of marble closed, the same syrup which had been used in the preceding experiments, and the density of which was 1.12, and I now obtained an endosmosis which manifested itself by an ascension of seven millimeters in four-and-twenty hours. This last experiment proved to me that carbonate of lime was not, as I had hitherto found it, totally without the power to produce endosmosis. I wished to compare this plate of marble with a piece of bladder of the same surface under the double point of view, of their permeability, and their respective properties of producing endosmosis. Having therefore taken off the plate of marble which closed the endosmometer, I replaced it by a piece of bladder whose permeability to water I measured in the same manner as above. I found this permeability very nearly equal to that of the plate of marble of one millimeter in thickness. I then put into this endosmometer some syrup similar in density to that which I had used in the same endosmometer closed with the plate of marble. The endosmosis which I obtained raised the syrup seventy-three millimeters in three hours. Thus the permeability to water being equal in the bladder and in the plate of marble, the endosmosis produced by the first was to the endosmosis produced by the second as 584 is to 7, a most extraordinary difference, and difficult to be accounted for. These experiments prove that carbonate of lime is but very little apt to produce endosmosis, in which it differs singularly from baked clay, thin laminæ of which are almost as apt to produce endosmosis as organic membranes.

The varieties of sulphate of lime which may be employed in endosmometrical experiments are not sufficiently numerous or of sufficient variety of permeability for it to be possible to appreciate the properties of this substance in relation to endosmosis. I found that the sulphate of lime used in the manufacture of plaster in the environs of Paris, employed in thin plates to close an endosmometer, did not produce endosmosis. But this mineral is perhaps too easily permeable. In fact it is found impossible to obtain endosmosis when the interior fluid of the endosmometer flows easily by filtration, in virtue of its weight, through porous plates. I should say as much of plates of freestone *(grès)* which I have employed without success in these experiments, but that I recollect to have obtained the phenomenon in a very slight degree with a plate of freestone very close-grained and very little permeable to fluids.

I have tried a variety of experiments shewing that an increase of temperature increases endosmosis. This result has been confirmed by repeated experiments.

The quantity of the same fluid introduced by endosmosis, and with the same sort of permeable partition, is generally in proportion to the extent of surface of this partition. The following experiment demonstrated this fact. I took two endosmometers, the membranes of which, taken from the same bladder, were of diameters in the relation of one to two; I filled the reservoirs of these two endosmometers with syrup of equal density, and then plunged them into pure water. I had taken care to weigh them previously with great exactness. After continuing the experiment for two hours, I weighed the instruments afresh, and found in the large endosmometer four times as great an increase of weight as in the small one, which proved that the first had introduced, by endosmosis, four times as much water as the second. This relation was exactly that of the extent of surface of their respective membranes, the diameters of which were as one is to two, and their surfaces consequently as one is to four.

I have thus enumerated the effects; let us now endeavour to ascertain their causes.

The first idea which presented itself to my mind to explain the phenomenon of endosmosis was that it was owing to electricity. We know that effects exactly similar to those of endosmosis are produced by means of the electricity of the voltaic pile in the experiment of M. Porret, inserted in the *Annales de Chimie*, vol. xi. p. 137. This naturalist having divided a vessel into two compartments by a septum of bladder, filled one of the compartments with water, and put only a small quantity in the other. Having placed the positive pole of the pile in communication with the compartment full of water, and the negative pole with the compartment containing little water, the fluid was forced through the bladder from the full compartment into the almost empty one, and there rose to a higher level than that to which it was reduced in the original full compartment.

I varied this experiment by applying it to my own apparatus. I put pure water into an endosmometer, the membrane of which was plunged into water. I made the interior water of the endosmometer communicate with the negative pole of the pile, and the exterior water with the positive pole. I soon saw the water rise in the tube of the instrument: endosmosis had taken place. The similarity of effects led me to admit that some particular and unknown mode or form of electricity was the cause of the endosmosis produced by the heterogeneous nature of fluids. It was in vain, however, that I tried to discover signs of this electricity with the most delicate electrometers.

In reflecting afterwards upon what might be the common cause of the phenomenon presented in Porret's experiment and that of ordinary endosmosis, I was inclined to think that electricity might not be the immediate cause of the effects exhibited, and that it only acted in the case cited by producing heterogeneousness of quality in the two fluids subjected to the positive and negative poles. Experience seems to have confirmed my doubts on this point. I took a small endosmometer of glass, closed by a piece of bladder, and filled its reservoir with water coloured blue with the colouring matter of violets; I plunged the reservoir of this endosmometer into the same coloured water contained in a small glass vessel; I put this latter fluid in communication with the positive pole of the voltaic pile, and the interior fluid of the endosmometer in communication with the negative pole. The exterior blue fluid soon became red, and consequently acid, and the interior blue fluid became green, and consequently alkaline. These two fluids having thus become heterogeneous, to this may be ascribed the endosmosis which manifested itself, and which increased the volume of the interior fluid at the expense of the volume of the exterior fluid. Thus electricity would not be in this case the immediate cause of endosmosis, but the remote one; it would only act in producing the heterogeneous quality in the two fluids, and it would be this quality which would produce the passage of fluids as in the experiments on endosmosis, the discovery of which belongs to me.

But let us now inquire in what way heterogeneousness of quality in two fluids, separated by a membranous partition, occasions the phenomenon of endosmosis. Upon this point opinions are greatly divided. M. Poisson and Mr. Power have each, in his own way, given an analytical explanation of the phenomenon, and ascribed it to the action of the capillary canals of the porous septum interposed between the two fluids. In this explanation the phenomenon of the current of exosmosis is set aside, or regarded as occurring merely accidentally. Now this is entirely opposed to the fact, —we have constantly evidence of the simultaneous existence of the two opposite and unequal currents of endosmosis and exosmosis.

Endosmosis by others has been held to be simply the effect of the viscidity of one of the fluids divided by a porous septum. This viscidity prevents the upper fluid from permeating the interposed septum, whilst the inferior fluid, little or not at all viscid, filters readily through the septum and mingles with the upper fluid, whose volume it consequently increases. This opinion, published by a man of distinction, deserves to be seriously investigated.

When an equal weight of gum arabic and of sugar is dissolved in two equal weights of water, the viscidity of the different solutions is by no means the same, the solution of the gum is obviously more viscid than that of the sugar. Now if these two solutions be divided by a piece of bladder, the current of endosmosis will be found to flow from the solution of the gum towards that of the sugar; in other words, from the more viscid to the less viscid fluid; in this instance, consequently, we see the more viscid fluid permeating the membrane with greater facility or in greater quantity than the less viscid fluid. More than this, the same phenomenon takes place if the quantity of the gum be made double that of the sugar. I have, for instance, tried a solution of two parts of gum arabic in thirty-two parts of water, (density 1.023,) and a solution of one part of sugar in the same quantity of the menstruum, (density 1.014,) divided by a piece of bladder, and found that the endosmotic current was still directed from the solution of the gum towards that of the sugar. These facts suffice to prove that the endosmotic current does not always flow from the less towards the more viscid fluid. It is not, therefore, the inequality of vicosity in these two fluids which is, in this instance, the cause of their unequal permeation across the porous lamina which separates them.

In order to place these facts beyond a doubt, the comparative viscidity of the gum-water and the sugar-water which were made use of in the experiments of which I have been speaking, required to be accurately measured. Such a comparative estimate of the viscidity of fluids may be obtained by observing the time which an equal quantity of each of them, at the same temperature, takes to run through a glass capillary tube. In this way I tried, 1st, pure water; 2d, a solution of one part of sugar in thirty-two parts of water; 3d, a solution of one part of gum-arabic in thirty-two parts of water; 4th, and lastly, a solution of two parts of gum in thirty-two of water. With a temperature of +7° cent. I found that fifteen centilitres of pure water passed through a capillary tube of glass in one hundred and fifty-seven seconds; that fifteen centilitres of the solution of one part of sugar in thirty-two of water passed through the same tube in one hundred and fifty-nine seconds and a half; that fifteen centilitres of the solution of one part of gum in thirty-two of water passed through in two hundred and sixty-two seconds and one-third; and that the same quantity of the solution of two parts of gum in thirty-two of water required three hundred and twenty-six seconds to pass through.

From these experiments it appears that the viscidity of the solution of sugar, in the proportion of one to thirty-two of water, (density 1.014,) is very little above that of pure water; that the viscidity of the solution of gum-arabic, in the proportion of one to thirty-two of water, is much greater than that of the sugared water just mentioned; and finally, that the viscidity of the gum-water, containing two parts of gum to thirty-two of water, (density 1.023,) is twice as viscid as the solution of sugar employed.

It seems that nothing more is wanting to these proofs of the fact that endosmosis does not depend on the mere viscidity of fluids. Nevertheless I shall cite another proof of this truth. The very singular fact I am about to mention will also prove that the septa employed exert a special influence on the direction in which endosmosis takes place.

It is well known that, in separating water from alcohol by an organized animal or vegetable membrane, the endosmotic current flows from the water towards the alcohol. I employed oil-silk *(taffetas gommé)* or silk covered with a layer of caoutchouc, which may be regarded as equivalent to a thin lamina of elastic gum, as the medium of separation between these two fluids. During the first thirty-six hours of the experiment, I observed an extremely slow endosmotic current from the alcohol towards the water. After this period the endosmosis, with the same direction, became very rapid. This increase in the rapidity of the endosmosis I considered due to some alteration in the caoutchouc produced by the action of the alcohol, and in consequence of which it became more readily permeable. The endosmotic current, however, let it be observed, is always from the water towards the alcohol in this experiment, instead of being from the alcohol towards the water, as is constantly the case when the septum between the spirit and the water is formed by an organic, whether animal or vegetable, tissue. We have thus a clear demonstration of the great influence possessed by the septum upon the direction of the current of endosmosis. We have, also, in the instance just quoted, a proof that the different degrees of viscidity of two liquids plays no part in the production of this phenomenon. I would remark that the endosmotic current carrying the alcohol towards the water athwart the septum of caoutchouc is accompanied by a counter-current, which carries the water towards the alcohol through the same septum. I assured myself that the alcohol had received some addition of water; and yet it is well known that caoutchouc is impermeable to water; which would seem to say that the latter fluid could only have passed through the septum of caoutchouc by becoming mingled with the alcohol occupying the molecular interstices of that substance. Once within these interstices the alcohol attracts the water by the affinity of mixture, *(affinité de mixtion)* and enables it to penetrate the substance of the caoutchouc, which denies all access to water when it is pure. It is therefore to the state of commixtion within the capillary tubes of the septum that the two opposed fluids proceed the one towards the other with cross but unequal motions. The means I took to ascertain the fact of water having become mixed with the alcohol was simple enough: I set fire to a quantity of the fluid which had served for the experiment, and found that, after all the spirit had burned out, a considerable quantity of water remained, whilst the alcohol, previously to being so employed, burned away entirely, leaving no water behind it.

The theoretical views of Magnus in regard to endosmosis have been adopted by Berzelius in his Chemistry, and the idea upon which they are based has been reproduced by M. Poisson. To give a clear notion of this theory, let us suppose that a measure of salt water is separated from a measure of pure water by a permeable septum, a piece of bladder for example; the current of endosmosis, in this instance, will be from the pure water towards the salt, and for the following reason: in the salt water there are three attractions, namely, the attraction of the molecules of the water for one another; secondly, the attraction of the molecules of the salt for one another; and thirdly, the reciprocal attraction of the molecules of the water and of the molecules of the salt. The pure water on the opposite side of the septum again has no more than a single form of attraction, to wit, that of its particles for one another. The salt water subjected to three attractions will be moved, it may be imagined, with greater difficulty than the pure water, the molecules of which are obedient to but one attraction. Consequently, in the reciprocal attraction of these two fluids, the one, the molecules of which are the least subjected to attraction among themselves, will make its way with greatest rapidity athwart the capillary conduits of the dividing membrane.

This theory has a seducing aspect, but we shall find immediately that it is inapplicable to certain endosmotic phenomena presented by acids.

I have shown above that it is not always towards the denser fluid that the endosmotic current is turned. Thus alcohol and ether are very much less dense than water, and yet it is towards these fluids of inferior density that water flows in endosmotic experiments. Alcohol and ether have this in common with dense fluids generally, that they rise to a less height in capillary tubes than water. From this observation I was led to imagine that the endosmotic current was always from the fluid having the greatest power of capillary ascension, towards the fluid having the least of this capacity. It is true, indeed, as we have already seen, that alcohol proceeds by endosmosis towards water when the medium dividing them is caoutchouc. This would seem to say that alcohol would rise higher than water in capillary tubes of caoutchouc; and it is certain that caoutchouc has a greater attraction for alcohol than for water, inasmuch as the surface of India-rubber is much more readily wetted by alcohol than by water, which only adheres to it partially and imperfectly. This fact, therefore, would not be in contradiction to my theory; although I must confess that it is not reconcilable with certain endosmotic phenomena presented by the acids, as we shall immediately have occasion to perceive. In spite of this, however, I do not think I ought to pass in silence all the proofs that seem to establish this theory upon a basis of sufficient solidity; for I cannot but perceive that it is applicable to the most general phenomena of endosmosis, phenomena, too, which the acids, like all other fluid bodies, exhibit, although they also present endosmotic phenomena in addition of a different nature, and which belong to them exclusively.

Inequality of density being one cause of endosmosis among fluids, it became a point with me first to ascertain what differences in power of capillary ascension resulted from determinate differences of density among fluids; and next, to discover whether the difference in power of capillary ascent of two fluids bore any constant ratio to the difference of endosmosis as it is proclaimed by experiment.

The height to which different fluids rise in capillary tubes depends on a variety of causes, in appearance very different, but which must have some fundamental analogy. Of all fluids water is that which rises highest; and substances held dissolved in it which increase its density, lessen its power of capillary ascent, which is also diminished by increase of temperature: hot water ascends a less way in a capillary tube than cold water. Combustible fluids, such as alcohol and ether, are like dense fluids in regard to power of capillary ascent; so that combustibility acts in the same manner as density in this respect. The matter of which capillary tubes are formed is also endowed with the power of modifying the capillary ascent of fluids. Thus water, at the same temperature, will not rise to the same height in a series of equal capillary tubes made of different materials. These multiplied elements, which enter into the determination of the capillary ascending power of different fluids, render it an extremely complicated phenomenon. To simplify the study of this phenomenon in the greatest possible degree, let us confine ourselves to the use of two fluids, namely, water and a solution of the hydrochlorate of soda. It is easy to try the latter fluid of different densities, and to compare the power of capillary ascent possessed by each of these with that of pure water at like temperatures. The same glass tube will answer for these comparative experiments. Before detailing these experiments, however, I have one important remark to make, which is this; that the layer of fluid which moistens, internally, the canal of a tube is one of the elements of the capillary ascension which this tube effects. Thus, water will rise to a determinate height, in a tube interiorly moistened with water; but if the interior of the tube be moistened by a saline solution, or by any other watery fluid, or by alcohol, pure water will not again rise so high in this tube as when it was moistened by water only. It will be in vain to attempt to cleanse the tube by passing water repeatedly through it; water will never detach the stratum of saline or other liquid which adheres to it, and which diminishes its power of producing capillary ascension. To detach this stratum of fluid you must pass a filiform body repeatedly through the tube full of water; it is only by the rubbing of this body that the stratum can be detached. It must be evident after this observation, that in making experiments on the power of capillary ascension with various fluids and with the same tube, it is necessary to cleanse this tube with great care before each experiment; without this we should have defective results. We must also take care not to warm the tube by holding it between the fingers, for if the temperature be increased it will no longer exert so strong a capillary attraction. Let us now pass to the detail of these experiments.

I prepared a solution of hydrochlorate of soda, the density of which was 1.12, the density of the water being one. I took a part of this solution and to it added an equal volume of water, which gave it a density of 1.06. I had thus two saline solutions, of which the excess of density, above the density of water, was 0.12 and 0.06. The excess was thus in the relation of two to one. From my former experiments, these two excesses ought to serve as measures of the endosmosis produced by each of these saline solutions, put successively into the same endosmometer plunged in pure water. In fact, having submitted both of the saline solutions to experiment, I obtained from the most dense solution an endosmosis exactly double of that which was produced by the least dense solution. I next inquired into the relation existing between the known density of these two saline solutions and water, and the power of capillary ascension possessed by the three fluids. I took a glass tube, whose capillary action raised water to the height of 12 lines at a temperature of + 10 degrees R. (50 Fahrenh.) I found that the same tube, at the same temperature, raised to $6\frac{1}{4}$ lines the solution of hydrochlorate of soda, the density of which was 1.12, and that it raised to $9\frac{1}{8}$ lines the solution of the same salt, the density of which was 1.06.

1. The capillary ascension of the water being	12
The capillary ascension of the most dense fluid being	$6\frac{1}{4}$
The excess of the capillary ascension of water is	$5\frac{3}{4}$
2. The capillary ascension of water being	12
The capillary ascension of the least dense saline solution being	$9\frac{1}{8}$
The excess of the capillary ascension of water is	$2\frac{7}{8}$

Thus the two excesses of the capillary ascension of water above the capillary ascension of each of these saline solutions are $5\frac{3}{4}$ and $2\frac{7}{8}$, or $\frac{46}{8}$ and $\frac{23}{8}$. numbers which are in the relation of two to one, as are the two excesses 0.12 and 0.06 of the density of the two saline solutions above the density of water. Here, then, are two saline solutions which, put separately in relation to pure water, produce endosmosis in the relation of 2 to 1. Shall we refer this result to the circumstance that the excesses of density of each of these saline solutions over the density of water are in the ratio of 2 to 1, or to this,—that the excesses in the power of capillary ascent of each of these saline solutions over the power of capillary ascent of water are in the ratio of 2 to 1? In other words, is it the respective density of the two fluids which regulates or determines their endosmosis, or is it the respective powers of capillary ascension of the fluids severally?

The following experiment will solve this question. We have seen above that a solution of sulphate of soda and a solution of hydrochlorate of soda of equal densities being put in relation to pure water, produce endosmoses which are in the relation of two to one. Here the difference of density does not interfere with the regulation of the endosmosis; we must then see if it be regulated by the power of capillary ascension. I prepared a solution of sulphate of soda and one of hydrochlorate of soda, having the same density 1.085, and tested their capillary ascension in the same tube in which we have seen pure water raised to a height of 12 lines at a temperature of + 10 degrees R. I found that in the same tube and at the same temperature the capillary ascension of the solution of sulphate of soda was of 8 lines, and that of the solution of hydrochlorate of soda was of 10 lines. The excess of the capillary ascension of water above that of the solution of sulphate of soda is consequently 4; the excess of the capillary ascension of water above the solution of hydrochlorate of soda is 2. These two excesses are in the relation of two to one, a relation which also measures the endosmosis produced with the concurrence of water by each of these two solutions of equal density. The result of this is that the capillary ascension, or power of capillary ascent, of fluids governs their endosmosis, and that their density only intervenes in this case as the determining cause of their capillary ascension. But how does the capillary action operate here? This appears to be difficult to determine. The capillary action never carries fluids out of the canals in which it takes place; how then apply this action to the phenomenon of double permeation, which takes place in endosmosis and exosmosis? This double permeation, which carries two heterogeneous fluids towards each other, seems as though it were the result of the reciprocal attraction of the two fluids, of their tendency to associate by admixture. In experiments of endosmosis made with a dense fluid and water, the tendency to mix is favoured by the respective positions of the two fluids; the dense fluid is above and the water below. This disposition may possibly be one cause which favours the reciprocal mixture of the two fluids, whose specific gravity would tend to place them in an inverse situation to that given them in the experiment. This does not take place when experiments on endosmosis are made with alcohol and water; then the alcohol, specifically lighter than water, is situated above this latter fluid, and, notwithstanding this, the endosmosis is exceedingly energetic; we must then acknowledge that the specific gravity of two fluids has not here the degree of influence that might be supposed to belong to it at first sight. We have consequently no means left to explain the course of the two fluids towards each other athwart the capillary canals of the partition which separates them, but their reciprocal attraction or tendency to admixture. In admitting that such is the efficient cause of this double permeation we must also necessarily admit that this efficient cause is governed in its operation by the capillary action of the partition.

Here another question presents itself,—do the two fluids accomplish their admixture in the capillary canals themselves, or do they cross the partition by different capillary canals, so that neither fluid mixes with its opposite fluid until the moment of its exit from the capillary canals? On the latter hypothesis it were necessary to admit that the number and diameter of the capillary canals followed separately by each of the two fluids must be perfectly equal, for, without that, how would the general result of this double permeation, a result which is explained by the quantity of endosmosis, be in exact relation with the capillary action on the two fluids? Now it is repugnant to reason to admit any such perfect equality among all the capillary canals, or to suppose an equal number especially fitted for the transmission of each of the two fluids. It must then necessarily be allowed that the transmission of the two opposite fluids takes place by the same capillary canals, and that consequently this double movement of transmission takes place by a reciprocal penetration of the two fluids.

The preceding theory, with which I was at one time inclined to rest satisfied, and which, indeed, seemed to be based on a sufficiently firm foundation, was however brought into jeopardy by a discovery which I made subsequently, in regard to the phenomena of endosmosis exhibited by certain acids separated from pure water by a layer of animal membrane.

In the earliest experiments I made on the endosmosis of the acids, I observed a number of anomalous phenomena, for which I felt myself incompetent to assign any sufficient reason. I had always placed the acids above the water, from which they were separated by a layer of animal membrane. Certain acids, such as the hydrochloric, at very different degrees of density, and nitric acid only at pretty high degrees of density, gave me an endosmosis, the current of which was directed from the inferior water towards the superior acid, so that the acid rose gradually in the tube of the endosmometer. On the other hand, I had always found the sulphuric acid pretty largely diluted, and the hydrosulphuric acid, under the same circumstances as the acids mentioned above, gradually to sink in the tube of the endosmometer. I concluded from this that these acids did not occasion any endosmosis, and that they passed mechanically, and merely in virtue of their gravity, athwart the animal membrane to mingle with the water. I had also found that the sulphuric and hydrosulphuric acids, added to gum-water, deprived it of the faculty of producing endosmosis, and that this acidulated water fell in the tube of the endosmometer, instead of rising, as simple gum-water constantly does. These facts induced me to say metaphorically that the sulphuric and hydrosulphuric acids were the *enemies of endosmosis.*

More recent inquiries have enabled me to see the above mentioned phenomena in another light. It was the oxalic acid which led me to the conclusions I shall now lay before the reader. Having poured a solution of this acid into the endosmometer closed with a piece of bladder, and placed the reservoir in water, I found the acid fluid sink rapidly in the tube, and flow towards the inferior water, making its way by filtration through the animal membrane. I then reversed the arrangement observed in this experiment. I filled the endosmometer with water, and plunged the reservoir into a solution of oxalic acid. I was now surprised to find the water making its way rapidly into the endosmometer, and the column rising in the tube, so that, in opposition to all I had yet observed, here was the current of endosmosis directed from the acid towards the water. The following are the particulars of this experiment. Having poured some rain-water into the reservoir of the endosmometer, I plunged the reservoir, closed with a piece of bladder, into a solution of oxalic acid of the density of 1.045, (11.6 parts of crystallized acid in 100 of the solution,) the temperature being + 25 cent. The ascent of the water in the tube of the endosmometer lasted for three days, becoming gradually slower and slower. The ascent having then become almost imperceptible, I emptied the endosmometer, in the contents of which I found water charged with oxalic acid. The exterior fluid was reduced in density to 1.033, so that, whilst the lower acid had penetrated the upper water by endosmosis, the water had penetrated the acid by exosmosis, and thus diminished its density; the permeation of the water, however, had been less considerable than that of the acid; so that the upper water, increased in volume, had risen in the tube of the endosmometer. We have thus, in the present instance, another obvious proof of the existence of two opposite and unequal currents. Having filled the reservoir of the endosmometer anew with rain-water, I placed it in the solution of oxalic acid already used, and of the reduced density of 1.033. The ascent in the tube which again occurred, having almost ceased at the end of two days, I tested the fluid in the endosmometer, and found it to contain oxalic acid, and discovered the density of the external fluid further reduced to 1.025. I repeated the same experiment a third time, filling the reservoir of the endosmometer with rain-water, and plunging it in the old acid solution. Endosmosis went on as before, but with less celerity. Having given up the experiment, after the lapse of twenty-four hours I found the density of the exterior fluid now reduced to 1.023, and the internal fluid to contain a portion of oxalic acid as before. I reduced the density of the exterior acid solution to 1.01, but the included water still gave evidence of a pretty active endosmosis. I reduced the density of the acid to 1.005, (1.2 of acid to 100 of the solution,) and the endosmosis was still very remarkable. In these experiments I found that the endosmosis was by so much the more rapid as the exterior acid solution was more dense, so that the capacity of oxalic acid to permeate an animal membrane would appear to increase with the density of its solution in water. In these experiments, too, we observe a fluid, more dense than water, and having a less power of capillary ascent than it, nevertheless forming the *stronger current*, or current of endosmosis, whilst the water opposed to this fluid forms the *weaker current*, or counter-current of exosmosis. This is in opposition to all I had observed before; and the theory I had raised on the different capacities of capillary ascent possessed by two opposed fluids is consequently shaken, or at all events proved to be no longer generally applicable. What may be the cause of this new phenomenon? Do animal membranes give passage more readily through their meshes to solutions of oxalic acid than to water? This point I sought to determine by the following experiments.

The filtration of a fluid, by virtue of its gravity, through a porous lamina, the capillary canals of which are very minute, is not readily appreciable, unless the inferior or outer surface of this porous plate is kept plunged in or moistened by the same fluid. It is in this way only that the filtration of fluids through animal membranes, the texture of which is dense (a piece of bladder for example,) becomes appreciable. It is essential that the inferior aspect of the membrane be bathed with the same fluid as that which rests on its superior aspect, in order that no foreign cause modify its filtration. We know in fact that the heterogeneousness of two fluids, by producing endosmosis, would completely mask the effects of simple filtration. Would I, then, try the filtration of water through a membrane, I apply this membrane to an endosmometer, which I fill with water to a certain height in the tube of the instrument; I next apply the lower surface of this membrane to the surface of a body of water placed below it. The water contained in the endosmometer filters through the membrane and mingles with the water in the vessel below; the amount of this filtration in a given time is indicated by the fall of the column in the graduated tube of the instrument. Would I essay comparatively the filtration of any watery solution, I place this solution in the same endosmometer, and taking care to keep the exterior of the membranous part of the instrument in contact with a solution of the same nature, situated below it, I observe the degree to which the depression of the column in the tube takes place in a space of time equal to that which was taken by the filtration of the water. It is necessary to begin by proving the filtration of water; after this the filtration of the watery solution may be tried; but it is always to be borne in mind that the membrane of the endosmometer must have been kept plunged in the watery solution about to be experimented on for at least a quarter of an hour, in order that it may become thoroughly impregnated with the solution, and to secure that this should take the place of the water which the membrane had formerly contained in its pores. Without this measure of precaution, the results of the second experiment would be faulty. It is also indispensable that the circumstances under which the two experiments are performed are in all respects exactly alike. It was in this way that I proceeded to ascertain comparatively the capacity of filtration of water to that of a watery solution of oxalic acid through a piece of bladder. I found that the filtrating power of rainwater, at the temperature of + 21 cent. being denoted by 24, the filtrating power of a watery solution of oxalic acid of no greater density than 1.005, (1.2 of acid to 100 of solution,) was denoted by 12. A solution of the same acid, of the density of 1.01, being tried, its filtrating power was found to be represented by 9. By these experiments it is therefore proved that water traverses an animal membrane more readily than a solution of oxalic acid. Why then does the latter solution traverse an animal membrane more readily and in greater quantity than water, when it is water which is in contact with the surface of the membrane opposite to that which is in contact with the acid? This is a question which I find it impossible to answer in the present state of our knowledge.

The discovery of this singular property of the oxalic acid to cause the endosmotic current to flow towards the water when separated from the latter fluid by a lamina of animal membrane, led me to imagine that all the acids would be found to possess a similar property. And this I ascertained, in the first instance, to be the case in regard to the tartaric and citric acids. Both of these acids are much more soluble in water than oxalic acid. The saturated solution of oxalic acid at + 25 cent. has no higher a density than 1.045 (11.6 acid to 100 of the solution.) But the solubility of the tartaric and citric acids is such that their watery solutions may have a density of far greater amount. I tried the endosmotic effects of the tartaric and citric acids in watery solution of various density, and I discovered, not without surprise, that very dense solutions of them and solutions of inferior density exhibited endosmotic phenomena in inverse ratios. Thus, when a solution of tartaric acid was of a density above 1.05, (11 crystallized acid in 100 of solution,) and it was divided from water by an animal membrane, the temperature being + 25 cent. the endosmotic current is directed from the water towards the acid; but when, under the same circumstances, the density of the acid solution is below 1.05, the current of endosmosis is directed from the acid towards the water, just as we have found it to be with reference to the oxalic acid. Consequently, according to its greater or less density, tartaric acid presents the phenomenon of endosmosis in two opposite directions. At the mean density of 1.05, at a temperature of + 25° cent. it exhibits no obvious endosmotic phenomena whatever; not that there is not reciprocal penetration between the acid and the water, which are divided by the animal membrane; but this reciprocal penetration takes place so equally on either side, that there is no increase of bulk of the one fluid at the cost of the other—there is *no endosmosis*. The citric acid exhibits precisely the same phenomena; the point of mean density, which divides its two opposed endosmotic capacities, is also very nearly the same, namely, 1.05 at a temperature of + 25° cent. These facts induced me to imagine that if the oxalic acid alone presented the endosmotic current directed from the acid towards the water, this arose from the fact of its solution at + 25° cent. falling short of the density necessary to permit the acid solution to cause the endosmotic current to flow from the water towards the acid.

The preceding observations were made during the heats of summer. The centigrade thermometer was standing at + 25° when I determined the *mean term of density* of the solution of tartaric acid, above and short of which the endosmosis happening between this solution and water is directed towards the acid. It was of importance to know whether a depression of temperature would cause any modification in these phenomena. I therefore repeated the same experiments when the temperature was + 15° cent. and I was astonished to find that the *mean term of density*, of which we have spoken above, was considerably altered, being made to move in the direction of the increase of density of the acid solution. Thus the mean term of density being 1.05, (11 crystallized acid to 100 solution,) at a temperature of + 25° cent. it came to be 1.1, (21 acid to 100 solution,) at a temperature of + 15° of the same scale; that is to say, the solution of tartaric acid, which now occupies the *mean term*, contains nearly twice as much acid as the solution which stood at the previous *mean term*, when the temperature was ten degrees of the centigrade scale higher. This first essay was enough to lead to the inference that the *mean term of density*, which we are now discussing, would undergo further alterations in the same sense with further depressions of temperature; and this was actually found to be the case. At a temperature of 8½° cent. the solution of tartaric acid, of the density 1.1, was no longer the solution of *mean density* dividing the two opposed endosmotic currents, as it was when the temperature was + 15° cent. This solution then caused the endosmotic current to flow freely towards the water. I had to increase its density to 1.15 (30 acid to 100 solution) to come to the new *mean term*, beyond which the current of endosmosis was directed towards the acid, and within which it was directed towards the water. With the temperature depressed to a quarter of a degree cent. above zero, the solution of tartaric acid, of the density of 1.15, no longer presented the *mean term*; this solution now occasioned endosmosis towards the water, which indicated that the mean term was to be sought for in a more dense solution of tartaric acid, and this I actually found in a solution of the density of 1.21 (40 acid to 100 solution). Every solution of this acid of greater density than 1.21, at the temperature of ½th of a degree above zero cent caused the endosmotic current to flow from the water towards the acid, and every solution of the same acid, under the density of 1.21, caused the endosmotic current from the acid towards the water. From all these experiments it follows that a fall of temperature favours the endosmosis towards the water, and that a rise of temperature favours the endosmosis towards the acid. In fact, the same solution of tartaric acid occasions at one time endosmosis towards the acid, when the temperature is high; at another, endosmosis towards the water when the temperature is relatively low. It would appear from this, that a depression of temperature renders the solution of tartaric acid more apt than water to permeate animal membranes, and that there is a certain concordance between this capacity of permeation and the temperature and the density of the acid solution. This phenomemon, at first sight, appears analogous to that which M. Girard discovered,* in regard to the comparative flow of a solution of nitre and of pure water through a capillary glass tube. M. Girard found that, at a temperature of + 10°, a solution of one part of nitrate of potash in three parts of water flows more rapidly than pure water through a capillary glass tube, whilst the same solution flows more slowly than water when the temperature is above + 10°. To discover whether this apparent analogy was well founded or not, I made an experiment to ascertain the relative duration of the flow through a capillary glass tube of a given measure of pure water, and a like measure of a solution of tartaric acid, the density of which was 1.05 (21.8 parts acid, 100 solution.) The temperature being + 7° cent. I found that fifteen centilitres of water flowed through a capillary glass tube in 157 seconds; but the same quantity of the solution of tartaric acid required 301 seconds to pass through the same capillary tube. There is consequently no actual analogy to be established between the results of the experiments of M. Girard and the fact of the endosmosis towards the water, which takes place when at a temperature of +7° cent. a solution of tartaric acid of the density of 1.105, is separated from a volume of pure water by a piece of an animal membrane. It may be as well if I here state that when a solution of one part of nitrate of potash in three parts of water was separated by a piece of bladder from pure water, I have always observed the endosmotic current directed towards the solution; the temperature might be at zero, or + 10°, or higher, the same phenomenon always occurred. This is sufficient to prove that endosmosis is governed by laws entirely different from those that preside over simple capillary filtration. I add, that the solution of tartaric acid, of 1.105 density, having a *viscidity* nearly the double of that of water, and passing, nevertheless, by endosmosis into the latter fluid, when it is separated from it by an animal membrane, and the temperature is + 7° cent. also proves that endosmosis does not generally depend on the viscidity of fluids.

* Mém. de l'Acad. des Sciences, 1816.

Acid solutions are the only fluids which have yet been found to occasion the endosmotic current to flow towards water when separated from this fluid by an animal membrane. The whole of the acids, without exception, exhibit this phenomenon, which was long overlooked by me, from its having been confounded with another phenomenon, namely, the abolition of endosmosis. I have in fact shown, in a work already before the public,* that all fluids which act chemically on the membrane of the endosmometer, put an end, with greater or less celerity, to the phenomenon of endosmosis,—it goes on for some time, but it never fails to cease at length. Sulphuric acid, above all the other acids, has the property of putting an end to endosmosis. This acid, poured into the endosmometer, sinks by virtue of its simple gravity towards the lower water, filtering mechanically through the membrane placed between it and the water. If the position of the two fluids be reversed, the endosmometer being charged with water, and the sulphuric acid placed externally and on the lower level, the water still sinks towards the acid, passing in its turn mechanically through the membranous septum of the instrument, rendered incapable of effecting endosmosis. From these experiments I was led at first to conclude that sulphuric acid was *inactive* as regards endosmosis; in other words, was incapable of exhibiting or producing this phenomenon. I have since found, however, that the sulphuric, like all the other acids, has the faculty of exerting endosmosis in the two opposite directions, but always during a very brief space of time only. Thus the temperature being + 10° cent., sulphuric acid, of the density of 1.093, separated from water by a piece of bladder, the endosmotic current is directed from the water towards the acid, but the phenomenon lasts only for a short time; the current soon ceases, and if the acid be on the higher level, it then begins to sink by simple mechanical filtration towards the water. At the same temperature of + 10° cent., the sulphuric acid attenuated to 1.054 being placed in the endosmometer, and the reservoir and a part of the tube being plunged in water, endosmosis is established, but in this case the current is from the acid towards the water, so that the acid liquor sinks in the tube; and that this sinking is due to endosmosis is demonstrated by the fact of the acid continuing to sink in the tube of the endosmometer a considerable way below the level of the external water, and not stopping short when the level is obtained, as it does when the descent is owing to simple mechanical filtration. In this experiment, as in the one detailed immediately be-

* Nouv. Recherches sur l'Endosmose, &c. p. 25. See also my Memoir in the 49th vol. of the Annales de Chimie, p. 415.

fore it, the endosmosis towards the water is abolished, and then the column in the endosmometer begins to rise again slowly, until the level of the external and included fluids correspond. We, therefore, see that at a temperature of + 10° cent., sulphuric acid, of the density of 1.093, presents the current of endosmosis from the water towards the acid; whilst the density being 1.054, the endosmosis is from the acid towards the water. Between these two opposite endosmotic currents there necessarily exists a *mean* when no phenomena of the kind occur. This *mean*, the temperature continuing + 10°, I find to belong to sulphuric acid of the density of 1.07. The two fluids, divided by the animal membrane of the endosmometer, penetrate one another athwart the septum reciprocally and in equal measure, so that the contents of the endosmometer remain for a certain time at the same height in the tube of the instrument; subsequently the contained fluid begins to sink in consequence of the cessation of all endosmosis. These experiments were necessarily undertaken when the temperature was moderate or low; the phenomena detailed would not else have been appreciable; for in a warm atmosphere the abolition of endosmosis by sulphuric acid is accomplished so rapidly, that it is with difficulty the slight current established in the first instance can be observed.

Sulphurous acid, of the density 1.02, separated from water by an animal membrane, only exhibits endosmosis towards the water; this endosmosis is pretty active at first; but after the lapse of a brief interval the current ceases, just as it does with the sulphuric acid. These results I came to after a number of experiments, the temperature being at one time + 5°, and at another + 25° cent.

Formerly I regarded the hydrosulphuric acid as *inactive* in regard to endosmosis; I assimilated it, in this respect, with the sulphuric acid. The fact, however, is that, like the sulphuric acid, it has the property of producing endosmosis. The acid I employed was of the density of 1.00628. With a piece of bladder between this acid and water, the endosmosis was constantly towards the water. This conclusion was not influenced by variations of temperature between + 4° and + 25° cent. The action was somewhat protracted, but the endosmosis never failed to cease after a certain time, as in the case of the sulphuric acid.

The nitric acid of considerable density exhibits endosmosis towards the acid when separated from water by a piece of animal membrane. Thus, at a temperature of + 10° cent. this acid (density 1.12 or higher) presents the current flowing towards the acid. Under the same circumstances, but of the density of 1.08, the endosmosis is towards the water. Of the density 1.09, the *mean term* between the two opposite endosmoses is obtained. At higher temperatures the nitric acid very speedily puts an end to the phenomena of endosmosis, especially when its density is not very high, so that it becomes difficult to perceive the very transient currents produced in the first instance.

The hydrochloric is the most potent of all the mineral acids in directing the current of endosmosis from the water towards the acid. Its density must be considerably reduced before it offers the direction of the current changed, or from the acid towards the water. At a temperature of + 22° cent, for instance, the hydrochloric acid has to be brought, by the addition of water, to a density no higher than 1.003, before it presents the endosmosis flowing towards the water, from which, as understood, it is divided by a layer of animal membrane. Of greater density the endosmosis is towards the acid. When the temperature is lower than + 22°, the same acid, of greater density, acquires the property of causing endosmosis towards the water. Thus, with the centigrade thermometer at + 10°, I found that hydrochloric acid of 1.017 density presented the mean term between the two opposite endosmoses. At the same temperature hydrochloric acid, of 1.02 density, presented endosmosis towards the acid, and of 1.015 density, endosmosis towards the water. Under a higher temperature, however, and of the latter density (1.015), the endosmosis was towards the water, so that a depression of 12° cent. in temperature causes the *mean term* of the density of hydrochloric acid, which separates the two opposed endosmoses, to rise from that of about 1.003 to that of 1.027; that is to say, the quantity of acid added to the water must be increased almost six-fold to produce the same effects.

In the present state of our knowledge, we find it quite impossible to give any explanation of the remarkable phenomenon exhibited in the changes of direction of the endosmotic currents according to the degree of density of the acid and the temperature. The singularity of this phenomenon will appear the greater when the following observation is taken into the account. Hitherto it was always by a layer of animal membrane that I separated the acid from the water. Instead of the animal membrane I now tried the effect of one of vegetable origin. We have seen above that oxalic acid, whatever its density and under whatever temperature, when separated from water by an animal membrane, always exhibited endosmosis from the acid towards the water. I filled a pod of the *colutea arborescens*, which being opened at one end only and forming a little bag, was readily attached by means of a ligature to a glass tube, with a solution of oxalic acid, and having plunged it into rain-water, endosmosis was manifested by the ascent of the contained acid fluid in the tube; that is to say, the current flowed from the water towards the acid. The lower part of the leek *(allium porrum)* is enveloped or sheathed by the tubular petioles of the leaves. By slitting these cylindrical tubes down one side, vegetable membranous webs, of sufficient breadth and strength to be tied upon the reservoir of an endosmometer, are readily obtained. An endosmometer, fitted with one of these vegetable membranes, having been filled with a solution of oxalic acid, and then plunged into rain-water, the included fluid rose gradually in the tube of the endosmometer, so that the endosmosis was from the water towards the acid, the reverse of that which takes place when the endosmometer is furnished with an animal membrane. The tartaric and citric acids of densities below 1.05, and at a temperature of + 25° cent, exhibit endosmosis towards the water with an animal membrane; but with a vegetable membrane the case is altered; the endosmosis being then directed from the water towards the acid. I have tried solutions of tartaric acid, decreasing gradually in density from 1.05 (11 tartaric acid to 100 solution) to a density so low as 1.0004, (1 tartaric acid, 1000 solution,) and always seen the endosmosis towards the acid. A gradual fall in the temperature from + 25° to near zero did not affect the result.

Sulphuric acid of 1.0274 density and at a temperature of + 4° centes. when separated from water by a vegetable membrane, exhibited endosmosis towards the acid; separated by an animal membrane, however, the endosmosis was towards the water.

Hydrosulphuric acid (density 1.00628) separated from water by an animal membrane, always shows endosmosis towards the water; but separated by a vegetable membrane, the current is as uniformly towards the acid. The experiment from which I deduce this result was only performed at a temperature of + 5°.

Sulphurous acid (density 1.02) separated from water by an animal membrane, exhibits an active endosmosis towards the water, at every temperature from zero up to + 25° centes. (I have made no experiments on endosmosis at higher temperatures.) When sulphurous acid, of the density of 1.02, is separated from water by a layer of vegetable membrane, it presents neither endosmosis towards the acid nor endosmosis towards the water; it then appears to be under the influence of the simple laws presiding over the flow of fluids by filtration: there is abolition of endosmosis. I was anxious to see what endosmotic effects it would produce with an endosmometer closed with a layer of baked clay, and it was not without surprise that I saw the current flowing vigorously towards the water. I had put the acid into the reservoir of the endosmometer; and the included fluid rose to a considerable height in the tube of the instrument, which I had taken care to immerse in water to the place where the acid rose in the tube. The acid continued to sink in the tube of the endosmometer for four hours, and had then fallen to about 12 centimetres below the level of the external water; it subsequently began to rise slowly in the tube, and finally gained the level of the external water, where it remained. It was obvious that the sulphurous acid had sunk in the tube below the level of the water, in consequence of *endosmosis towards the water*, and that its subsequent rise to the level of the water was due to simple filtration through the membrane. Endosmosis had then ceased. Sulphuric acid, diluted with water to the density of 1.0549, exhibits the same phenomena as sulphurous acid when separated from water by a lamina of baked clay: it first occasions endosmosis towards the water, but after some minutes this endosmosis ceases, and is not replaced by endosmosis of an opposite nature; simple filtration from the effect of gravity is all that then takes place; endosmosis of each kind is put a stop to. Hydrosulphuric acid, separated from water by a lamina of baked clay, gives the same results precisely as the sulphuric acid. This phenomenon is rendered still more strange by the fact of its not being general. Thus the oxalic acid exhibits endosmosis towards the acid when this is separated from water by a lamina of baked clay. This fact I ascertained under a variety of temperatures from + 4° to + 25° centes. and with solutions of the acid of as great density as could be obtained at each temperature, as well as with solutions of very low density. The tartaric acid also presents endosmosis towards the acid when separated from water by a lamina of baked clay. I had formerly found * that a little sulphuric or hydrosulphuric acid added to gum-water, causes the current of endosmosis to cease flowing from the water towards the gum-water, so that the latter fluid, instead of rising in the tube of the endosmometer, begins gradually to fall. I then attributed this phenomenon to the abolition of endosmosis; but it is evident that in certain cases it is owing to the current of endosmosis changing its direction and flowing from the acid towards the water. Thus, with reference to the acidulated gum-water, of which I have just spoken, when placed above water, from which it was separated by an animal membrane, it fell in the stem of the endosmometer and flowed towards the water, either from the abolition of endosmosis, and in virtue of its gravity, or in consequence of the establishment of an endosmotic current towards the external water. Experiment can alone determine which of these two causes is the efficient one of the descent of the acidulated fluid in the stem of the endosmometer. The whole of the acids used of such density as comports with the production of endosmosis towards water, and in sufficient quantity, are adequate to overcome the disposition which any fluid may possess to produce endosmosis in the opposite direction. Here is a case in illustration of this point. The power of sugar-water in causing endosmosis is very great, as I have shown already. Water holding no more than one-sixteenth of its weight of sugar in solution causes rapid endosmosis from the water towards the solution. But I have found that, by adding to this sweet liquid a quantity of oxalic acid equal in weight to that of the sugar which it holds in solution, the direction of the endosmotic current is immediately changed; the flow is no longer from the water towards the solution, but from the sweet-sour solution towards the water, so that the oxalic acid may be said to compel the saccharine solution to which it is added to take the direction of the endosmotic current which is proper to it. Here it is the viscid and dense fluid, with little power of capillary ascent, which traverses the animal membrane with

* Nouv. Rech. sur l'Endosmose, p. 8.

greater ease and more rapidity than pure water. This may be added to the facts set forth already to prove, in the most decided manner, that the greater power of permeation manifested by one of the two fluids in experiments on endosmosis does not follow from any greater viscidity it may possess than the fluid opposed to it. In sixteen parts of water I dissolved two parts of sugar and one part of oxalic acid. In this solution I plunged the reservoir of an endosmometer, closed with a piece of bladder, and filled with pure water: this did not show any difference of level in the tube during the two hours that I continued the experiment. There was consequently no endosmosis. Nevertheless, I found that the water contained in the endosmometer contained a large quantity of oxalic acid, whether tested by the addition of lime-water or by the palate, which last also detected the presence of sugar. Thus the sweet-sour fluid, exterior to the endosmometer, had penetrated the water contained within its cavity. If this circumstance was proclaimed by no increase in the volume of the water, this undoubtedly was owing to the included water having lost by the descending counter-current an amount exactly equal to the amount it had gained by the inward or ascending current. There was no *endosmosis* in the sense in which I use that word, although it is certain that there were two active antagonist currents athwart the membrane which separated the two fluids. It must not be lost sight of that I only give the title of *endosmosis* to a *stronger current* opposed to a *weaker counter-current*, antagonists to each other, and proceeding simultaneously athwart the septum, dividing the two fluids which are made the subjects of experiment. The instant these two antagonist currents become equal, there is no accumulation of fluid on one side, and there is then no longer any effort at dilatation or impulsion; in a word, there is no longer any *endosmosis.*

The opposite directions in which the endosmosis towards water, effected by acids of determinate density, and the endosmosis from water occasioned by other fluids, would lead us to conclude that in placing such a fluid as gum-water or sugar-water in an endosmometer furnished with an animal membrane, and in contact externally with an acid solution of appropriate density, we should have a much more rapid endosmosis towards the included fluid than if it were pure water in which the endosmometer was plunged; and this in fact is what I have found to be the case by experiment. Into an endosmometer, closed with a piece of bladder, I poured a solution of five parts of sugar in twenty-four parts of water. Having plunged the reservoir of the instrument into water, I obtained in the course of an hour an ascent of the included fluid, which may be represented by the number 9. The reservoir of the same endosmometer filled with a portion of the same saccharine solution, having been plunged into a solution of oxalic acid, the density of which was 1.014, (3.2 parts acid to 100 solution,) I obtained in the course of an hour an ascent of the included fluid, which required to be represented by the number 27. The substitution of a solution of oxalic acid for pure water consequently caused the amount of endosmosis in the same interval of time to be tripled. I obtained like results with the tartaric and citric acids, employed of the densities required to enable them to produce endosmosis towards water. From these experiments it would appear that water, charged with a small proportion of one of the acids, of which mention has been made, possesses a *power of penetration* athwart animal membranes greater than that inherent in pure water. But a direct experiment, detailed in an earlier part of this paper, proves that this is not the case; pure water used by itself is still the fluid that possesses the greatest power of penetrating through animal membranes. If, consequently, in those experiments which I have last described, the water charged with acid passed more readily and more copiously into the saccharine solution than pure water, this happens undoubtedly from other causes or conditions which I cannot take upon me to explain, but which appear to be: 1st. A reciprocal action between the two heterogeneous fluids, an action which modifies, which even completely inverts the natural power of penetration possessed by each of the fluids when employed singly; 2d. A particular action of the membrane upon the two fluids which penetrate it, an action which, with the animal membrane, gives the *stronger current* or current of endosmosis to the acid solution of due density, and the *weaker current* or counter-current of exosmosis to the pure water. It seems to me impossible to deny this peculiar action to the animal membrane, when we see that a vegetable membrane in the same circumstances produces endosmotic phenomena directly the reverse. The peculiar influence of the membranous septum is likewise manifested in a very striking way in the experiment in which I have shown that the current of endosmosis flows from water towards alcohol when these two fluids are divided by an animal membrane, and, on the contrary, that the current of endosmosis flows from alcohol towards water when the two fluids are separated by a membranous septum of caoutchouc.

Endosmosis, in the present order of things, is a phenomenon restricted to the realm of organization; it is nowhere observed in the inorganic world. It is in fact only among organized beings that we observe fluids of different density separated by thin septa and capillary pores; we meet with nothing of the same kind among inorganic bodies. Endosmosis, then, is a physical phenomenon inherent exclusively in organic bodies, and observation teaches us that this phenomenon plays a part of the highest importance in their economy. It is among vegetables especially that the importance of the phenomenon strikes us; I have, in fact, demonstrated that it is to endosmosis that are due, in great part, the motions of the sap, and particularly its very energetic ascending motion. I have also shown that all the spontaneous motions of vegetables are referable to endosmosis. The organic vegetable tissue is composed of a multitude of agglomerated cells mingled with tubes. The whole of these hollow organs, the parietes of which are extremely thin, and which contain fluids the densities of which vary, necessarily make mutual exchanges of their contents by way of endosmosis and exosmosis. Nor can we suppose but that the same phenomena take place among the various cells and cavities exhibited by the organism of animals. But the effects of endosmosis, its influence on the physiological phenomena presented by animals, has yet to be determined; and here, undoubtedly, the physiologist has an ample field before him for inquiry. I shall only say in conclusion, and with reference to this very interesting part of the subject, that I have satisfied myself that it is to endosmosis that the motions of the well-known *spiral spring tubes* of the milt of the cuttle-fish, when put into water, are owing.

(H. Dutrochet.)

ENTOZOA, (εντος, intus, ζωον, animal,) ελμινθες στρογγυλοι, ελμινθες πλατειαι, ασκαριδες, Arist. et Antiq. *Vers Intestinaux*, Cuv. *Entelmintha, Splanchnelmintha*, Zeder.

The term Entozoa, like the term *Infusoria*, is indicative of a series of animals, associated together chiefly in consequence of a similarity of local habitation; which in the present class is the internal parts of animals.

In treating therefore of the organization of these parasites, we are compelled to consider them, not as a class of animals established on any common, exclusive, or intelligible characters, but as the inhabitants of a peculiar district or country.

They do not, indeed, present the types of so many distinct groups as those into which the naturalist finds it necessary to distribute the subjects of a local Fauna, yet they can as little be regarded as constituting one natural assemblage in the system of Animated Nature. And it may be further observed that as the members of no single class of animals are confined to one particular country, so neither are the different natural groups of Entozoa exclusively represented by species parasitic in the interior of animal bodies. Few zoologists, we apprehend, would dissociate and place in separate classes, in any system professing to set forth the natural affinities of the animal kingdom, the *Planariæ* from the *Trematoda*, or the *Vibrionidæ* from the microscopic parasite of the human muscles.

In the present article it is proposed to divide the various animals confounded together under the common term of Entozoa or Entelmintha into three primary groups or classes; and, as in speaking of the traits of organization common to each, it becomes not only convenient but necessary to have terms for the groups so spoken of, they will be denominated *Protelmintha, Sterelmintha*, and *Cœlelmintha* respectively.

It may be observed that each of these groups, which here follow one another in the order of their respective superiority or complexity of organization, has been indicated, and more or less accurately defined by previous zoologists. After the dismemberment of the *Infusoria* of Cuvier into the classes *Polygastrica* and *Rotifera*, which resulted from the researches of Professor Ehrenberg into the structure of these microscopic beings, there remained certain families of Animalcules which could not be definitely classed with either: these were the *Cercariadæ* and *Vibrionidæ*. Mr. Pritchard, in his very useful work on Animalcules, has applied to the latter family the term *Entozoa*, from the analogy of their external form to the ordinary species of intestinal worms; and it is somewhat singular that a species referrible to the *Vibrionidæ* should subsequently have been detected in the human body itself. Premising that the tribe *Vibrionidæ* as at present constituted is by no means a natural group, and that some of the higher organized genera, as *Anguillula*, are referrible to the highest rather than the lowest of the classes of Entozoa, we join the lower organized genera, which have no distinct oviducts, and which, like the parasitic *Trichina*, resemble the fœtal stage of the Nematoid worms, with the *Cercariadæ*, in which the generative apparatus is equally inconspicuous; and these families, dismembered from the *Infusoria* of Lamarck, constitute the class Protelmintha, the first or earliest forms of *Entozoa*.

The second and third classes correspond to the two divisions of the class *Intestinalia*, in the 'Règne Animal' of Cuvier, and which are there respectively denominated 'Vers Intestinaux Parenchymateux,' and 'Vers Intestinaux Cavitaires.' The characters of these classes will be fully considered hereafter; and in the meanwhile but little apology seems necessary for inventing names expressive of the leading distinction of each group as Latin equivalents for the compound French phrases by which they have hitherto been designated. Ελμινς appears to have been applied by the Greeks to the intestinal worms generally, as Aristotle speaks of ελμινθες πλατειαι, *intestinalia lata*, and ελμινθες στρογγυλαι, *intestinalia teretia*. In framing the terms *Sterelmintha* and *Cœlelmintha*, from ελμινς στερεα, a solid or parenchymatous worm, and ελμινς κοιλη, a hollow or cavitary worm, I follow the example of Zeder, and omit the aspirate letter. It may be observed by the way that Zeder's term *Splanchnelmintha*, besides including animals which are developed in other parts than the viscera, is, like the term *Entozoa*, open to the objection of being applied to a series of animals which, according to their organization, belong to distinct classes.

The limits and object of the present article obviously forbid an extensive or very minute consideration of the anatomical details of each of these classes of animals, and we are compelled to confine ourselves almost exclusively to such illustrations of their respective plans of organization as are afforded by the species referrible to each which inhabit the human body.

If a drop of the secretion of the testicle be expressed from the divided vas deferens in a recently killed mammiferous animal, which has arrived at maturity, and be diluted with a little pure tepid water and placed in the field of a microscope, a swarm of minute beings resembling tadpoles will be observed moving about with various degrees of velocity, and in various directions, apparently by means of the inflexions of a filamentary caudal appendage. These are the seminal animalcules, Zoosperms, or *Spermatozoa* (*fig.* 51): and, as it is still undetermined whether they are to be regarded as analogous to the moving filaments of the pollen of plants, or as independent organisms, it has been deemed more convenient to consider them zoographically in the present article as members of the class Entozoa.

The body to which the tail is attached is of an oval and flattened or compressed form, so that, when viewed sideways, the Zoosperm appears to be a moving filament like a minute *Vibrio*. It is this compressed form of the body which principally distinguishes the *Spermatozoa* or seminal *Cercariæ*, from the true *Cercariæ* of vegetable infusions, in which the body is ovoid or cylindrical; the caudal appendage of the *Spermatozoa* is also proportionally longer than in the *Cercariæ*.

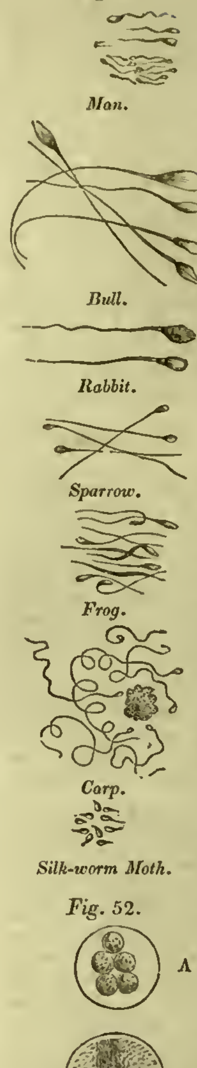
In some species of the latter genus an oral aperture and ocelliform specks of an opake red colour have been observed on the anterior part of the body, and they manifest their sensibility to light by collecting towards the side of the vessel exposed to that influence. In the Zoosperms, which are developed exclusively in the dark recesses of animal bodies, the simplest rudiments of a visual organ would be superfluous; they are, in fact, devoid of ocelli, and even an oral aperture has not yet been detected in these simplest and most minute of *Entozoa*. In neither the Zoosperms nor the *Cercariæ* has the polygastric structure been determined. On the contrary, some of the non-parasitic species, as the *Cercaria Lemnæ*, are stated to have 'a true alimentary canal, not polygastric.'*

The *Spermatozoa* are not, however, the only examples of the present order of *Protelmintha* which have their *habitat* in the interior of living animals; many of the *Entozoa* themselves have been observed to be infested by internal parasites, which are referrible by their external form to the *Cercariadæ*.

Although no distinct organs of generation have been detected, there is reason to suspect that the *Spermatozoa* are oviparous: they are also stated to propagate by spontaneous fission; the separation taking place between the disc of the body and the caudal appendage; each of which develope the part required to form a perfect whole.

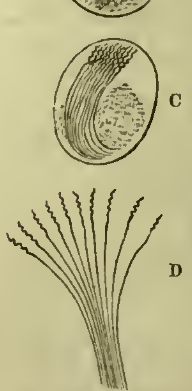
The Zoosperms of each genus of animals present differences of form or proportion, and frequently also differences of relative size as compared to the animal in which they are developed; thus, in the figures subjoined, which are all magnified in the same degree, the Zoosperm from the Rabbit is nearly as large as that from the Bull, (*fig.* 51.)

Fig. 51.



Silk-worm Moth.

Fig. 52.



Development of Spermatozoa, Bunting.

They appear to be formed in the seminal secretion under similar laws to those which preside over the development of other *Entozoa* in the mucous secretion of the Intestines, &c., but are more constant in their existence, and must therefore be regarded as fulfilling some more important office in the economy of the animal in which they exist.

They are not found in the seminal passages or glands until the full period of puberty; and in some cases would seem to be periodically developed. In the Hedgehog and Mole, which exhibit a periodical variation in the size of the testes in a well-marked degree, the Spermatozoa are not observable in those glands during their state of quiescence and partial atrophy. Professor Wagner* examined the testes of different Passerine Birds in the winter season, when those bodies are much diminished in size. (See vol. i. p. 354, *fig.* 183.) They then contained only granular substances, without a trace of the *Spermatozoa*. When the same bodies were examined in spring, they were found to contain spherical granules of different sizes and appearances, (A, B, *fig.* 52,) which led to the supposition that they were the ova of the *Spermatozoa* in different stages of development, and capsules containing each a numerous group of *Spermatozoa* (C) were also present; whence it would appear that many of these animalcules were developed from a single ovum. In the semen contained in the vasa deferentia the *Spermatozoa* (D) were in great numbers, having escaped from their capsules; they exhibit a remarkable rotation on their

* Pritchard's Animalcules, p. 184.

* Müller's Archiv. 1836, p. 225.

axis, which continues for five or ten minutes after the death of the bird in which they are developed. Some have supposed that these animalcules were the result of a putrefactive process, but this is disproved by their presence in testicles which have been removed from living animals, and by their ceasing in fact to exist when the seminal secretion begins to undergo a decomposition. Their extraordinary number is such that a drop of semen appears as a moving mass, in which nothing can be distinguished until it has been diluted as before-mentioned, when the animalcules are seen to disengage themselves and commence their undulatory movements. By means of the continual agitation thus produced the chemical elements of the fecundating fluid are probably kept in a due state of admixture. By the same movements the impregnating influence of the semen may be carried beyond the boundary which it reaches in the female organs from the expulsive actions of the coitus. It has been conjectured that from the rapid and extensive multiplication of these animalcules they may contribute to produce the stimulus of the rut. But the consideration of the part which the Zoosperms may play in generation belongs to the Physiological history of that function, and would lead to discussions foreign to the present article, which treats of their form and structure simply as the parasites of animal bodies.

In the human subject the form of the Zoosperm is accurately represented in *fig.* 51.

Among the cold-blooded Reptiles the Zoosperms of the Frog (*fig.* 51) have been examined with most attention, and have been the subject of interesting experiments in the hands of Spallanzani and Dumas.

The milt or developed testicle of the osseous Fishes abounds with moving bodies of a globular form. In the Shark and Ray the Zoosperms are of a linear and spiral form.

The molluscous animals are favourable subjects for the examination of the present tribe of *Entozoa* on account of the great relative size of the parasites of the seminal secretion. They are mostly of a filamentary form, and have long been known in the Cephalopods. The Zoosperms of the Snail (*Helix Pomatia*) present an undulated capillary body, and move sufficiently slowly to permit their being readily followed by the eye.

The *Spermatozoa* have been detected and described in the different classes of the Articulate Animals. In Insects they are of a fine capillary form, and are generally aggregated in bundles. They abound in the semen of the Anellides and Cirripeds; lastly, these parasites have been found to exist in vast numbers in the spermatic tubes of the higher organized Entozoa themselves.

The second tribe of *Protelmintha* includes those cylindrical, filiform, eel-like, microscopic Animalcules which abound in decayed vegetable paste, stale vinegar, &c. together with others which have attracted particular attention by the destructive waste caused by certain species which are parasitic on living vegetables. These animalcules are termed *Vibrionidæ* from their darting or quivering motion. They differ from the polygastric Infusories, not only in the absence of internal stomachs but also of external cilia, which is inferred by their not exciting any currents when placed in coloured water. They present a higher grade of organization than the *Cercarian* tribe in the presence of a straight alimentary canal, which is remarkably distinct in some of the higher forms of the group, as the *Gordioides* and *Oxyuroides* of Bory St. Vincent.

The higher organized *Vibriones* have distinct generative organs, and are ovo-viviparous.

In the species of *Vibrio* which infests the grains of wheat and occasions the destructive disease called Ear-cockle or Purples, Mr. Bauer found the ova arranged between the alimentary canal and the integument, in a chaplet or moniliform oviduct which terminated by a bilabiate orifice at a little distance from the caudal extremity of the body. The ova are discharged at this orifice in strings of five or six, adhering to each other. Each egg is about $\frac{1}{300}$th of an inch long, and $\frac{1}{800}$th or $\frac{1}{900}$th in diameter: and they are sufficiently transparent to allow of the young worm being seen within: and the embryo, in about an hour and a half after the egg is laid, extricates itself from the egg-coverings. Of the numerous individuals examined by Mr. Bauer, not any exhibited external distinctions of sex, and he believes them to be hermaphrodites.

In the *Anguillula aceti*, or common Vinegar-eel, Bory St. Vincent has distinguished individuals in which a slender spiculum is protruded from the labiate orifice corresponding to that above described from which the ova are extruded; these individuals he considers to be males; they are much less numerous than the females; are considerably smaller; and the internal chaplet of ova is not discernible in them. In the female the ova are arranged in two series on each side of the alimentary canal, and the embryo worms are usually seen to escape from the egg-coverings while yet within the body of the parent, and to be born alive. Ehrenberg figures the two sexes of *Anguillula fluviatilis* in his first treatise on the *Infusoria* (tab. vii. fig. 5.*) The granular testis and intromittent spiculum, which is single, are conspicuous in the male; the ova in the female are large and arranged as in *Anguillula aceti*. Such an organization, it is obvious, closely approximates these higher Vibrionidæ to the nematoid Entozoa, as the *Ascarides* and *Oxyuri*, and further researches on this interesting group will doubtless lead to the dismemberment of the Oxyuroid family from the more simple *Vibrionidæ*, as the genera *Bacterium*, *Spirillum*, and *Vibrio*, with which they are at present associated.

To the group composed of the three last-named genera, the microscopic parasite of the human muscles, termed *Trichina Spiralis*, is referrible.†

* Organisation, systematik und georaphisches Verhältniss der Infusionthierchen, 1830.

† Zool. Trans. vol. i. p. 315, and Zool. Proceedings, for February, 1835.

This singular Entozoon I discovered in a portion of the muscles of a male subject, which was transmitted to me for examination, at the beginning of 1835, by Mr. Wormald, Demonstrator of Anatomy at St. Bartholomew's Hospital, on account of a peculiar speckled appearance of those parts. This state of the muscles had been noticed by that gentleman as an occasional but rare occurrence in subjects dissected at St. Bartholomew's in several previous years.

The portion of muscle was beset with minute whitish specks, as represented in the subjoined cut (*fig.* 53): and in fourteen subsequent instances which have come to my knowledge of the presence of this entozoon in the human subject, the muscles have presented very similar appearances. The specks are produced by the cysts containing the worm, and vary, as to their distinctness, according to their degrees of opacity, whiteness, and hardness.

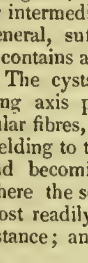
Fig. 53.

Cysts of the Trichina Spiralis in situ, natural size.

The cysts are very readily detected by gently compressing a thin slice of the infected muscle between two pieces of glass and applying a magnifying power of an inch focus. They are of an elliptical figure, with the extremities more or less attenuated, often unequally elongated, and always more opaque than the body or intermediate part of the cyst, which is, in general, sufficiently transparent to shew that it contains a minute coiled-up worm.

The cysts are always arranged with their long axis parallel to the course of the muscular fibres, which probably results from their yielding to the pressure of the contained worm, and becoming elongated at the two points where the separation of the muscular fasciculi most readily takes place, and offers least resistance; and for the same reason one or both of the extremities of the cyst become from repeated pressure and irritation thicker and more opaque than the rest. That the adhesive process in the cellular tissue, to which I refer the formation of the cyst, was most active at the extremities of the cyst is also evinced by the closer adhesion which these parts have to the surrounding cellular tissue.

Fig. 54.



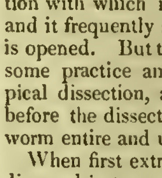
A separate Cyst of the Trichina, which is seen coiled up through the transparent coats, magnified.

The cysts measure generally about $\frac{1}{50}$th of an inch in their longitudinal, and $\frac{1}{100}$th of an inch in their transverse diameters: like other cysts which are the result of the adhesive inflammation, they have a rough exterior, and are of a laminated texture. The innermost layer (*fig.* 54), however, can sometimes be detached entire, like a distinct cyst, from the outer portion, and its contour is generally well marked when seen by transmitted light. By cutting off the extremity of the cyst, which may be done with a cataract needle or fine knife, and gently pressing on the opposite extremity, the Trichina and the granular secretion with which it is surrounded, will escape; and it frequently starts out as soon as the cyst is opened. But this delicate operation requires some practice and familiarity with microscopical dissection, and many attempts may fail before the dissector succeeds in liberating the worm entire and uninjured.

When first extracted, the Trichina is usually disposed in two or two and a half spiral coils: when straightened out (which is to be done with a pair of hooked needles, when the surrounding moisture is so far evaporated as that the adhesion of the middle of the worm to the glass it rests upon shall afford a due resistance to a pressure of the needle upon the extremities), it measures $\frac{1}{30}$th of an inch in length and $\frac{1}{700}$th of an iuch in diameter, and now requires for its satisfactory examination a magnifying powei of at least 200 linear admeasurement.

The worm (*fig.* 55) is cylindrical and filiform, terminating obtusely at both extremities, which are of unequal sizes; tapering towards one end for about one-fourth part of its length, but continuing of uniform diameter from that point to the opposite extremity.

Fig. 55.



Trichina spiralis magnified.

Until lately it was only at the larger extremity that I have been able to distinguish an indication of an orifice, and this is situated in many specimens in the centre of a transverse, bilabiate, linear mouth, (*a*, *fig.* 54.)

A recently extracted living worm, when examined by a good achromatic instrument before any evaporation of the surrounding fluid has affected the integument, presents a smooth transparent exterior skin, inclosing apparently a fine granular parenchyma. It is curious to watch the variety of deceptive appearances of a more complex organization which result from the wrinkling of the delicate integument. I have sometimes perceived what seemed to be a sacculated or spiral intestine; and, as evaporation proceeds, this has apparently been surrounded by minute tortuous tubes; but the fallacy of the latter appearance is easily detected. A structure, which I have found in more recent and better preserved specimens than those which were the subjects of my first description, is evidently real, and may probably belong to the generative system of the *Trichina*; it consists of a small rounded cluster of granules of a darker or more opaque nature than the rest of the body; it is situated about one-fifth of the length of the animal from the larger or anterior extremity, and extends about half-way across the body.

Dr. Arthur Farre, whose powers of patient and minute observation and practised skill with the microscope, are well known to those who have the pleasure of his acquaintance, discovered, by the examination of recent Trichinæ under favourable circumstances, that they possess an intestinal canal with distinct parietes. He describes it as commencing at the large end of the worm, bounded by two parallel but slightly irregular lines for about one-fifth of the length of the body, and then assuming a sacculated structure which "becomes gradually lost towards the smaller end where the canal assumes a zig-zag or perhaps spiral course, and at length terminates at the small end."*

In a recent examination of some *Trichinæ* from an aged male subject at St. Bartholomew's Hospital, I perceived a transverse slit close to the small extremity on the concave side, which I regard as the anus.

The muscles which are affected by the *Trichinæ* are those of the voluntary class; and the superficial ones are found to contain them in greater numbers than those which are deep-seated; the pectoralis major, latissimus dorsi, and other large flat muscles usually present them in great abundance. They have been detected in the muscles of the eye, and even in those belonging to the ossicles of the ear, and of whose actions we are wholly unconscious: they also occur in the diaphragm, in the muscles of the tongue, in those of the soft palate, in the constrictors of the pharynx, in the levator ani, in the external sphincter ani, and in the muscles of the urethra. But they have not yet been detected in the muscular tunic of the stomach and intestines, in the detrusor urinæ, or in the heart. It is an interesting fact that all the muscles infested by the *Trichina* are characterized by the striated appearance of the ultimate fasciculi: while the muscles of organic life, in which they are absent, have, with the exception of the heart, smooth fibres, not grouped into fasciculi, but reticularly united.

From the instances of this parasitical affection of the human body which have already been recorded, and from other unpublished cases in which I have examined the worms, it is evident that their presence in the system is unconnected with age, sex, or any particular form of disease. They have been found in the bodies of persons who have died of cancer of the penis; tubercles in the lungs; exhaustion of the vital powers by extensive external ulceration of the leg; fever combined with tubercles in the lungs; aneurism of the aorta; sudden depression of the vital powers after a comminuted fracture of the humerus; diarrhœa.

The cases which had occurred before the publication of the first description of this Entozoon led me to conceive that, although the species was of so minute a size, yet the number of individuals infesting the body was so immense, and their distribution through the muscular system so extensive, that they might occasion debility from the quantity of nutriment required for their support; and I observed "that it was satisfactory to believe, that the *Trichinæ* are productive of no other consequences than debility of the muscular system; and it may be questioned how far they can be considered as a primary cause of debility, since an enfeebled state of the vital powers is the probable condition under which they are originally developed. No painful or inconvenient symptoms were present in any of the above-mentioned cases to lead the medical attendants to suspect the condition of the muscular system, which dissection afterwards disclosed: and it is probable that in all cases the patient himself will be unconscious of the presence of the microscopic parasites which are enjoying their vitality at his expense."* Since writing the above, a case has occurred in which the Trichinæ were met with in the muscles of a man who was killed while in the apparent enjoyment of robust health by a fracture of the skull. I received portions of the muscles of the larynx of this individual from my friend Mr. Curling, Assistant-Surgeon to the London-Hospital, who has recorded the case in the Medical Gazette, and the worms were similar in every respect to those occurring in the diseased subjects. The deduction therefore of the development of the *Trichina* being dependent on an enfeeblement of the vital powers is invalidated by this interesting example.†

Leaving now the consideration of Entozoa, which from their minute size and organization would have ranked with the vast assemblage of animalcules which are collected under the head *Infusoria* in the Règne Animal, we come next to the consideration of the animals which form that scarcely less heterogeneous class, the *Entozoa* of Rudolphi. These are distributed by that Naturalist into five orders, which may be synthetically arranged and characterized as follows.

ORDO I. CYSTICA, Rud. (κυστις, *vesica.*) *Vermes vesiculares*, *Blasenwürmer*, *Cyst-worms* or Hydatids.

Char. *Body* flattened or rounded, continued posteriorly into a cyst, which is sometimes common to many individuals. *Head* provided with pits (*bothria* two or four) or suctorious pores (four), and with a circle of hooklets or with four unarmed or uncinated tentacles. No discernible organs of generation.

Obs. This order is not a very natural one; the species composing it are closely allied to the Tape-worms in the structure of the head, and when this is combined with a jointed structure of the body, as in the *Cysticercus fascioluris* common in the liver of Rats, the small caudal vesicle forms but a slight ground for a distinction of ordinal importance. The *Cystica* of Rudolphi form part of the Order *Tænioidea* of Cuvier; and may be regarded as representing

* See Medical Gazette, December, 1835.

* Zoological Transactions, vol. i. p. 315.
† Zool. Trans. vol. i. p. 323.

the immature states of the higher orders of *Sterelmintha.*

ORDO II. CESTOIDEA, (κεστος, *cingulum*, ειδος, *forma.*)

Vermes tæniæformes, *Bandwürmer*, *Tape-worms.*

Char. *Body* elongated, flattened, soft, continuous, or articulated. *Head* either simply labiate, or provided with pits *(bothria)* or suctorious orifices *(oscula suctoria)* either two or four in number, and sometimes with four retractile unarmed or uncinated tentacles. Androgynous generative organs.

Obs. In this order Rudolphi includes the inarticulated *Ligulæ*, with simple heads unprovided with bothria or suckers; a conjunction which detracts from the natural character of the group. Cuvier separates the *Ligulæ* from the *Tæniæ*, and they form exclusively his Order *Cestoidea;* it must be observed, however, that the passage from the one to the other is rendered very gradual by the traces of bothria, and of generative organs which appear in the higher organized *Ligulæ* found in the intestines of Birds; and respecting which Rudolphi hazards the theory that they are the more simple *Ligulæ* of Fishes, developed into a higher grade of structure by the warmth and abundant nutriment which they meet with in the intestines of Birds which have swallowed the Fishes infested by them.

ORDO III. TREMATODA, (τρημα, *foramen*, τρηματωδης *foraminosus.*)

Vermes suctorii, *Saugwürmer*, *Flukeworms.*

Char. *Body* soft, rounded, or flattened. *Head* indistinct, with a suctorious foramen; generally one or more suctorious cavities for adhesion in different parts of the body. *Organs of both sexes* in each individual.

Obs. This very natural order includes, in the system of Cuvier, many species which do not infest other animals, but are found only in fresh waters; these non-parasitic species form the greater part of the genus *Planaria* of Muller, (*fig.* 80.) Rudolphi, who seems to have supposed the *Planariæ* to be of a more simple organization than they truly possess, approximates them to the Ligulæ or inarticulated *Cestoidea.* Other naturalists, unwilling to associate the *Planariæ* with the Entozoa, have placed them in the Class Anellida, but the absence of a ganglionic abdominal nervous chord, of a floating intestine, and of an anus, renders such an association very arbitrary.

ORDO IV. ACANTHOCEPHALA, (ακανθα, *spina*, κεφαλη, *caput.*)

Vermes uncinati, *Hacken-würmer*, *Hooked-worms.*

Char. *Body* elongated, round, sub-elastic. *Head* with a retractile proboscis armed with recurved spines, (*fig.* 74.) *Sexual Organs* appropriated to distinct individuals, male and female.

Obs. This natural group includes the most noxious of the internal parasites; fortunately no species is known to infest the human body. They abound in the lower animals, and present great diversity of form, some being cylindrical and others sacciform.

ORDO V. NEMATOIDEA, (νημα, *filum*, ειδος, *forma.*)

Vermes teretes, *Rund-würmer. Round-worms.*

Char. *Body* elongated, rounded, elastic. *Mouth* variously organized according to the genera. A true intestinal canal terminating by a distinct anus. *Sexes* distinct.

Obs. The internal character which Rudolphi has introduced in his definition of this Order,* viz. that derived from the structure of the alimentary canal, its free course through the body, and its termination by a distinct anus at the extremity opposite the mouth, is one of much greater value than any of the external modifications of the body which characterize the four preceding orders. It is, in fact, a trait of organization which is accompanied by corresponding modifications of other important parts, more especially the nervous system.

The Entozoa which manifest this higher type of structure form in the system of Cuvier a group equivalent to that which is constituted by the four other orders combined. The Entozoa composing the first four orders above characterized have no distinct abdominal cavity or intestine, but the digestive function is carried on in canals without an anal outlet excavated in the parenchymatous substance of the body, and Cuvier accordingly denominates them the *Vers intestinaux parenchymateux.* The *Nematoidea*, with which Cuvier rightly associates the genus *Pentastoma* of Rudolphi, and also (but less naturally) the *Vers rigidules* of Lamarck, or Epizoa, he denominates '*Vers intestinaux cavitaires.*'

With respect to the Epizoa, or the external Lernæan parasites of Fishes, although they agree with the Nematoidea and all inferior Entozoa in the absence of distinct respiratory organs, yet the ciliated natatory members which they possess in the young state, and the external ovarian appendages of the adult, are characters which raise them above the Entozoa as a distinct and higher class of animals, having intimate relations with the soft-skinned Siphonostomous Crustaceans.

Limiting, then, the Cavitary Entozoa to the *Nematoidea* of Rudolphi, and the Genera *Linguatula*, *Pentastoma*, *Porocephalus*, and *Syngamus*, which, under the habit of Cestoid or Trematode Worms, mask a higher grade of organization, we propose to regard them as a group equivalent to the *Sterelmintha*, and to retain for them the name of *Cœlelmintha.*

The class of Entozoa thus constituted embraces already the types of three different orders, of which one is formed by the *Nematoidea* of Rudolphi, a second has been established by Diesing for the genus *Pentastoma* and its congeneric forms, under the name of

* "Corpus teres elasticum, tractus intestinalis hinc ore, illinc ano terminatus. Alia individua mascula, alia feminea."—*Synops. Entoz.* p. 3.

Acanthotheca; and the singular organization of the *Syngamus* of Siebold, presently to be described, clearly indicates the type of a third order of Cavitary Entozoa.

As a short description has already been given of the species of Protelmintha which inhabit the human body, we shall proceed to notice those species belonging to the two divisions of Entozoa above defined, which have a similar locality, before entering upon the organization of the class generally.

The first and simplest parasite which demands our attention is the common globular Hydatid, which is frequently developed in the substance of the liver, kidney, or other abdominal viscera, and occasionally exists in prodigious numbers in dropsical cysts in the human subject.

Considerable diversity of opinion still exists as to the nature of these ambiguous productions, to which Laennec first gave the name of Acephalocysts; we shall nevertheless admit them into the category of human parasites, for reasons which are stated in the following description.

The Acephalocyst is an organized being, consisting of a globular bag, which is composed of condensed albuminous matter, of a laminated texture, and contains a limpid colourless fluid, with a little albuminous and a greater proportion of gelatinous substance.

The properties by which we recognize the Acephalocyst as an independent or individual organized being are, first, growth, by intrinsic power of imbibition; and, secondly, reproduction of its species by gemmation. The young Acephalocysts are developed between the layers of the parent cyst, and thrown off either internally or externally according to the species.

As the best observers agree in stating that the Acephalocyst is impassive under the application of stimuli of any kind, and manifests no contractile power either partial or general, save such as evidently results from elasticity, in short, neither feels nor moves, it cannot, as the animal kingdom is at present characterized, be referred to that division of organic nature.

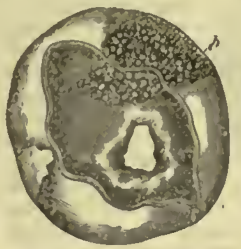
It would then be a question how far its chemical composition forbids us to rank the Acephalocyst among vegetables. In this kingdom it would obviously take place next those simple and minute vesicles, which, in the aggregate, constitute the green matter of Priestly, (*Protococcus viridis*, Agardh;) or those equally simple but differently coloured *Psychodiariæ*, which give rise to the red snow of the Arctic regions, (*Protococcus Kermesianus.*) These "first-born of Flora" consist in fact of a simple transparent cyst, and propagate their kind by gemmules developed from the external surface of the parent.

Or shall we, from the accidental circumstance of the Acephalocyst being developed in the interior of animal bodies, regard it, as Rudolphi would persuade, in the same light as an ulcer, or pustule,—as a mere morbid product?

The reasons assigned by the learned Professor* do induce us to consider the Acephalocyst as a being far inferior in the scale of organization to the *Cysticercus;* but still not the less as an independent organized species, sharing its place of development and sphere of existence in common with the rest of the Entozoa.

Acephalocystis endogena. Pill-box Hydatid of Hunter, (*fig.* 56). This species is so called from the circumstance of the gemmules being detached from the internal surface of the cyst, where they grow, and, in like manner, propagate their kind, so that the successive generations produce the appearance described by Hunter and other pathologists.

Fig. 56.



Acephalocystis endogena.

The membrane of the cyst is thin, delicate, transparent, or with a certain pearly semi-opacity; it tears readily and equally in every direction, and can, in large specimens, be separated into laminæ. The phenomenon of endosmose is readily seen by placing the recent Acephalocyst in a coloured liquid, little streams of which are gradually transmitted and mingle with the fluid of the parasite. The vesicles or gemmules, developed in the parietes of the cyst, may be observed of different sizes, some of microscopic dimensions, others of a line in diameter before they are cast off, see *fig.* 56, where *a* shows the laminated membrane, *b* the minute Acephalocysts developed between its layers.

The Acephalocyst of the Ox and other Ruminant Animals differs from that of the Human Subject in excluding the gemmule from the external surface, whence the species is termed *Acephalocystis exogena* by Kuhl. Both kinds are contained in an adventitious cyst, composed of the condensed cellular substance of the organ in which they are developed.

The Genus *Echinococcus* is admitted by Rudolphi into the Order *Cystica*, less on account of the external globular cyst, which, like the Acephalocyst, is unprovided with a head or mouth, than from the structure of the minute bodies which it contains, and which are described as possessing the armed and suctorious head characteristic of the *Cœnuri* and *Cysticerci*. It must be observed that Rudolphi† does not ascribe this

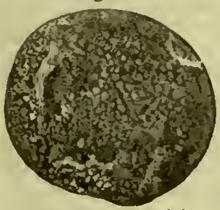
* Mihi, quidem, ea tandem hydatis animal vivum vocatur, quæ vitam propriam degit uti Cysticerci, Cœnuri, &c. Quæ autem organismi alieni (v. c. humani) particulum efficit animal, me judice, dici nequit. Mortua non est, quamdiu organismi partem sistit, uti etiam ulcus, pustula, efflorescentia; sed hæc ideo non sunt animalia.—*Synops. Entoz.* p. 551.

† Vermiculi globosi, subglobosi, obovati, obcordati, etc.; pro *capite* plus minus vel exserto vel retracto; postice mox obtusissimi, mox obtusi, mox acuti. Corona *uncinulorum*, uti videtur, duplex.

complicated structure to the vermiculi of the Human *Echinococcus* on his own authority, and speaks doubtfully respecting the coronet of hooklets and suctorious mouths of the vermiculi contained in the cyst of the *Echinococcus* of the Sheep, Hog, &c.

The *Echinococcus hominis, (fig.* 57,) which occurs in cysts in the liver, spleen, omentum, or mesentery, is composed of an external yellow coriaceous, sometimes crustaceous tunic, and an internal transparent, firm, gelatinous membrane. The form of the contained vermiculi is represented in the magnified view subjoined, *(fig.* 58,) taken from the *Elmintografia humana* of Delle Chiaje.

Fig. 57.



Echinococcus hominis.

Fig. 58.

Vermiculi of Echinococcus hominis, highly magnified.

Müller* has recently described a species of *Echinococcus* voided with the urine by a young man labouring under symptoms of renal disease. The tunic of the containing cyst was a thick white membrane, not naturally divided into laminæ; the animalcules floating in the contained fluid presented a circle of hooklets and four obtuse processes round the head; the posterior end of the body obtuse: some of them were inclosed in small vesicles floating in the large one; others presented a filamentary process at their obtuse end, probably a connecting pedicle which had been broken through.

Of the species entitled *Echinococcus veterinorum* we have carefully examined several individuals soon after they were extracted from the recently-killed animal, (a sow, in which they existed in great abundance in cysts in the abdomen.) The containing cysts were composed of two layers, artificially separable, both of a gelatinous texture, nearly colourless and subtransparent, the external one being the firmest. The contained fluid was colourless and limpid, with a few granular bodies floating in it, and immense numbers of extremely minute particles applied but not adherent to the internal surface of the cyst. On examining these particles with a high magnifying power, they were seen to be living animalcules of an ovate form, moving freely by means of superficial vibratile cilia, having an orifice at the smaller end from which a granular and glairy substance was occasionally discharged, and a trilobate depression at the greater and anterior extremity produced by the retraction of part of the body. I watched attentively and for a long period a number of these animalcules in the hope of seeing the head completely protruded, but without success. On compressing the animalculæ between plates of glass, a group of long, slender, straight, sharp-pointed spines became visible within the body, at its anterior part, and directed towards the anterior depression, precisely resembling the parts described and figured by Ehrenberg as the teeth of the Polygastric Infusories; the rest of the body was occupied by large clear globules, the stomachs? and smaller granules. Animalcules thus organized, it is evident, cannot be classed with cystic Entozoa, but must be referred to the Polygastric Infusoria.

The globular cyst which is commonly developed in the brain of Sheep differs from the *Echinococcus* in having organically attached to it a number of small vermiform appendages, provided severally with suctorious orifices, and an uncinated rostellum, similar to those in the head of the Armed Tæniæ. But as this cystic genus, denominated *Cænurus,* (κοινος, *communis,* ουρα, *cauda,* from the terminal cyst being common to many bodies and heads,) is not met with in the human subject, a simple notice of it is here sufficient.

When the dilated cyst forms the termination of a *single* Entozoon, organized as above described, it is termed *Cysticercus,* (κυστις, *vesica,* κερκος, *cauda),* and of this genus there are several species, distinguished for the most part by the forms and proportions of the neck or body intervening between the head and the cyst; as for example, the *Cyst. fasciolaris, Cyst. fistularis, Cyst. longicollis, Cyst. tenuicollis,* &c. The only species of this genus known to infest the human body is the *Cysticercus cellulosæ,* Rud. (the *Hydatis Finna* of Blumenbach). It is developed, like the Trichina, in the interfascicular cellular tissue of the muscles, and, like it, is invariably surrounded by an adventitious capsule of the surrounding substance condensed by the adhesive inflammation. *Fig.* 59 exhi-

Fig. 59.

Portion of human muscle, with Cysticercus cellulosæ.

Oscula suctoria quatuor; an hæc in omnibus? Ipse saltem in suis Echinococcis non vidi, sed dum Berolini recens examinarem, microscopio solito et bono destitutus eram.—*Hist. Entoz.*

* Archiv fur Physiol. (Jahresbericht), 1836.

bits a portion of muscle thus infested; *a* the adventitious cyst laid open, exposing the Hydatid; *a'* the adventitious cyst elongated by the extension of the head and neck of the inclosed hydatid *b* in the direction of the muscular fibres. The cysticercus itself sometimes attains the size exhibited in *fig*. 60, in which *a* indicates the

Fig. 60.

Cysticercus cellulosæ.

Fig. 61.

Magnified head of Cysticerus cellulosæ.

head, *b* the neck or body, and *c* the dilated vesicular tail. *Fig*. 61 exhibits the head sufficiently magnified to show the uncinated rostellum or proboscis *d* for irritation and adhesion, and the suctorious discs *e e* for imbibing the surrounding nutriment.

The occurrence of this Entozoon in the Human Subject appears to be less common in this country than on the Continent. In the course of five years we have become acquainted with only two cases, one in a subject at the Dissecting-Rooms of St. Bartholomew's, the other in a subject at the Webb-street School of Anatomy. Rudolphi relates that out of two hundred and fifty bodies dissected annually at the Anatomical School of Berlin, from four to five were found through nine consecutive years to be infested more or less copiously with the *Cysticercus cellulosæ*; for the most part the subjects had been of the leucophlegmatic temperament, but not affected with ascites or anasarca. The muscles most obnoxious to the Entozoon in question are the glutæi, psoas, iliacus internus, and the extensors of the thigh; they have been found also in the muscular tissue of the heart, and in parts not muscular, as the brain and eye. Soëmmering detected one specimen of the *Cysticercus cellulosæ* in the anterior chamber of the eye of a young woman æt. 18.* The following is a more recent account of a specimen which was developed in the anterior chamber of the eye of a patient in the Glasgow Ophthalmic Infirmary.

"*Case.*—From the month of August, 1832, till about the middle of January, 1833, when she was first brought to Mr. Logan, the child had suffered repeated attacks of inflammation in the left eye. Mr. L. found the cornea so nebulous, and the ophthalmia so severe, that he dreaded a total loss of sight. He treated the case as one of scrofulous ophthalmia; and after the use of alterative medicines, and the application of a blister behind the ear, the inflammatory symptoms subsided, leaving, however, a slight opacity of the lower part of the cornea. After a week, the child was again brought to Mr. L., who, on examining the eye, discovered, to his great surprise, a semitransparent body, of about two lines in diameter, floating unattached in the anterior chamber. This body appeared almost perfectly spherical, except that there proceeded from its lower edge a slender process, of a white colour, with a slightly bulbous extremity, not unlike the proboscis of a common fly. This process Mr. L. observed to be of greater specific gravity than the spherical or cystic portion, so that it always turned into the most depending position. He also remarked that it was projected or elongated from time to time, and again retracted, so as to be completely hid within the cystic portion; while this, in its turn, assumed various changes of form, explicable only on the supposition of the whole constituting a living hydatid.

"On the 3d April, when I examined the case, I found the cornea slightly nebulous, the eye free from inflammation and pain, and the appearances and movements of the animal exactly such as described by Mr. Logan. When the patient kept her head at rest, as she sat before me, in a moderate light, the animal covered the two lower thirds of the pupil. Watching it carefully, its cystic portion was seen to become more or less spherical, and then to assume a flattened form, while its head I saw at one moment thrust suddenly down to the bottom of the anterior chamber, and at the next drawn up so completely as scarcely to be visible. Mr. Meikle turned the child's head gently back, and instantly the hydatid revolved through the aqueous humour, so that the head fell to the upper edge of the cornea, now become the more depending part. On the child again leaning forwards, it settled like a little balloon in its former position, preventing the patient from seeing objects directly before her, or below the level of the eye, but permitting the vision of such as were placed above. Mr. Logan had observed no increase of size in the animal while it was under his inspection. Mr. Meikle had watched it carefully for three weeks without observing any other change than a slight increase in the opacity of the cystic portion.

"To every one who had seen or heard of Mr. Logan's case, the question naturally occurred, Ought not this animal to be removed from the eye? Mr. Logan and Mr. Meikle appeared to have deferred employing any means for destroying or removing it; first, because it seemed to be producing no mischief: and, secondly, because there was a probability that it was a short-lived animal, and likely therefore speedily to perish and shrink away, so as to give no greater irritation than a shred of lenticular capsule. Various means naturally suggested themselves for killing the animal, such as passing electric or galvanic shocks through the eye, rubbing in oil of turpentine round the orbital region, giving this medicine internally in small doses, or putting the child on a course of sulphate of quina, or some other vegetable

* See Isis, 1830, p. 717, as quoted by Nordmann, Mikrographische Beiträge zur Naturgeschichte der wirbellosen thiere.

bitter known to be inimical to the life of the Entozoa. As the patient appeared to be in perfect health, it was natural to suppose that the other organs were free from hydatids, and that a change of diet would have little or no effect upon the solitary individual in the aqueous humour. Had she, on the contrary, presented a cachectic constitution, with pale complexion, tumid belly, debility, and fever, none of which symptoms were present, we should have been led to suspect that what was visible in the eye was but a sample of innumerable hydatids in the internal parts of the body, and might have recommended a change of diet, with some hopes of success. In the course of six weeks after I saw the patient, the cysticercus having enlarged in size, the vessels of the conjunctiva and sclerotica became turgid, the iris changed in colour, and less free in its motions, while the child complained much of pain in the eye; it was decided that the operation of extraction should be attempted, and I owe to Dr. Robertson of Edinburgh, who operated, the communication of the following particulars. The incision of the cornea was performed without the slightest difficulty, but no persuasion or threats could induce the child again to open the eye; she became perfectly unruly, and the muscles compressed the eye-ball so powerfully that the lens was forced out, and the hydatid ruptured. The patient was put to bed in this state. In the evening Dr. R. succeeded in getting the girl to open the eyelids, when with the forceps he extracted from the lips of the incision the remains of the animal in shreds, it being so delicate as scarcely to bear the slightest touch. A portion of the iris remained in the wound, which nothing would induce the girl to allow Dr. R. to attempt to return.

"After the eye healed, the cornea remained clear, except at the cicatrice, where it was only semitransparent; the pupil, in consequence of adhesion to the cicatrice, was elliptical, and the opaque capsule of the lens occupied the pupillary aperture. The patient readily recognized the presence of light."

The *Cysticercus cellulosæ* occurs also in quadrupeds, and is found most commonly and in greatest abundance in the Hog, giving rise to that state of the muscles which is called "measly pork."

Of the Cestoid Order of Entozoa two species belonging to different genera infest the Human Body. The Swiss and Russians are troubled with the *Bothriocephalus latus;* the English, Dutch, and Germans with the *Tænia solium:* both kinds occur, but not simultaneously in the same individual, in the French. It is not in our province to dwell upon the medical remedies for these parasites, but we may observe that the old vermifuge mentioned by Celsus, viz. the bark of the pomegranate, is equally efficacious and safer perhaps than the *oleum terebinthinæ* commonly employed in this country for the expulsion of the Tape-worm.

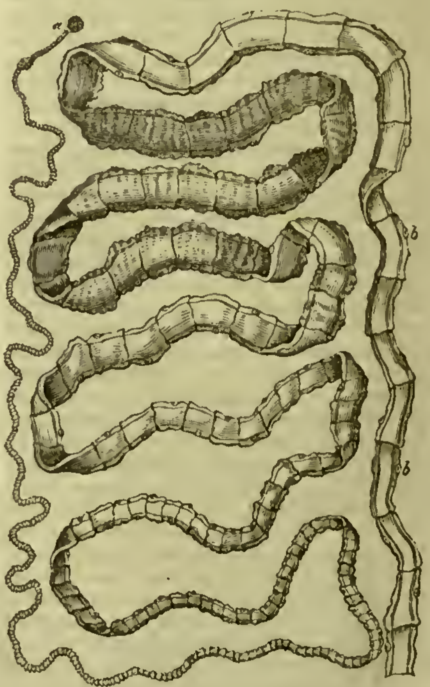
From the singular geographical distribution, as it may be termed, of the above Cestoid parasites, the *Bothriocephalus latus* rarely falls under the observation of the English Entozoologist. It may be readily distinguished from the *Tænia solium* by the form of the segments, which are broader than they are long, and by the position of the genital pores, which occur in a series along the middle of one of the flattened surfaces of the body, and not at the margin of each segment as in the *Tænia solium.* The head, which was for a long time a desideratum in natural history, has at length been discovered by Bremser. It is of an elongated form, two-thirds of a line in length, and presents, instead of the four round oscula characteristic of the true *Tæniæ*, two lateral longitudinal fossæ, or bothria, *(a a, fig.* 62, which is a highly-magnified view of the head of the *Bothriocephalus latus.)*

Fig. 62.

Head of Bothriocephalus latus magnified.

The *Tænia solium (fig.* 63) attains the length of from four to ten feet, and has been observed to extend from the pylorus to within seven inches of the anus of the human intestine.* Its breadth varies from one-fourth of a line at its anterior part to three or four lines towards the posterior part of the body, which then again diminishes. The head is small, and generally hemispherical, broader than long, and often as if truncated anteriorly: the

Fig 63.



Tænia solium, two-thirds natural size.

* See Robin, in Journal de Médecine, tom. xxv. (1766), p. 222.

four mouths, or oscula, are situated on the anterior surface, (*a*, *fig*. 63,) and surround the central rostellum, which is very short, terminated by a minute apical papilla, and surrounded by a double circle of small recurved hooks. The segments of the neck, or anterior part of the body, are represented by transverse rugæ, the marginal angles of which scarcely project beyond the lateral line; the succeeding segments are subquadrate, their length scarcely exceeding their breadth, they then become sensibly longer, narrower anteriorly, thicker and broader at the posterior margin, which slightly overlaps the succeeding joint; the last series of segments are sometimes twice or three times as long as they are broad. The generative orifices (*b*, *b*) are placed near the middle of one of the margins of each joint, and are generally alternate.

The *Tænia solium* is subject to many varieties of form or malformations; the head has been observed to present six oscula instead of four. In the Imperial Museum at Vienna, so celebrated for its entozoological collection, there is a portion of a *Tænia solium*, of which one of the margins is single and the other double, as it were two tæniæ joined by one margin. In the Museum of the College of Surgeons is preserved a fragment of the Tænia solium of unusual size; it swells out suddenly to the breadth of three-fourths of an inch with a proportionate degree of thickness, and then diminishes to the usual breadth.*

The species of *Tænia* infesting the intestines of other animals are extremely numerous, nevertheless they are rare in Fishes, in which they seem to be replaced by the *Bothriocephali* and *Ligulæ*. The determination of the species in this, as in every other natural and circumscribed genus, is extremely difficult and often uncertain: their study is facilitated by distributing them into the three following sections, of which the first includes those species which are deprived of a proboscis, *Tæniæ inermes;* the second those which have a proboscis, but unarmed, *Tæniæ rostellatæ;* the third the Tape-worms with an uncinated proboscis, *Tæniæ armatæ*.

Fig. 64.

Distoma hepaticum, twice natural size.

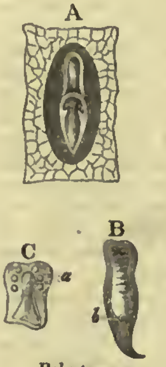
The Trematode Order, which is the most extensive division of the Parenchymatous class of Entozoa, and embraces the greatest number of generic forms, includes only two species infesting the human body, one of which, the liver-fluke (*Distoma hepaticum*), is extremely rare, and the other (*Polystoma Pinguicola*) somewhat problematical.

The *Distoma hepaticum* (*fig*. 64) is found in the gall-bladder and ducts of the liver of a variety of quadrupeds, and very commonly in the Sheep. When it occurs in the Human species, it is generally developed in the same locality. The form of this species of Entozoa is ovate, elongate, flattened; the anterior pore or true mouth (*a*) is round and small, the posterior cavity (*b*), which is imperforate and subservient only to adhesion and locomotion, is large, transversely oval, and situated on the ventral surface of the body in the anterior moiety. Between these cavities there is a third orifice (*c*) exclusively destined, like the orifice on each joint of the Tænia, to the generative system; and from which a small cylindrical process, or *lemniscus*, is generally protruded in the full-sized specimens.

The form of the body is so different in the young *Distomata*, that Rudolphi was induced to believe the specimens from the human gall-bladder which were in this state, to belong to a distinct species, which he termed *lanceolatum;* this modification, which is wholly dependent upon age, is shown in the subjoined figure; and we shall hereafter have to notice the more extraordinary changes, amounting to a metamorphosis, which the *Distomata* infesting the intestines of Fish undergo.

The *Polystoma Pinguicola* was discovered by Treutler, in the cavity of an indurated adipose tubercle, in the left ovarium of a female, ætat. 20; it is represented *in situ*, at A, *fig*. 62.

Fig. 65.



Polystoma Pinguicola.

Its natural size and shape is shewn at B, the body is depressed, subconvex above, concave below, subtruncate anteriorly, a little contracted behind the head, pointed at the posterior extremity. On the under side of the head C, there are six orbicular pores disposed in a semilunar form: a larger suctorious cavity occurs on the ventral aspect at the beginning of the tail (*b* B), and a small orifice is situated at the apical extremity.

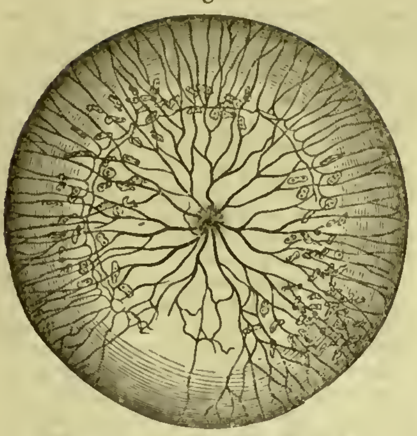
A second species of Polystoma (*Polystoma Venarum*), stated by Treutler to have been situated in the anterior tibial vein of a Man, which was accidentally ruptured while bathing, is generally supposed to have belonged to a species of *Planaria*, and to have been accidentally introduced into the strange locality above-mentioned.

The worms of the Trematode order are those which are most frequent in the interior of the eyes of different animals, perhaps the most singular situation in which Entozoa have as yet been found, and respecting which much interesting information has recently been given by Dr. Nordmann, in the first part of his beautiful work entitled "Mikrographische Beiträge zur Naturgeschicte der Wirbellosen Thiere." Of the species described and figured in that work, we have selected for illustration the *Diplostomum volvens*.

Fig. 66 exhibits a magnified view of the vitreous humour of a Perch (*Perca fluviatilis*, Linn.) containing numerous specimens of this

* See Catal. of Nat. Hist. No. 216.

Fig. 66.



Diplostomum volvens in the eye of a Perch.

parasite, which sometimes exists in such prodigious numbers, that the cavity of the eyeball is almost exclusively filled by them. They not only infest the vitreous but also the aqueous humours, and have been found in the choroid gland.

All the species of *Diplostomum* are very small, seldom exceeding a sixth part of a line in length. They resemble the genus *Distoma*, and present some affinity to the *Cercariæ*, which infest the fresh-water Snails; but they have characters peculiar to themselves which entitle them to rank as a distinct genus; of these the principal external one is the additional sucker developed on the ventral aspect of the body, as compared with *Distoma*, whence *Nordmann* calls the genus *Diplostomum*, though *Diplo-cotylus* would be the more appropriate designation, since, as before observed, the ventral depressions are simply organs of adhesion, and have no communication with the alimentary canal. Besides the suckers the Diplostomum has an anterior mouth (*a, fig.* 81), as in the *Distoma*. The first or anterior sucker (*b, fig.* 81) is twice the size of the mouth; and the second (*c, fig.* 81) is again double the size of the former. As the figure shows the vessels from the dorsal aspect, these suckers can only be seen in outline. The animal has great power over them and can contract the parenchyma of the body surrounding them, so as to make them project like rudimental extremities from the ventral surface.

It has been already observed that no species of the Acanthocephalous order of Entozoa has hitherto been found in the Human body, the illustration of this form of the *Sterelmintha* will therefore be confined to the section treating of the general anatomy of the Entozoa.

The Class *Cœlelmintha* contains several species of Entozoa which are obnoxious to man; of these may be first mentioned the Medina or Guinea-worm (*Filaria Medinensis*, Gmel.) This species is developed in the subcutaneous cellular texture, generally in the lower extremities, especially the feet, sometimes in the scrotum, and also, but very rarely, beneath the *tunica conjunctiva* of the eye. It appears to be endemic in the tropical regions of Asia aod Africa.

Fig. 67.

Filaria Medinensis.

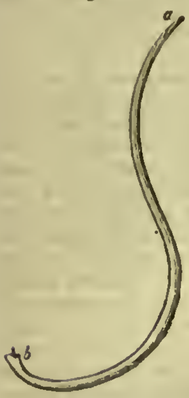
The length of this worm varies from six inches, to two, eight, or twelve feet; its thickness from half to two-thirds of a line; it is of a whitish colour in general, but sometimes of a dark brown hue. The body is round and subequal, a little attenuated towards the anterior extremity. In a recent specimen of small size, we have observed that the orbicular mouth was surrounded by three slightly raised swellings, which were continued a little way along the body and gradually lost; the body is traversed by two longitudinal lines corresponding to the intervals of the two well-marked fasciculi of longitudinal muscular fibres. The caudal extremity of the male is obtuse, and emits a single spiculum; in the female it is acute and suddenly inflected.

The *Filaria Medinensis*, as has just been observed, is occasionally located in the close vicinity of the organ of vision; but another much smaller species of the same Genus of Nematoidea infests the cavity of the eyeball itself.

The *Filaria oculi humani* was detected by Nordmann in the *Liquor Morgagni* of the capsule of a crystalline lens of a man who had undergone the operation of extraction for cataract under the hands of the Baron von Gräfe. In this instance the capsule of the lens had been extracted entire, and upon a careful examination half an hour after extraction there were observed in the fluid above-mentioned two minute and delicate *Filariæ* coiled up in the form of a ring. One of these worms, when examined microscopically, presented a rupture in the middle of its body, probably occasioned by the extracting needle, from which rupture the intestinal canal was protruding; the other was entire and measured three-fourths of a line in length; it presented a simple mouth without any apparent papillæ, (as are observed to characterize the large *Filaria* which infests the eye of the Horse,) and through the transparent integument could be seen a straight intestinal canal, surrounded by convolutions of the oviducts, and terminating at an incurved anal extremity.

The third species of *Filaria* enumerated among the *Entozoa Hominis* is the *Filaria* *bronchialis* (*fig.* 68); it was detected by Treutler* in the enlarged bronchial glands of a man: the length of this worm is about an inch; it is slender, subattenuated anteriorly (*a*), and emitting the male spiculum from an incurved obtuse anal extremity (*b*).

Fig. 68.

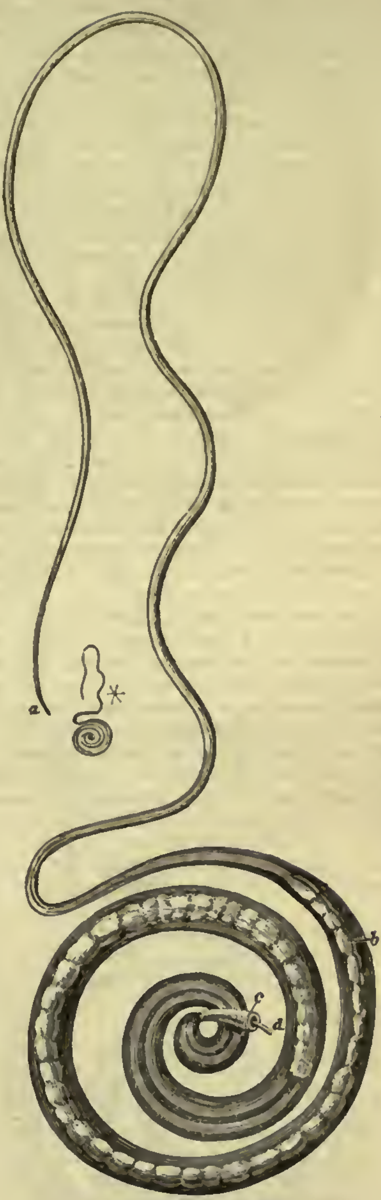


Filaria bronchialis, magnified.

The next Human Entozoon of the Nematoid order belongs to the genus *Trichocephalus*, which, like *Filaria*, is characterized by an orbicular mouth, but differs from it in the capillary form of the anterior part of the body, and in the form of the sheath or preputial covering of the male spiculum. The species in question, the *Tricocephalus dispar*, Rud. is of small size, and the male (* *fig.* 69) is rather less than the female. It occurs most commonly in the cœcum and colon, more rarely in the small intestines. Occasionally it is found loose in the abdominal cavity, having perforated the coats of the intestine. The capillary portion of this species makes about two-thirds of its entire length; it is transversely striated, and contains a simple straight intestinal canal; the head (*a*) is acute, with a small simple terminal mouth. The thick part of the body is spirally convoluted on the same plane, and exhibits more plainly the dilated moniliform intestine (*b*); it terminates in an obtuse anal extremity, from the inner side of which project the intromittent spiculum and its sheath (c, *d*). The corresponding extremity in the female exhibits a simple foramen, which, like the outlet of a cloaca, serves the office of both anus and vulva.

With respect to the following parasite of the Human body, the *Spiroptera Hominis*, Rud., considerable obscurity prevails. A poor woman, who is still living in the workhouse of the parish of St. Sepulchre, London, has been subject, since the year 1806, (when she was twenty-four years old,) up to the present time, to retention of urine, accompanied with distress and pain indicative of disease of the bladder. The catheter has been employed from time to time during this long period to draw off the urine, and its application has been, and continues occasionally to be, followed by the extraction and subsequent discharge of worms, or vermiform substances, with numerous small granular bodies. The latter are of uniform size, resembling small grains of sand: those which we have examined, and which were preserved in spirit, present a subglobular, or irregularly flattened form; but when recently

Fig 69.



Trichocephalus dispar. (**Natural size.*)

expelled, I am assured by my friend Dr. Arthur Farre, that they are perfectly spherical; they consist of an external smooth, firm, diaphanous coat, including a compact mass of brown and minutely granular substance. The inner surface of the containing capsule presents, under the microscope, a regular, beautiful, and minute reticulation, produced by depressions or cells of a hexagonal form. These, therefore, we regard as ova, and not as fortuitous morbid productions.* The vermi-

* Opusc. Patholog. Anat. p. 10, tab. ii. fig. 3—7. *Hamularia Lymphatica.*

* "Ovula vero sic dicta subglobosa cum arenulis

form substances are elongated bodies of a moderately firm, solid, homogeneous texture, varying in length from four to eight inches; attenuated at both extremities; having the diameter of a line half-way between the extremities and the middle part, where the body is contracted and abruptly bent upon itself. Some are irregularly trigonal, others tetragonal. In the three-sided specimens one surface is broad, convex, and smooth; the other two are narrow and concave, and separated by a narrow longitudinal groove, in which is sometimes lodged a filamentary brown concretion. In the tetragonal portions the broad smooth surface is divided into two parts by the rising of the middle part of the convexity into an angle. The most remarkable appearance in these ambiguous productions is the beautiful crenation of one of the angles or ridges between the convex and concave facet; which, from its regularity and constancy, can hardly be accounted for on the theory of their nature and origin suggested by Rudolphi: 'lymphamque in canalibus fistulosis coactam passimque compressam filum inæquale efformare crediderim.'* On the other hand it is equally difficult to form any satisfactory notion of these substances as organized bodies growing by an inherent and independent vitality. We have not been able to observe a single example in which the substance had both extremities well defined and unbroken; these, on the contrary, are flattened, membranous, and more or less jagged and irregular. They present no trace of alimentary or generative orifices on any part of their exterior surface, nor any canals subservient to those functions, in the interior parenchyma. If subsequent observations on recently expelled specimens of these most curious and interesting productions should, however, establish their claims to be regarded as Entozoa, they will probably rank as a simple form of *Sterelmintha*.*

Fig. 70.

Spiroptera hominis. (**Natural size.*)

The existence of the *Spiroptera Hominis* is founded on the observation of substances very different from the preceding productions. The specimens so called were transmitted to Rudolphi, in a separate phial, at the same time with the ova and larger parenchymatous bodies above described, and are presumed to have been expelled from the same female under the same circumstances. They consisted of six small Nematoid worms of different sexes; the males (*fig.* 70*) were eight, the females ten lines in length, slender, white, highly elastic.

The head (*a*, *fig.* 70) truncated, and with one or two papillæ; the mouth orbicular, the body attenuated at both extremities, but especially anteriorly. The tail in the female thicker, and with a short obtuse apex; that of the male more slender, and emitting a small mesial *tubulus* (*c*), probably the sheath of the penis: a dermal aliform production near the same extremity determines the reference of this Entozoon to the genus *Spiroptera*.

There are no specimens of this Entozoon among the substances discharged from the urethra of the female, whose case is above alluded to, which are preserved in the Museum of the College of Surgeons.

The following parasite of the urinary apparatus, concerning which no obscurity or doubt prevails, is the *Strongylus gigas* (*fig.* 71), the giant not only of its genus but of the whole class of cavitary worms. This species is developed in the parenchyma of the kidney itself, and occasionally attains the length of three feet, with a diameter of half an inch. A worm of nearly this magnitude, which occupied the entire capsule of the left kidney, of the parenchyma of which it had occasioned the total destruction, is preserved in the collection of the Royal College of Surgeons.

The male *Strongylus gigas* is less than the female, and is slightly attenuated at both extremities. The head (*a*) is obtuse, the mouth orbicular, and surrounded by six hemispherical papillæ (A); the body is slightly impressed with circular striæ, and with two longitudinal impressions; the tail is incurved in the male, and terminated by a dilated pouch or *bursa*, from the base of which the single intromittent spiculum (*b*) projects. In the female the caudal extremity is less attenuated and straighter, with the anus (c) a little below the apex: the vulva (*d*, *fig.* 95) is situated at a short distance from the anterior extremity.

The *Strongylus gigas* is not confined to the Human Subject, but more frequently infests the kidney of the Dog, Wolf, Otter, Raccoon, Glutton, Horse, and Bull. It is generally of a dark blood-colour, which seems to be owing

per catheterem ex vesica pauperculæ educta, nequaquam talia habenda sunt. Corpuscula sunt plus minus globosa, tertiam lineæ partem diametro superantia, duriuscula, forcipi comprimenti renitentia, dissecta solida visa, quominus pro hydatulis haberi possint, quales primo suspicatus sum. Concrementa sunt lymphatica in vesica morbosa ex humoribus alienatis ibidem secretis, simili forsan modo acarenulæ ex lotio præcipitata."—*Rudolphi*, *Synops. Entoz.* p. 251.

* Ibid. p. 252.

* These bodies are figured in the excellent account of the present anomalous case by Mr. Lawrence, in the Medico-Chirurgical Transactions, vol. ii. pl. 8, p. 385.

Fig. 71.

Strongylus gigas, male.

to the nature of its food, which is derived from the vessels of the kidney, as, where suppuration has taken place around it, the worm has been found of a whitish hue.

The Round-worm (*Ascaris Lumbricoides*, Linn.) (*fig.* 72) is the first described* and most common of the Human Entozoa, and is that which has been subjected to the most repeated, minute, and successful anatomical examinations. It is found in the intestines of Man, the Hog, and the Ox. In the Human subject the round worms are much more common in children than in adults, and are extremely rare in aged persons. They are most obnoxious to individuals of the lymphatic temperament, and such as use gross and indigestible food, or who inhabit low and damp localities. They generally occur in the small intestines.

Fig. 72.

Ascaris lumbricoides.

The body is round, elastic, with a smooth shining surface, of a whitish or yellowish colour; attenuated towards both extremities, but chiefly towards the anterior one (*a, fig.* 72), which commences abruptly by three tubercles which surround the mouth, and characterize the genus. The posterior extremity (*b*) terminates in an obtuse point, at the apex of which a small black point may frequently be observed. In the female this extremity is straighter and thicker than in the male, in which it is terminated more acutely, and is abruptly curved towards the ventral side of the body. The anus is situated in both sexes close to the extremity of the tail, in form like a transverse fissure. In the female the body generally presents a constriction at the junction of the anterior with the middle third (*c*) in which the *vulva* (*d*) is situated.

The body of the *Ascaris lumbricoides* is transversely furrowed with numerous very fine striæ, and is marked with four longitudinal equidistant lines extending from the head to the tail. These lines are independent of the exterior envelope, which simply covers them; two are lateral, and are larger than the others, which are dorsal and ventral. The lateral lines commence on each side the mouth, but, from their extreme fineness, can with difficulty be perceived; they slightly enlarge as they pass downwards to about one-third of a line in diameter in large specimens, and then gradually diminish to the sides of the caudal extremity. They are occasionally of a red colour, and denote the situation of the principal vessels of the body. The dorsal and abdominal longitudinal lines (*e, fig.* 72) are less marked than the preceding, and by no means widen in the same proportion at the middle of the body. They correspond to the two nervous chords, hereafter to be described.

The last species of Human Entozoon which remains to be noticed is the *Ascaris vermicularis* (*fig.* 73), a small worm, also noticed by Hippocrates under the name of *ασκαρις*, and claiming the attention of all physicians since his time, as one of the most troublesome parasites of children, and occasionally of adults; in both of whom it infests the larger intestines, especially the rectum.

The size of the *Ascaris vermicularis* varies

* It is the ἑλμινς στρογγυλος of Hippocrates.

according to the sex; the males rarely equal two lines in length; the females attain to five lines (* *fig.* 73.) They are proportionally slender, white, and highly elastic. The head is obtuse, and presents, according to the repeated observations of the experienced Rudolphi, the three valvular papillæ characteristic of the genus *Ascaris;* but other Helminthologists, who have failed in detecting this organization, refer the species to the genus *Oxyuris.* Besides the papillæ the head presents a lateral, semi-obovate membrane on each side, the broader end being anterior. The body soon begins to grow smaller, and gradually diminishes to a subulate straight extremity in the female. In the male the posterior extremity is thicker, and is spirally inflected and terminates obtusely; the head is narrower than in the female.

Fig. 73.

*Ascaris vermicularis. (*Natural size of female.)*

In the following tabular arrangement of the internal parasites of the Human body, they are disposed in the classes to which they appear respectively to belong according to their organization.

ENTOZOA HOMINIS.

Classis Psychodiaria, Bory St. Vincent.

1. *Acephalocystis endogena,* cui locus Hepar, cavum Abdominis, &c.
2. *Echinococcus Hominis,* Hepar, Lien, Omentum.

Classis Polygastrica, Ehrenberg.

3. *Animalcula Echinococci,* Hepar, &c. in Echinococco abdita.*

Classis Protelmintha.

4. *Cercaria Seminis,* Semen virile.
5. *Trichina spiralis,* Musculi voluntarii.

Classis Sterelmintha.

6. *Cysticercus cellulosæ,* Musculi, Cerebrum, Oculus.
7. *Tænia Solium,* Intestina tenuia.
8. *Bothriocepalus latus,* Intestina tenuia.
9. *Polystoma Pinguicola,* Ovaria.
10. *Distoma hepaticum,* Vesica fellea.

Classis Cœlelmintha.

11. *Filaria Medinensis,* Contextus cellulosus.
12. *Filaria oculi,* Cavum Oculi.
13. *Filaria bronchialis,* Glandulæ bronchiales.
14. *Tricocephalus dispar,* Cœcum, Intestina crassa.
15. *Spiroptera hominis,* Vesica urinaria.
16. *Strongylus gigas,* Ren.
17. *Ascaris lumbricoides,* Intestina tenuia.
18. *Ascaris vermicularis,* Intestinum rectum.

Anatomy of the Entozoa.

Tegumentary System.—There are few species of the *Sterelmintha* in which a distinct external tegumentary covering can be demonstrated. In the Cystic, Cestoid, and most of the Trematode worms, the parenchymatous substance of the body is simply condensed at the surface into a smooth and polished corium of a whitish colour, without any development of pigmental or cuticular layers. The various wrinkles and irregularities, which the superficies of these Entozoa frequently presents, result from the action of the contractile tissue of the corium: this substance, in the larger *Tæniæ,* begins to assume a fibrous disposition, and tears most readily in the longitudinal direction; it can be more distinctly demonstrated as a muscular structure in the larger species of *Trematoda.* By maceration in warm water the rugæ of the integument disappear; the smooth external surface, so well adapted to glide over the irregularities of a mucous membrane, is then distinctly demonstrated; and, when magnified, an infinite number of minute pores, variously disposed, are seen perforating the whole surface, especially in the Acanthocephalous worms. It is these pores which, in the dead worm at least, allow a ready passage to the surrounding fluid into the interstices of the parenchyma, where it sometimes accumulates so as to swell out the body to three or four times its previous bulk; and it may be readily supposed, therefore, that the skin here performs some share in the nutrient functions, by absorbing a proportion of the mucous or serous secretions in which the Entozoa are habitually bathed.

In the *Acanthocephala* the skin, which is but little extensible and friable, is united to the subjacent muscular fibres by means of a whitish spongy tissue which adheres to it most strongly opposite the dorsal and ventral longitudinal lines or canals. As, however, the skin is with difficulty changed by maceration, while the parts which it surrounds soon go into putrefaction, it can thus be easily separated and demonstrated as a distinct substance. It presents no definite fibrous structure under the microscope, and tears with equal facility in every direction.

In a large Trematode worm, the *Distoma clavatum,* Rud., which infests the intestines of the Albicore and Bonito, the body is protected by a crisp sub-diaphanous cuticle, resembling in its structure and properties that of the *Echinorhynchus.*

A similar covering may be demonstrated very readily in the genus *Linguatula,* among the *Cœlelmintha,* and can be separated, but with more difficulty, from the subjacent muscles in the *Ascarides.* In the great Round-worm *(Ascaris lumbricoides)* the integument is smooth and unctuous, is more extensible in the longitudinal than the transverse directions, tears with an unequal rupture like a thin layer of transparent horn, and preserves its transparency in solutions of corrosive sublimate, alum, and in alcohol. In this species, in which the digestive canal is completely developed, it is worthy of remark that the microscope does not demonstrate pores in the cuticle, as in the external covering of the

* These may be considered rather as the Parasites of the Echinococcus than of the human subject.

Echinorhynchus and other sterelminthoid worms; but a series of extremely minute close-set parallel transverse lines are brought into view, which are permanent, and depend on the texture of the epidermoid substance itself.

Although a distinct and general epidermic covering cannot be demonstrated in the more simple *Sterelmintha*, the soft bodies of which entirely dissolve after a few days' maceration, and which, in animals examined soon after death, are often found in consequence to have lost their natural form, and to have degenerated into a kind of mucus,* yet in most species traces of the epidermic system are manifested in some limited parts of the body: thus it appears in the form of hard transparent horny hooklets around the oral proboscis in the Cystic genera, as in the *Cysticercus cellulosæ* (*fig.* 61), and most of the Cestoid worms. In the *Floriceps*, Cuv., these recurved spines are arranged along the margins of four retractile tentacles, which thus serve to fix the worm to the slippery membranes among which it seeks its subsistence. In the Trematode worms epidermic spines are seldom developed; the species which infests the human subject (*Distoma hepaticum*) presents no trace of them. When they exist in this order, they are either confined to the head, or are at the same time spread over a greater or less proportion of the surface of the body. Of the first disposition we have an example in the *Gryporhynchus pusillus*, (a trematode worm infesting the intestines of the Tench,) which manifests an affinity to the *Tæniæ armatæ* in its proboscis armed with sixteen strong recurved spines arranged in a double circular series. In the *Distoma trigonocephalum* there are two straight spines on each side of the head. In *Distoma armatum* the head is entirely surrounded by similar straight spines. In *Distoma ferox* the head bears a circle of recurved spines. In *Distoma denticulatum* the head is surrounded by a series of large straight spines, and there is a series of smaller spines around the neck. In *Distoma spinulosa* the anterior part of the body is beset with reflected spines; and in the *Distoma perlutam*, Nord., the whole surface of the body is armed with hooklets, arranged in

Fig. 74.

Proboscis of Echinorhynchus gigas, magnified.

* Rudolphi, Hist. Entoz. i. p. 230.

transverse rows, each being supported on a cutaneous prominence and bent backwards, (see *fig.* 91).

For a description of the complicated horny and cartilaginous parts of the dermo-skeleton, which enter into the mechanism of the suckers of the worms belonging to the genera *Diplozoon* and *Octobothrium*, we are compelled from want of space to refer the reader to Nordmann's Mikrographische Beiträge, (*Erstes Heft.*)

In the *Acanthocephala* the head, as the name implies, is armed with recurved spines or hooks, which are arranged in quincunx order around a retractile proboscis, (*fig.* 74); and, in addition to these, some species have smaller and less curved spines dispersed over the neck or body.

Among the *Cœlelmintha* the genus *Linguatula* is remarkable for the development of four large reflected spines, arranged two on each side the central mouth; and which can be partially retracted within depressions of an elongated semilunar figure. The worm attaches itself so firmly by means of the horny hooks that it will suffer its head to be torn from its body rather than quit its hold when an attempt is made to remove it while alive. In the *Trichocephalus uncinatus* the truncated head presents at its anterior margin a series of hard reflected hooks continued directly from the integument. In the *Strongylus armatus*, which has sometimes a singular nidus in the mesenteric arteries of the Horse and Ass, the globose head is terminated anteriorly by straight spines, but in the *Strongylus dentatus* with hooklets. Lastly, we may notice the very singular worm found by Rudolphi in the œsophagus of the Water-hen, and which he calls the *Strongylus horridus*, where the body presents four longitudinal rows of reflected hooklets.

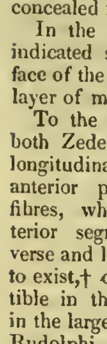
The epidermic processes, when thus traced through the different orders of Entozoa, present but few modifications of form, and have little variety of function; the straight spines at the mouth serve to irritate and increase the secretion of the membrane or cyst with which the worm is in contact; the recurved hooklets serve as prehensile instruments to retain the proboscis and the worm in its position; and when they are spread over the surface of the body, they may have the additional function of aiding in the locomotion of the species, analogous to the spines which arm the segments of the *Œstrus*, which passes its larva state, like an Entozoon, in the interior of the stomach and intestines of a higher organized animal.

Muscular system.—Although in every order both of the Parenchymatous and Cavitary worms, living specimens have been observed to exhibit sufficiently conspicuous motions, yet the muscular fibre is not always distinctly eliminated in them. In the *Cysticerci*, however, Rudolphi describes two bundles of fibres as arising from the inferior part of the body, and expanding upon the upper part of the cyst. We have traced corresponding fibres extending to the head in a large *Cysticercus tenuicollis*; which fibres were doubtless the principal agents in retracting the head within the terminal cyst; and this part, in the same specimen also, presented a remarkably distinct series of transverse striæ, indicating most probably the circular fibres which contract the cyst in the transverse direction, and protrude the proboscis.* This species of Hydatid, which is common in the abdomen of Sheep, where it is either suspended in a cyst to the mesentery or omentum, or embedded in the liver, &c. has been the subject of numerous observations, and is generally selected to demonstrate the muscular phenomena in an animal of very simple organization. When extracted from a recently killed sheep, and placed in water at the blood-heat, the cyst may then be observed to become elongated, and agitated with undulatory movements; the retracted part of the body is thrust forth, and again, perhaps, drawn in; during the latter action the anterior part of the cyst becomes wrinkled and is drawn back, gliding into the posterior part of the cyst; the anterior part of the body is at the same time retracted, and is received into the posterior; and thus by degrees the head and all the body become concealed in the terminal cyst.

In the *Cestoidea* the muscular structure is indicated slightly by impressions on the surface of the body, but it is seldom that a distinct layer of muscular fibres can be demonstrated.

To the worms of the genus *Caryophylleus* both Zeder and Rudolphi agree in ascribing longitudinal fibres, which extend along the anterior part of the body and transverse fibres, which are conspicuous in the posterior segments. In the *Tæniæ* both transverse and longitudinal strata of fibrils are stated to exist,† obscure indeed, or almost imperceptible in the smaller species; but more evident in the larger specimens, in which, according to Rudolphi, each segment has in general its own strata, whence it enjoys, for some time after being separated from the rest of the body, distinct and peculiar motions; and such joints have been described as distinct species of Entozoa, under the name of *Cucurbitinæ*. In the *Bothriocephalus latus*, on the other hand, the longitudinal fibres are continued from one joint to another, whence the segments are less readily separable, and a common and continuous covering may be dissected from off the body of this species.

Fig. 75.



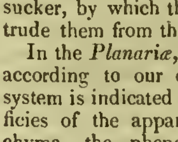
Tænia solium.

Living Tæniæ placed in warm water exhibit undulatory motions. The body of one of these worms is sometimes found to be tied at some part in a complicated knot, as seen in *fig.* 75, doubtless by means of these motions. The *Tænia solium*, when recently expelled from the body by the irritation of a vermifuge remedy, is occasionally contracted to the length of a few inches, the segments appearing as close-set transverse striæ; when placed in water, after a few hours it will have returned to a length of as many feet. Werner* relates an instance of a Tænia which extended from the anus of a patient to the length of three feet, and which returned itself almost wholly into the intestine, the dependent part being drawn upwards by the superior. Other and still more extraordinary instances of the movements of the Cestoid worms are on record; but that the separated joints of the *Tænia solium* should be able to creep several feet up a perpendicular wall could scarcely gain a moment's credit, if the fact were not related by no less distinguished a naturalist than Pallas.†

In general the muscular fibres cannot be observed in the diaphanous bodies of the smaller *Trematoda*, yet every part is endowed with active contractility: in the larger species, however, both longitudinal and transverse strata of fibres, may be demonstrated in the tegumentary muscular covering of the body; both which we have distinctly seen in the large *Distoma clavatum*. The muscular fibres of the acetabula are disposed in two series, one radiating from the centre to the circumference, the other in concentric circles. The muscular tissue is also well developed around the base of the sucker, by which the animal is enabled to protrude them from the surface.

In the *Planariæ*, in which, as in the *Tæniæ*, according to our observations, the muscular system is indicated only by striæ on the superficies of the apparently homogeneous parenchyma, the phenomena of muscularity are strikingly displayed in the varied and energetic actions of the living animal. They lengthen, shorten, widen, contract, or contort the body in various degrees and directions: their mode of locomotion on a solid plane is by an insensible undulation, or successive approximation of small proportions of the body, producing a gliding movement, as in the Slug; and the same actions take place in swimming through the water, except that the body is reversed; and the ventral surface turned upwards, as in the *Carinaria* and other aquatic Gastropods. When seizing a living prey, as in *fig.* 76, the contractions of the body are more vigorous and extensive.

Fig. 76.



Planaria lactea (B), feeding on a Nais.

In the *Echinorhynchus* the muscular fibres are of a whitish colour, semi-transparent, and of a gelatinous appearance; they are eminently contractile, and readily respond to the application of both chemical and physical stimuli. Cloquet observed them to contract under the influence of the galvanic current six hours after the cessation

* See Preparation, No. 409 A, Physiological Series Mus. Roy. Coll. of Surg. Catalogue, vol. i. p. 115.

† Rudolphi, Hist. Entoz. i. p. 223.

* As quoted by Rudolphi. 'Tænia ad trium ulnarum longitudinem ex mulieris ano propendens, in casu quem Wernerus (l. c. 47) refert, tota fere in pristinum hospitium rediit, pars propendens itaque a superiore sursum ducta: similes omnino casus Andryus habet.'—Ibid. p. 223.

† Also quoted by Rudolphi, p. 223.

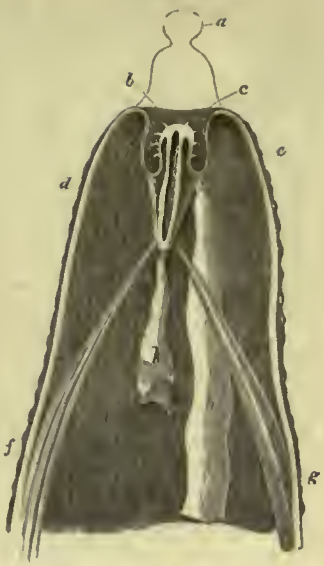
of all spontaneous movement. The general muscles of the body are disposed in two layers, of which the fibres of the external are transverse, those of the internal longitudinal.

With respect to the disposition of the muscular system of the Nematoid worms, a difference of opinion is entertained by some experienced comparative anatomists.

Professor De Blainville* describes, in the *Ascaris lumbricoides*, the external stratum of muscular fibres as being longitudinal, while the internal, he observes, are evidently transverse, and much more numerous at the anterior than the posterior part of the body. M. Cloquet, on the contrary, in his elaborate monograph on the *Ascaris lumbricoides*, states that the exterior layers of muscular fibres are transverse, and the internal longitudinal. In a large specimen of the *Strongylus gigas*, Rud., which we have dissected and examined microscopically for the muscular system, we find that a very thin layer of transverse fibres adheres strongly to the integument, the fibres being imbedded in delicate furrows on the internal surface of the skin; within this layer, and adhering to it, but less firmly than the transverse fibres do to the integument, there is a thicker layer of longitudinal fasciculi, which are a little separated from one another, and distributed, not in eight distinct series, but pretty equally over the whole internal circumference of the body. Each fasciculus is seen under a high magnifying power to be composed of many very fine fibres, but these do not present the transverse striæ which are visible by the same power in the voluntary muscular fibres of the higher animals. The longitudinal fibres are covered with a soft tissue composed of small obtuse processes, filled with a pulpy substance, and containing innumerable pellucid globules, and at the anterior extremity of the body this tissue assumes a disposition as of transverse fasciculi (*fig.* 79). In the *Ascaris lumbricoides* similar internal transverse bands are shown in *fig.* 88, *e*, *e*, and are those which Professor Blainville regards as muscular, and Cloquet as vascular organs. We cannot detect a tubular structure in these parts, neither have they the texture and consistence of the true fibrous parts: they are soft pulpy substances, doubtless connected with the nutritious functions, and probably the organs of absorption.

Besides the general muscular investment of the body, there are distinct muscles in most of the Entozoa, developed for the movement of particular parts, as the retractile hooks of the *Linguatula* and *Porocephalus*, and the proboscides of the Cestoid and Acanthocephalous worms. Of the latter organ the *Echinorhynchus gigas* offers a good example. The proboscis in this species (*fig.* 77) is a short, firm, elastic, cylindrical tube, buried with its appropriate muscles in the neck of the animal, as in a sheath; and having its anterior extremity (*a*, *b*) terminated

Fig. 77.



Retracted proboscis and its muscles, Echynorhynchus gigas. Cloquet.

by a spherical eminence armed with four rows of recurved spines. The retractor muscles are four in number, two superior and two inferior, (*f*, *g*,) flattened, elongated, and of a triangular figure. They are continuous at their base or posterior extremity, with the longitudinal fibres of the body; their anterior extremity, which is extremely delicate, is inserted into the posterior part of the proboscis. The protractile muscles (*c*, *d*) are also four in number, short but strong, and forming, as it were, a sheath to the proboscis; they are attached to the anterior part of the tegumentary sheath, and pass backwards to be inserted into the posterior extremity of the proboscis in the intervals left by the retractor muscles. The motions of the proboscis thus liberally supplied, are, as might be expected, more lively than those exhibited by any other part of the body. When it is drawn back into its sheath by means of the retractor muscles, the hooklets seem to be drawn close to the side of the bulbous extremity, whence we may infer that these also have their appropriate muscles.

Nervous system. — The Entozoa in which the nerves can be most easily and distinctly demonstrated, are the *Linguatula tænioides* and the larger species of the Nematoidea, especially the *Strongylus gigas*.

In the *Linguatula* a proportionally large ganglion (*g*, *fig.* 78) is situated immediately behind the mouth, and below the œsophagus, which is turned forward in the figure, at *o*; small nerves (*h*, *i*, *k*) radiate from this centre to supply the muscular apparatus of the mouth and contiguous prehensile hooklets; and two large chords (*l*, *l*) pass backwards and extend along the sides of the abdominal aspect of the body to near the posterior extremity, where

* Dictionnaire des Sciences Naturelles, tom. iii. App. p. 40.

† Anatomie de l'Ascaride Lombricoide, p. 17.

Fig. 78.

Nervous system and female organs of generation of Linguatula tænioides, magnified.

they gradually become expanded and blended with the muscular tissue.

In the *Strongylus gigas*, a slender nervous ring (*a*, *a*, *fig.* 79) surrounds the beginning of the gullet, and a single chord is continued from its inferior part and extends in a straight line along the middle of the ventral aspect (*c*, *d*) to the opposite extremity of the body, where a slight swelling is formed immediately anterior to the anus, which is surrounded by a loop (*e*) analogous to that with which the nervous chord commenced. The abdominal nerve is situated internal to the longitudinal muscular fibres, and is easily distinguishable from them with the naked eye by its whiter colour, and the slender branches (*b*, *b*) which it sends off on each side. These transverse twigs are given off at pretty regular intervals of about half a line, and may be traced round to nearly the opposite side of the body. The entire nervous chord in the female of this species passes to the left side of the vulva, and does not divide to give passage to the termination of the vagina, as Cloquet describes the corresponding ventral chord to do in the *Ascaris Lumbricoides*. In the latter species, and most other Nematoidea, a dorsal nervous chord is continued from the œsophageal ring down the middle line of that aspect of the body corresponding to the ventral chord on the opposite aspect; but we have not found the dorsal chord in the *Strongylus gigas*. The nervous system in the latter Entozoon obviously therefore approximates to that of the Anellides; but it differs in the absence of the ganglions, which in all the red-blooded worms unite at regular intervals two lateral nervous columns; it resembles on the other hand most closely the simple and single ventral chord in the *Sipunculus*.

Living Ascarides are sensible to different mechanical stimuli applied to the surface of the body, and the sudden and convulsive movements which take place when alcohol, vinegar, or alum-solution are applied to the mouth, would seem to imply that they possess a sense of taste: to light, noise, or odour they

Fig. 79.

Commencement and termination of the nervous system, Strongylus gigas, magnified.

are, as might be expected from the sphere of their existence, totally insensible.

In those Entozoa which infest the parts of an animal body, where they may be exposed to the influence of light, as the gills of fishes, we should not be unprepared to meet with coloured eye-specks, or such simple forms of the organ of vision as occur in *Infusoria* and other invertebrate animals of a low grade of organization. Nordmann detected four small round ocelli, of a dark-brown colour, in the *Gyroductylus auriculatus*, a Cestoid worm, found in the branchial mucus of the Bream and Carp; the eye-specks are situated a little way behind the head, and yield on pressure a blackish pigment. V. Baer observed two small blackish ocelli behind the orifice of the mouth in the *Polystomum Integerrimum*, a Trematode species, which infests the urinary or allantoid bladder of the Frog and Toad. Now this large receptacle is well known to contain almost pure water; and as the *Polystomum* is very closely allied to the *Planariæ*, which habitually live in fresh water, it is probable that the allantoid bladder may be only its occasional and accidental habitation. With respect to the *Planariæ* these are almost universally provided with eye-specks, varying in number from two, as in the *Planaria lactea*, (*fig.* 80, A) to forty, of a brown or black colour, the external covering of which is transparent and corneous. From the experiments of M. Dugès* on these non-parasitic *Sterelmintha*, we learn that when the solar light is directed to the head, they escape from its influence by a sudden movement, and they also give unequivocal, though less energetic, proofs of their subjection to the influence of diffused and artificial light. The temporary ocelli observed in the young of certain species of *Distoma*† will be presently noticed.

Fig. 80.

A

Planaria lactea.

* Annales des Sciences Naturelles, 1828, p. 10.

† Conf. also Rudolphi, Synops. Entoz. p. 442, where, in the description of the *Scolex polymorphus*, a Cestoid worm infesting the intestines of Fish and Cephalopoda, he observes, "*puncta duo* volo corporis albi *sanguinea*, sæpe fulgentia, qualia nullis in Entozois aliis videre licuit, quæque in Gobii minuti Scolece vasa duo rubra parallela pono caput incipientia et retrorsum ducta, in corpore autem evanida, effingere observavi."

Digestive organs.—We have already alluded to the two leading modifications of the alimentary canal, on which the binary division of the Entozoa of Rudolphi is founded, viz. into *Sterelmintha* or those in which the nutrient tubes, without anal outlet, are simply excavated in the general parenchyma, and into the *Cœlelmintha*, in which an intestinal canal, with proper parietes, floats in a distinct abdominal cavity, and has a separate outlet for the excrements. In both these divisions the mouth is variously modified, so as to afford zoological characters for the subordinate groups; and the alimentary canal itself in the Sterelmintha presents several important differences of structure.

Cystica.—The *Cystic* worms are generally gifted, as in the species *(Cysticercus cellulosæ)* which occasionally infests the human subject, with an uncinated proboscis for adhering to and irritating, and four suctorious mouths for absorbing the fluid secreted by, the adventitious cyst in which they are lodged. In the larger *Cysticerci* lateral canals may be traced from the suctorious pores extending down the body towards the terminal cyst, but they appear not to terminate in that cavity, the fluid of which is more probably the result of secretion or endosmosis. We cannot, however, participate in the opinion of Rudolphi,* that the retracted head derives nutriment from the surrounding fluid of the caudal vesicle, for if that were the case, where would be the necessity for an armed rostellum in addition to the absorbent pores? The frequency with which the *Cysticerci* are found with the head so retracted, may be attributed to the instinctive action arising from the stimulus of diminished temperature and other changes in the surrounding parts occasioned by the death of the animal in which the hydatid has been developed.

Cestoidea.—In the *Cestoidea* the digestive apparatus commences for the most part by two or four oral apertures, to which, in many species (the *Tæniæ armatæ)*, a central uncinated proboscis is superadded, as in the *Cysticerci*. Sometimes the mouths are in the form of oblong pits or fossæ, as in the *Bothriocephalus latus*, and the allied species grouped under the same generic name; or they have the structure of circular suctorious discs, as in the *Tænia solium* and other true *Tæniæ*.† In both genera two alimentary canals are continued backwards in a straight line near the lateral margins of the body *(e, e, fig.* 90), and are united by transverse canals *(f, f, fig.* 90) passing across the posterior margins of the segments. These connecting canals are relatively wider in the *Tænia solium* than in the *Bothriocephalus latus*, their size apparently depending on the length of the segments, which is much greater in the former than the latter. Neither the transverse nor the longitudinal vessels undergo any partial dilatations. The chief point at issue respecting the digestive organs of the Tape-worms is, whether the nutriment is imbibed by them through the pores which occur at the sides or margins of each joint, or whether the entire body is dependent for its nutriment upon the anterior mouths from which the lateral canals commence. The results of numerous examinations, which I have made with this view, both on Bothriocephali* and Tæniæ, have uniformly corresponded with those of Rudolphi, and I entirely subscribe to the opinion of that experienced helminthologist, that the marginal or lateral orifices of the segments are exclusively the outlets of the generative organs.

In some species of Tape-worm, as the *Tænia sphænocephalus*, in which no ovaria have been detected, there has been a corresponding absence both of lateral and marginal pores, while the lateral longitudinal canals have been present and of the ordinary size. In the *Tænia solium* the generative pores being placed at one or other of the lateral margins of the segments, the ducts of the ovary and testis *(g, h, fig.* 90) cross the longitudinal canal of that side, and give rise to a deceptive appearance, as if a short tube were continued from the alimentary canal to the pore. But in the *Bothriocephalus latus* and *Bothriocephalus Pythonis* the generative pores open upon the middle of one of the surfaces of each segment, and in these it is plain that the lateral nutrient vessels have no communication with the central pores. The orifices of the segments, in short, correspond with the modifications of the generative apparatus, while the nutrient canals undergo no corresponding change. Nutrition may be assisted by superficial absorption; and, as Rudolphi suggests,† the separated segments may for a short time imbibe nutriment by the open orifices of the broken canals; but setting aside cutaneous absorption and the more problematical action of the rup-

* "Osculis tamen canalibusque dictis omnem aquæ vim vesica caudali collectam parari potuisse vix credibile, sed hâc paratâ vermem eandem absorbere ideoque semper fere caput huic immissum offerre, longe aliam vero fluidi advehendi viam dari, plurima suadent."—Hist. Entoz. i. p. 279.

† Many beautiful preparations, showing the nutrient canals of the *Tænia solium* injected with coloured size and quicksilver, are preserved in the Hunterian collection, (see Nos. 843, 844, 845.) These were prepared, during the life-time of John Hunter, and were presented to that great anatomist by Sir Anthony Carlisle, by whom they are described in the 'Observations upon the Structure and Œconomy of Tæniæ,' in the second volume of the Linnæan Transactions, (1794).

* Principally on that species which infests the intestines of the large serpent commonly exhibited in this country the *Python Tigris*, Daud. And we invite the attention of comparative anatomists interested in this point to an injected preparation of one of these worms in the Museum of the Royal College of Surgeons, No. 845 A.

† "Al. Olfers (de veget. et anim. p. 35) articulos *Tæniæ* singulos ope absorptionis cutaneæ perparum, maxime autem ope osculi marginalis nutriri contendit, sed osculum hoc vere ad genitalia pertinere in capite insequente evincam. Si ct. vir absorptionem cutaneam minoris æstumat, hac de re non litigabo, sed res alio modo explicari potest. Annon enim ad vasa linearia nutrientia, utrinque longitudinaliter decurrentia, si articulus solutus est, in utroque ejus fine utrinque hiantia, absorbendi officium deferri posset."—*Synops. Entoz.* p. 585.

tured vessels, the head of the Tape-worm is the sole natural instrument by which it imbibes its nutriment, and it is to the expulsion of this part that the attention of the physician should be principally directed, in his attempts to relieve a patient from these exhausting parasites.

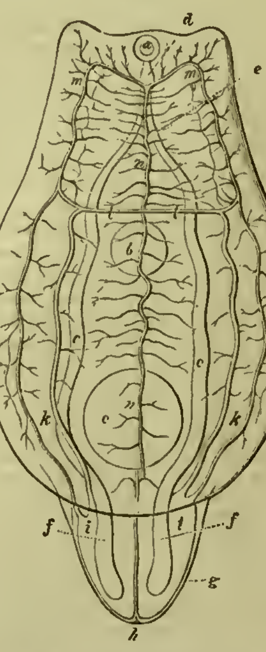
Trematoda.—Four kinds of vessels or canals are met with in the parenchymatous body of the Trematode worms, viz. digestive, nutritive or sanguiferous, seminal, and ovigerous. In the genus *Monostoma*, the digestive canal is bifurcated, each branch traverses in a serpentine direction the sides of the body, and they are united, in some species, by a transverse communicating vessel at the caudal extremity; in others, as *Monost. mutabile*, they converge and terminate in an arched vessel at the posterior part of the body. They are of small size, and not very clearly distinguishable from the sanguiferous vessels.

In the *Distoma hepaticum*, the digestive organs are more distinctly developed. The œsophagus is continued from the anterior pore, and forms a short wide tube, shaped like an inverted funnel. Two intestinal canals are continued from its apex, which immediately begin to send off from their outer sides short and wide cœcal processes, and continue thus ramifying to the opposite end of the body, but have no anal outlet. Rudolphi* states that when successfully injected with mercury, more minute vessels are continued from the apices of the digestive canals, which form a network over the superficies of the body. A similar dendritic form of the digestive canal obtains in the singular genus *Diplozoon*, discovered by Nordmann in the gills of the Bream; the central canal and ramified cœcal processes in this Entozoon are represented (*fig.* 328, vol. i. p. 654,) on that moiety, which is opposite the left hand of the observer: on the other moiety the vascular system alone is delineated. The latter is not, like the digestive canal, common to both halves of the body, but consists of two closed systems of vessels, each peculiar to its own moiety. Two principal trunks, *a, a*, traverse the sides of each moiety, preserving a uniform diameter throughout their entire course. In the external vessels marked *a, a*, Nordmann states that the blood is conveyed forwards or towards the head: in the internal ones, it passes backwards in the opposite direction. The latter vessels commence by many minute branches which unite in the space between the oral suckers and the anterior extremity of the body, and terminate between the disc and suckers at the posterior extremity of the body. The exterior or ascending vessels begin where these disappear and pass towards the opposite end of the body: both trunks freely intercommunicate by means of superficial capillaries. The blood moves through them with great rapidity, but without being influenced by any contraction or dilatation of the vessels themselves. The circulation continues for three or four hours to go on uninterruptedly in each moiety of the Diplozoon, after they have been separated from one another by a division of the connecting band. The blood itself is perfectly limpid. It should be observed, with reference to the above description, that the appearance of circulatory movements in the vessels of the *Diplozoon paradoxum* is ascribed by Ehrenberg (*Weigmann's Archiven*, 1835, th. ii.) and Siebold (*Ibid.* 1836, th. ii.) to the motion of cilia on the inner surface of the vascular canals.

In the genus *Diplostomum*, in which the nutritious and vascular systems characteristic of the Trematoda are peculiarly well displayed, (*fig.* 81,) a short and slightly dilated canal is continued from the mouth, and soon divides into two alimentary passages or intestines, *e, e*, which diverge, and proceed in a slightly undulating course, towards the hinder sacciform appendage of the body, dilating as they descend, and ultimately terminating each in a blind extremity, *f, f*. The contents of this long bifid blind alimentary canal are of a yellowish brown colour, especially in old individuals, and consist of a finely granular substance. As there is no separate anal aperture, the crude and effete particles are probably regurgitated and cast out by the mouth, as in all other *Trematoda*.

The posterior projection of the body, *g*, Nordmann compares to the posterior appendage in the *Cercariæ*; it is terminated by a posterior aperture which seems to be the excretory outlet of some secerning organ; since a milky fluid is sometimes ejected from it with force. In a species of *Distoma* (*Distoma clavatum*, Rud.) which I recently dissected,

Fig. 81.

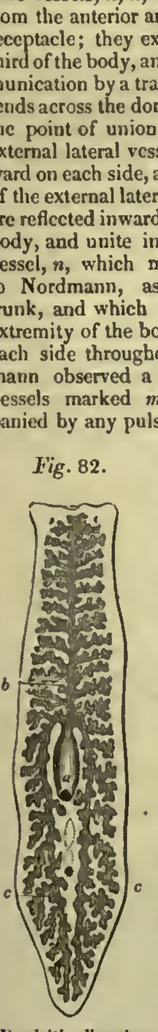


Digestive and nutrient canals, Diplostomum volvens, magnified.

* Entoz. Synopsis, p. 583.

there is a similar aperture which forms the outlet of a vertically compressed sac situated between the chyle-receptacles (see Transactions of the Zoological Society, *plate* 4, p. 381, *pl.* 41, *figs.* 17, 18, *d*, *g*). In the *Diplostomum volvens* Nordmann supposes the aperture in question, *h*, to be the termination of a canal continued from the oviduct. Besides this canal the posterior appendage of the body is occupied by a sac of a corresponding form containing a milky fluid, *i*, *i*, and to which the term of chyle-receptacle is given by Nordmann, as was previously done by Laurer to a corresponding cavity in the *Amphistoma conicum*. The nutritious contents of this canal would seem to exude through the parietes of the cœcal extremities of the intestines, as no distinct aperture of communication is obvious. Two vessels, *k*, *k*, are continued on each side from the anterior and external part of the chyle receptacle; they extend forwards to the anterior third of the body, and are there brought into communication by a transverse vessel, *l*, *l*, which extends across the dorsal aspect of the body. From the point of union of the transverse with the external lateral vessels, a vessel is continued forward on each side, appearing as the continuation of the external lateral one. These vessels, *m*, *m*, are reflected inward at the anterior angles of the body, and unite in the middle line to form the vessel, *n*, which may be regarded, according to Nordmann, as representing the arterial trunk, and which is continued to the posterior extremity of the body, distributing branches on each side throughout its whole length. Nordmann observed a circulation of fluid in the vessels marked *m*, *m*, which was unaccompanied by any pulsation, and which may therefore be compared to the cyclosis of the nutrient fluids in the vessels of Polygastrica, Polypi, and other Acrita, and is probably due to the action of vibratile cilia.

Fig. 82.



Dendritic digestive cavity, Planaria lactea.

In a few species of *Planariæ* the mouth is terminal and anterior, as in the *Distomata;* these form the subgenus *Prostoma* of Professor Dugès.* In the greater number of these non-parasitic *Sterelmintha* the alimentary canal commences from a cavity situated at the middle of the inferior surface of the body. A proboscis or suctorious tube (*a*, *fig.* 82), varying in length according to the species, is contained in this cavity, from which it can be protruded, and the mouth is situated in the form of a round pore at the extremity of this proboscis. The action of this tube is well displayed when a hungry *Planaria* makes an attack upon a *Nais;* it then wraps its flat body around its prey (see *fig.* 76,) and applies to it the extremity of its trumpet-shaped sucker; the red-blood of the little Anellide is seen to disappear from the part in contact with the sucker; and if the body of the Nais be broken in the conflict, the *Planaria* directs the extremity of the proboscis to the torn and bleeding surface. After a meal of this kind the digestive canals of the Planaria are displayed by the red colour of their contents, like the corresponding parts of the Liver-fluke when filled with bile, and they greatly resemble the latter in structure; instead of two canals, however, three are continued from the base of the proboscis; one of these is central (*b*), and passes upwards to the anterior extremity of the body, distributing its wide cœca on either side; the other two (*c*, *c*) descend, almost parallel to one another, and give off their cœcal processes chiefly from the outer margin, as in the *Distoma.* The *Planariæ* are, equally with the parasitic Trematoda, devoid of an anus: and the remains of Polygastric infusories swallowed by them have been seen to be regurgitated by the proboscis. Minute nutrient vessels are continued from the extremities of the intestinal cœca, and form a very fine cutaneous network, which communicate with a mesial and dorsal canal and two lateral vessels, as in the *Diplostomum.*

Some species of the Trematode Entozoa are infested by parasitic *Polygastrica* which belong to the Monads: Nordmann observed some brown corpuscles by the sides of the alimentary canal of a *Diplostomum*, which contained minute particles in continual and lively motion. On crushing the corpuscles between plates of glass an immense concourse of the moving atoms escaped: they were smaller than the *Monas atomos* of Müller, of an oval form, and of a clear yellow colour; their movements were very singular: they whirled rapidly round on their axis, then darted forward in a straight line, whirled round again, and again darted forward. When we consider that the Diplostomum itself does not exceed a quarter of a line in length, and that the aqueous humour of a single eye serves as the sphere of existence to hundreds of individuals, what views does the fact of the parasites of so minute an Entozoon open of the boundless and inexhaustible field of the animal creation!

Acanthocephala.—The worms of this order, although in external form, in the development of the tegumentary and muscular system, and above all in their diœcious generation, they approach very closely the Nematoid Worms, yet preserve the distinguishing character of the Sterelminthoid class in the structure of the digestive organs. In the *Echinorhynchus gigas* the mouth is an extremely minute pore, situated on a projectile armed proboscis, the structure of which we have already described. From its posterior part are continued two long cylindrical canals (*e*, *e*, *figs.* 83, 84) which adhere closely to the muscular fibres by their outer side, and project on the opposite side into the triangular cavity (*h*, *fig.* 84) left between the

* Dugès, Annales des Sciences, 1828, p. 16.

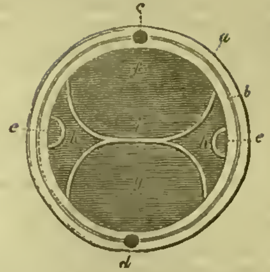
Fig. 83.

Digestive and generative organs, Echinorhynchus gigas, female.

ovaries in the female and testes in the male. They are extremely minute at their commencement, but increase so as to be readily visible in the middle of their course. They are transparent and irregularly dilated or sacculated at intervals. Posteriorly they terminate in a *cul-de-sac*, and have no anal outlet. They contain a transparent inodorous albuminous liquid, give off no visible lateral branches, and do not communicate together in any part of their course. Besides these canals we find in the cavity of the body of an Echinorhynchus two long wavy tubes called *lemnisci*, (*d*, *d*, *fig.* 83). They are attached to the lateral parts of the neck by an extremely attenuated anterior extremity, float freely in the remainder of their extent, and terminate in an enlarged obtuse and imperforate extremity. They are of a whitish colour, transparent in the living worm, but become opake after death; they present considerable variety of form, and would seem to be highly irritable parts, since they are not unfrequently found folded into a packet, or twisted both together, and turned to one side of the body. When examined with a high microscopic power, a transparent vessel is perceived running through the centre and ramifying as it descends in the substance of the lemniscus, which is soft, fragile, and granular. Cloquet compares these organs to the nutrient processes which project into the abdominal cavity of the Ascaris, and they are also regarded by Goeze, Zeder, and Rudolphi as belonging to the organs of nutrition.

In the *Cœlelmintha* or Cavitary Entozoa, the alimentary canal is single and of large size, and extends nearly in a straight line from the mouth to the anus, which are at opposite extremities of the body. With regard to the existence of an anal outlet, the parasitic Entozoon, (*Syngamus trachealis*, Siebold,) which infests the windpipe of our common Gallinaceous Birds, presents an exception. It was supposed by Montague to be a single individual with two pedunculate mouths:

Fig. 84.



Transverse section of Echinorhynchus gigas.

and by Rudolphi was placed in the same group as *Distoma furcatum*, which is a true double-necked Trematode worm. But the digestive system has the essential character of the cœlelminthic structure, the intestine floating freely in an abdominal cavity. The orifice at the extremity of the smaller or male branch leads to a muscular œsophagus, which is continuous with a somewhat broader reddish-brown intestine, continued in a tortuous manner down the neck, and terminating in a cul-de-sac prior to the confluence of the extremity of this branch with the body of the female. The mouth of the larger branch, which is the true continuation of the larger and single body, leads first to a horny basin-like cavity, which communicates by an opposite pore, surrounded by six horny hooks or teeth, with the œsophagus, from which a similar reddish-brown intestine is continued, but in a more tortuous manner than in the male, through the whole body, terminating in a cul-de-sac at the caudal extremity. In both intestinal canals are molecules of apparently the colouring matter of blood. Their inner surface is reticulate.

In the freedom of these intestines from the muscular parietes of the body, and in the cylindrical form of the latter, we have a close affinity to the Nematoid type: but the intestine is blind—without an anal outlet. It is not, however, bifurcate, as in the true Trematoda.

In the genus *Linguatula* or *Pentastoma* of Rudolphi, the intestine is a simple straight tube, and is surrounded by the convolutions of the oviduct: the two *intestinula cæca* with which Rudolphi describes the alimentary canal as being complicated,* appertain to the generative system, and communicate exclusively with the oviduct: the intestine terminates by a distinct anus at the posterior extremity of the body.

In the *Nematoidea* the intestine is also frequently concealed in a part of its extent by the coils of the genital tubes, but these are disposed in masses by the side of the alimentary canal, and not wound around it as in the *Linguatula*: in most species the alimentary canal is attached to the internal parietes of the abdominal cavity by means of numerous small laminated or filamentary processes.

In the *Strongylus gigas* the mouth (A, *fig.* 71) is surrounded by six papillæ; the œsopha-

* Synopsis Entoz. p. 564.

gus (*b*, *fig.* 95) is round and slightly contorted, and suddenly dilates at the distance of about two inches from the mouth into the intestinal canal; there is no gastric portion marked off in this canal by an inferior constriction, but it is continued of uniform structure, slightly enlarging in diameter to the anus. The chief peculiarity of the intestine in this species is that it is a square and not a cylindrical tube, and the mesenteric processes pass from the four longitudinal and nearly equidistant angles of the intestine to the abdominal parietes. These processes, when viewed by a high magnifying power, are partly composed of fibres and partly of strings of clear globules, which appear like moniliform vessels turning around the fibres. The whole inner surface of the abdominal cavity is beset with soft, short, obtuse, pulpy processes, which probably imbibe the nutriment exuded from the intestine into the general cavity of the body, and carry it to the four longitudinal vessels, which traverse at equal distances the muscular parietes. The analogous processes are more highly developed in the *Ascaris lumbricoides*, in which species we shall consider the digestive and nutritive apparatus more in detail.

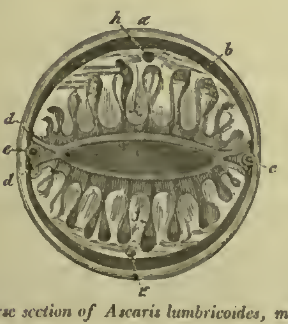
The mouth (*d*, *fig.* 87 and *fig.* 85) is surrounded with three tubercles, of which one is superior (*a*, *fig.* 85), the others inferior (*b*, *b*); they are rounded externally, triangular internally, and slightly granulated on the opposed surfaces which form the boundaries of the oral aperture (*c*). The longitudinal muscles of the body are attached to these tubercles; the dorsal fasciculus converges to a point to be inserted into the superior one; the ventral fasciculus contracts and then divides to be inserted into the two which are situated below. By means of these attachments the longitudinal muscles serve to produce the divarication of the tubercles and the opening of the mouth; the tubercles are approximated by the action of a sphincter muscle.

Fig. 85.

Head and mouth of Ascaris lumbricoides.

The œsophagus (*e*, *fig.* 87) is muscular and four or five lines in length, narrow, slightly dilated posteriorly, and attached to the muscular parietes of the body by means of slender, radiated filaments: its cavity is occupied by three longitudinal ridges, which meet in the centre and reduce the canal to a triangular form. The œsophagus is separated by a well-marked constriction from the second part of the digestive canal, which in the rest of its course presents no natural division into stomach and intestine. The anterior portion of the canal is attached by filaments, as in the *Strongylus*, to the processes and lining membrane of the abdominal cavity. Those which come off from the sides of the canal (*d*, *d*) communicate with the nutritious vessels and appendages, and in passing from the intestine they diverge and leave on each side a triangular space, of which the base corresponds to the lateral line or vessel (*e*, *fig.* 86), and the apex to the side of the intestine. These lateral spaces are filled with a serous fluid, and are continuous with the common cavity containing the alimentary and generative tubes. About the middle of the body the intestine becomes narrower, being here surrounded and compressed by the aggregated loops of the oviduct or testis, and the mesenteric processes or filaments diminish in number, and at last leave the intestine quite free, which then gradually enlarges to within a short distance of its termination (*h*).

Fig. 86.



Transverse section of Ascaris lumbricoides, magnified.

Fig. 87.

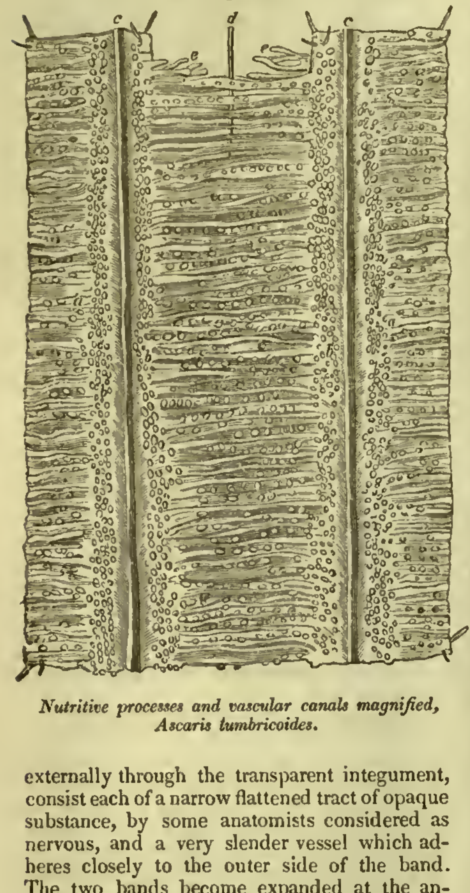
Digestive and generative tubes, Ascaris lumbricoides, male.

The parietes of the intestine are thin and transparent, and easily lacerable; they consist of a gelatinous membrane, the internal surface of which is disposed in irregular angular meshes and transverse folds, which gradually disappear towards the lower part of the canal.

The soft obtuse processes (*f*, *f*, *fig.* 86) analogous to those which project from the lining membrane of the abdominal cavity in the *Strongylus*, acquire a considerable development in the Ascaris. They arise chiefly in the dorsal and ventral regions, and are continued from numerous transverse bands (*c*, *c*, *fig.* 88) which pass across the body from one lateral absorbent vessel to the other. In the anterior third of the body these transverse bands (*vaisseaux nourriciers*, Cloquet,) are quite concealed by the processes in question (*appendices nourriciers*, Cloquet), but are very conspicuous at the posterior part of the body. The nervous chord passes at a right angle to the transverse bands between them and the longitudinal muscles, and sometimes is included in loops of the former, as at *d*, *fig.* 88. Both the pendant processes and the transverse bands are composed of a homogeneous spongy tissue, without any central cavity, and appear to form a nidus of nutrient matter like the fatty omental processes in higher animals.

The longitudinal lines (*c*,*c*, *fig.* 86, 88), which extend along each side the body of the *Ascaris Lumbricoides*, and which are very conspicuous

Fig. 88.



Nutritive processes and vascular canals magnified, Ascaris lumbricoides.

externally through the transparent integument, consist each of a narrow flattened tract of opaque substance, by some anatomists considered as nervous, and a very slender vessel which adheres closely to the outer side of the band. The two bands become expanded at the anterior extremity of the body, and unite in forming a circle around the œsophagus: the vessels, on the contrary, become detached from the bands, and pass transversely below the œsophagus to anastomose together, forming a simple loop or arch, the convexity of which is anterior. By pressure the reddish fluid contained in these vessels may be made to traverse them backwards and forwards.

With respect to the *accessory glands of the digestive system* of the Entozoa, I have hitherto met with them in two species only of the *Nematoidea*, in both of which they presented the primitive form of simple elongated unbranched cœca. The first being developed from the commencement of the alimentary canal, and co-existing with a pair of rudimental jaws, must be regarded as *salivary organs.* They exist in a species of worm which infests the stomach of the Tiger, and which I have recently described under the name of *Gnathostoma aculeatum.** They consist of four slender elongated cœca, communicating with the mouth, and gradually increasing in size as they extend backwards into the abdominal cavity, where they end each in a cul-de-sac; they are placed at equal distances around the alimentary canal, and have no attachment except at their open anterior extremity. The length of each cœcum is about one-twentieth of the entire alimentary canal. Their parietes under a high magnifying power present a beautiful arrangement of spirally decussating fibres. Their contents when recent are clear, but become opaque when immersed in alcohol. That the *Gnathostoma* is not the larva of an insect is proved by the complete development of the generative system, which resembles that of the Ascarides, and by the absence of a ganglionic nervous system.

The second example of an accessory digestive gland occurs in a species of *Ascaris* infesting the stomach of the Dugong: here a single elongated cœcum is developed from the intestine at a distance of half an inch from the mouth; and is continued upwards, lying by the side of the beginning of the intestine, with its blind extremity close to the mouth; from the position where the secretion of this cœcum enters the intestine, it may be regarded as representing a rudimental liver.†

Respiratory Organs.—The Entozoa have no distinct internal or external organs of respiration. The skin in many of the *Trematoda* and *Acanthocephala* is highly vascular,‡ and the circulating fluids in these worms may become oxygenated by contact with the vascular mucous membranes of the higher organized animals which they infest. In the *Planariæ* the surrounding water is renewed upon the vascular surface of the body by means of the currents excited by the action of vibratile cilia; and the young of certain species of *Distomata*, which pass the first epoch of their existence under the form of Polygastric Infusoria, freely moving in water, are provided with superficial vibratile cilia arranged in longitudinal rows; but these organs of locomotion and adjuncts to the respiratory process are lost when the *Distomata* resume their position as parasites in the intestines of the Fishes from which they were originally expelled.

Excretory glands.—As an example of an organ of excretion, we may refer to the glandular sac lodged in the enlarged extremity of the *Distoma clavatum*, which opens externally

* Proceedings of the Zoological Society, Nov. 1836.

† See the Preparation, No. 429 A, Mus. Coll. Surgeons, Phys. Catalogue, p. 121.

‡ Conf. Echinorhynchus vasculosus, Entoz. Synop. p. 581.

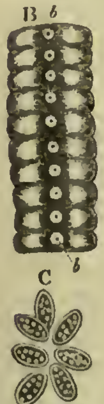
by a small orifice in the centre of that part,* and the corresponding cavities from which a clear or milky fluid is ejected by the posterior pores of some smaller species of *Distomata* and *Diplostomata*.†

Organs of generation.—The generative system in the Entozoa presents great varieties in the form, structure, and combination of its several parts. Sometimes the female or productive organs alone are discernible. In many *Cestoidea*, and in all the *Trematoda*, the male gland is present and communicates with the oviduct, so that each individual is sufficient for itself in the reproductive capacity. In the *Acanthocephala* and *Nematoidea* the sexes are distinct, and a concurrence of two individuals is required for impregnation.

No trace of a generative apparatus has hitherto been detected in the *Cystic* Entozoa. They would seem to be gemmiparous, and to have the reproductive power diffused over the whole cyst, at least in the Acephalocysts, in which the young are not developed from any special organ, or limited to any particular part of the cyst.

The ovaries in the most simple of the *Cestoid* worms, as the *Ligula*, are situated in the centre of each joint, where they open by a transverse aperture, from which projects a small filamentary process or lemniscus, regarded by Rudolphi as a male organ. In the *Bothriocephali* the ovaries have a similar position, and in the *Bothriocephalus latus* (*fig.* 89) assume a stellated figure, with the aperture in the centre, which is situated in the middle of each joint. In the *Bothriocephalus microcephalus* the ovary consists of one or two rounded corpuscles in the centre of the joints, but the generative orifices are marginal and irregularly alternate, and the oviducts may be distinctly seen passing backwards to them.

Fig. 89.



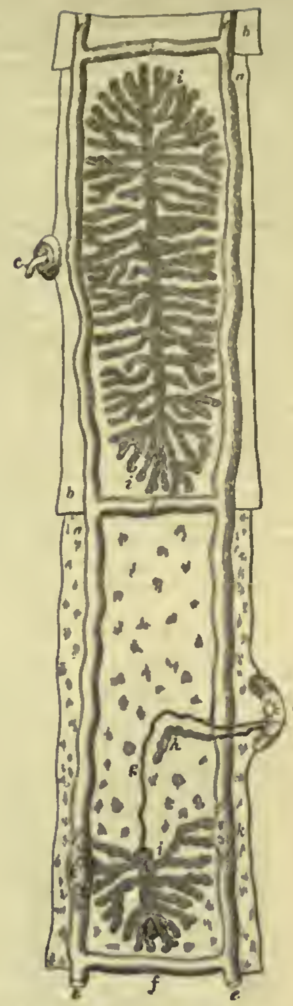
Ovarian apertures and ova, Bothriocephalus latus.

In the *Tænia Candelabraria* a sacciform ovary exists in each segment, which sends off an oviduct to the marginal outlet. Besides which, according to Rudolphi, there is a longitudinal canal, uniting the different ovaries together, and undergoing a partial dilatation at the anterior part of each joint.—May not this be the male organ?

The androgynous structure of the generative apparatus is very well displayed in the Tapeworm of this country, the *Tænia Solium*.

In each joint of this worm there is a large branched ovarium (*i*, *fig.* 90) from which a duct (*h*) is continued to the lateral open-

Fig. 90.



Generative organs magnified, Tænia solium.

ing. The ova are crowded in the ovary; and in those situated in the posterior segments of the body, they generally present a brownish colour, which renders the form of their receptacle sufficiently conspicuous.* In segments which have been expelled separately, we have observed the ovary to be nearly empty, and it is in these that the male duct and gland is most easily perceived. For this purpose it is only necessary to place the segment between two slips of glass, and view it by means of a simple lens, magnifying from twenty to thirty diameters: a well-defined line (*g*), more slender and opake than the oviduct, may then be traced extending from the termination of the oviduct, at the lateral opening, to the middle of the joint, and inclining in a curved or

* See Zool. Trans. pt. iv. vol. i. p. 381. pl. 41. fig. 18. See Nordmann, loc. cit. p. 38.

† See Nordmann, loc. cit. p. 140.

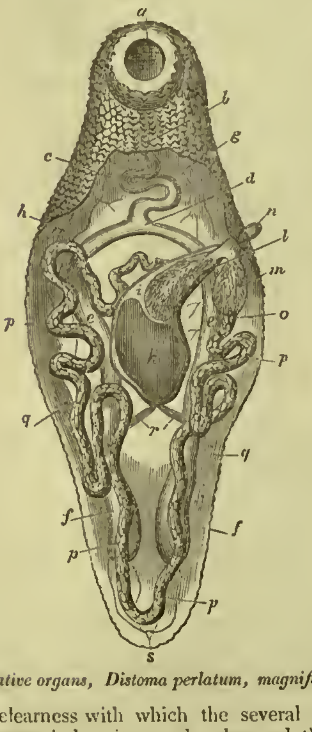
* The dendritic ovarian receptacles can also be injected with mercury or coloured size, and they have been regarded, but erroneously, as forming part of the nutrient apparatus.

slightly wavy line to near the middle of the posterior margin of the segment, where it terminates in a small oval vesicle. This, as seen by transmitted light, is sub-transparent in the centre and opaque at the circumference, indicating its hollow or vesicular structure. The duct, or vas deferens, contains a grumous secretion; it is slightly dilated just before its termination.

In this species therefore, as also in *Amphistoma conicum*, the ova are impregnated in their passage outward. But in several species of *Distomata*, as *D. clavigerum*, *ovatum*, *cirrigerum*, and in the *Distoma hepaticum*, the ova escape by an aperture situated near the base of the penis, and reciprocal fecundation exists. The concourse of two individuals must also take place in those species of the genus *Monostomum*, which, like the *Monostomum mutabile*, are viviparous, and in which the orifices of the male and female parts are distinct.

All the *Sterelmintha* of the Trematode order are androgynous; but the generative apparatus, instead of being divided and multiplied as in the *Tæniæ*, is individualized, and its several parts receive a higher degree of development. We have selected the figure which Nordmann has given of the *Distoma perlatum*, on account

Fig. 91.



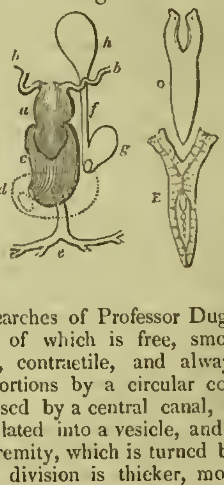
Generative organs, Distoma perlatum, magnified.

of the clearness with which the several parts are delineated, but it must be observed that it deviates in some remarkable peculiarities from what may be regarded as the Trematode type of the reproductive organs.

The specimen is seen from the under side, part of the parietes of the body having been removed: *a* is the oral aperture, *b* the œsophagus seen through the transparent integument, *c d* the windings of the beginning of the simple digestive cavity, *c e* the two intestinal prolongations, *f f* the dilated claviform cœcal terminations of the intestines, *g* the two internal, and *h* the two external trunks of the vascular system proceeding to the anterior part of the body; *i* is the great sacciform uterus, *k* apparently glandular bodies contained therein, *l m* the two testes, which are beset internally with small spines or *cilia;* *n* the projecting *cirrus* from which the ova are expelled, *o* the terminal dilatation of the oviduct which communicates with the testes, *p p p p* convolutions of the oviduct which are filled with ova, *q q* the mass of ova which lies above the oviduct, and occupies almost the whole cavity of the body, *r r* the passages by which the ovaries communicate with the uterus or dilated commencement of the oviduct.

The generative organs present some varieties in the *Planariæ*, but are essentially the same as in the *Distomata*. In the *Planaria lactea* the penis and oviduct are situated below, and the two vesicular and secerning parts of the apparatus towards the upper part of the body. The male organ (*a*, *fig.* 92) consists, according

Fig. 92.



to the researches of Professor Dugès, of two parts, one of which is free, smooth, semi-transparent, contractile, and always divided into two portions by a circular constriction; it is traversed by a central canal, susceptible of being dilated into a vesicle, and is open at its free extremity, which is turned backwards; the second division is thicker, more opaque, vesicular, adherent to the contiguous parenchyma, and receives two flexuous spermatic canals (*b*, *b*). The free portion of the penis is contained within a cylindrical muscular sheath (*c*), which is adherent to the circumference of the base of the intromittent organ, and serves to protrude it externally. This sheath communicates with the terminal sac of the female apparatus near its outlet by a projecting orifice (*d*). The oviduct (*e*) opens into the posterior part of the terminal sac: it is a narrow tube which passes directly backwards, and dividing into two equal branches, again subdivides and ramifies amongst the branches of the dendritic digestive organ. Besides the ovary there are two accessory vesicles (*g* and *h*), communicating together by a narrow duct (*f*), and opening into the terminal generative sac.

M. Baer twice witnessed the copulation of

Planariæ in the species *Planaria torva.* Upon separating the individuals, he perceived a long white tube projecting from the genital pore of each, proving the reciprocity of fecundation.

Notwithstanding the complicated apparatus above described, the *Planariæ* are remarkable for their spontaneous fissiparous generation, and the facility with which detached or mutilated parts assume the form and functions of the perfect animal. *Fig.* 92, o, represents a *Planaria lactea*, with the anterior part of the body artificially divided in the longitudinal direction; *fig.* 92, E, shews the same individual having two perfect heads, the result of the preceding operation.

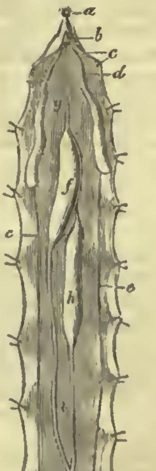
The female generative organs of the *Linguatula (Pentastoma) tænioides* present a structure in some respects analogous to that of the *Distoma perlatum*: the ovary (*n*, *n*, *fig.* 78) is a part distinct from the tubular oviduct, and is attached to the integument or parietes of the body, extending down the middle of the dorsal aspect. It consists of a thin stratum of minute granules; clustered in a ramified form to minute white tubes, which converge and ultimately unite to form two oviducts (*o*, *o*, *fig.* 78). These tubes proceed from the anterior extremity of the ovary, diverge, pass on each side of the alimentary canal, and unite beneath the origins of the nerves of the body, so as to surround the œsophagus and these nerves as in a loop. The single tube (*p*) formed by the union of the two oviducts above described, descends, winding round the alimentary canal in numerous coils, and terminates at the anal extremity of the body. The single oviduct, besides receiving the ova from the two tubes (*o*, *o*), communicates at its commencement with two elongated pyriform sacs (*m*, *m*), which prepare and pour into the oviduct an opaque white secretion. These bodies, from their analogy to the impregnating glands in the Trematoda, I was led to regard (in the description, published in the Zoological Transactions, of the only individual of this interesting species that I have hitherto been able to procure for dissection,) as testes, and the generation of the Linguatula to be androgynous, without reciprocal fecundation; individuals, however, of the male sex have since been described in this species by Miram* and Diesing.

The male *Linguatula* is, as in diœcious Entozoa generally, much smaller than the female: the generative apparatus consists of two winding seminal tubes or testes, and a single vas deferens, which carries the semen from the testes by a very narrow tube, and afterwards grows wider. It communicates anteriorly with two capillary processes, or *penes*, which are connected together at their origin by a cordiform glandular body, representing a prostate or vesicula seminalis. The external orifices of the male apparatus, according to Miram, are two in number, and are situated on the dorsal aspect of the body, just behind the head.

Diesing, however, describes the male *Pentastoma* as having only a single penis, which perforates the interspace between the second and first segments of the body, and protrudes below and behind the oral aperture.

Much interest attends the consideration of the reproductive organs of the diœcious Entozoa, since they are the first and most simple forms of the animal kingdom which present that condition of the generative function. In the Acanthocephala the structure of the generative apparatus has been ably elucidated by Cloquet in the species which commonly infests the Hog, viz. the *Echinorhynchus gigas.* The male organs consist of two testes, two vasa deferentia, which unite together to terminate in a single vesicula seminalis, and a long *penis* gifted with a particular muscular apparatus.

Fig. 93.



Male organs of generation, Echinorhynchus gigas.

The testes (*f*, *h*, *fig.* 93) are cylindrical bodies, pointed at both extremities, of nearly the same magnitude, but situated one a little anterior to the other. The anterior one is attached by a filamentary process (*g*) to the posterior extremity of the proboscis: the posterior gland is connected by a similar filament to the internal parietes of the body. The *vasa deferentia* (*i*), after their union, form several irregular dilatations (*k*), which together constitute a lobulated *vesicula seminalis.* This reservoir is filled with a white grumous fluid like that which is found in the testes, and it is embraced posteriorly by the retractor muscles of the penis (*r*, *r*), which form a kind of conical sheath for it.

A small, firm, white, and apparently glandular body (*q*) is situated at the point of union between the vesicula seminalis and the penis.

The penis is a straight, cylindrical, firm, white organ, and in the retracted state is terminated by a dilated portion (*o*), occupying the posterior extremity of the body, but which disappears when the intromittent organ is protruded. This action is produced by the muscles *s*, *s*, when the penis presents the form of a short broad cone, adhering by the apex to the caudal extremity of the body: it is retracted by the muscles *r*, *r*, above described.

The female organs consist of two ovaries and one oviduct. The former are long and wide cylindrical canals, which of themselves occupy almost the whole cavity of the body extending from the proboscis to the tail (*h*, *h*, *fig.* 83). They are situated, one at the ventral, the other at the dorsal aspects of the body, and

* Nova Acta Acad. Naturæ Curios. tom. xvii.

are separated in the greater part of their extent by a septum: see *fig.* 84, *f*, *g*, which shows them in transverse section. They contain a prodigious quantity of ova, and adhere by their outer surfaces very firmly to the muscular parietes of the body.

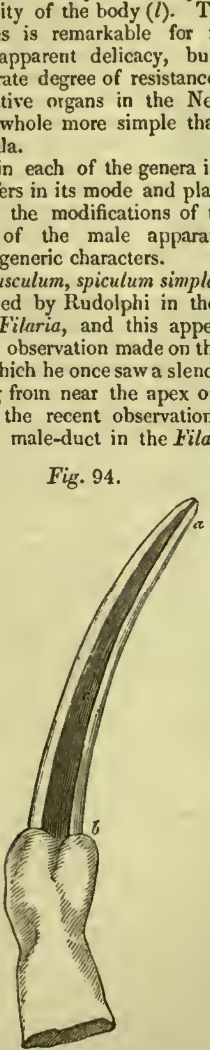
The dorsal ovary opens into the ventral one by an oblique valvular aperture about an inch distant from the extremity of the proboscis, anterior to which the common cavity extends forwards between the lateral lemnisci, and terminates by a conical canal (*i*, *fig.* 83), which is attached to the posterior portion of the proboscis. The two ovaries terminate in a different manner posteriorly, the dorsal one ending in a cul-de-sac, the ventral becoming continued in a slender oviduct (*k*), which opens by an extremely minute pore at the caudal extremity of the body (*l*). The tissue of the ovaries is remarkable for its transparency and apparent delicacy, but it possesses a moderate degree of resistance.

The generative organs in the Nematoidea are upon the whole more simple than in the Acanthocephala.

The testis in each of the genera is a single tube, but differs in its mode and place of termination, and the modifications of the intromittent part of the male apparatus have afforded good generic characters.

Genitale masculum, spiculum simplex, is the phrase employed by Rudolphi in the formula of the genus *Filaria,* and this appears to be founded on an observation made on the *Filaria papillosa,* in which he once saw a slender spiculum projecting from near the apex of the tail. According to the recent observations of Dr. Leblond,* the male-duct in the *Filaria papillosa* terminates at the anterior extremity of the body close to the mouth. From this aperture the slender duct, after a slight contortion, is continued straight down the body to a dilated elongated sac, which represents the testis.

Fig. 94.



Penis of Ascaris lumbricoides.

In the *Ascaris lumbricoides* the penis (*a*, *fig.* 94) projects from the anterior part of the anus in the form of a slender, conical, slightly curved process, at the extremity of which a minute pore may be observed with the aid of the microscope. The base of the penis (*b*) communicates with a seminal reservoir, and is attached to several muscular fibres, destined for its retraction and protrusion: the reservoir is about an inch in length, and gradually enlarges as it advances forwards: the testis or seminal tube is continued from the middle of the anterior truncated extremity of the reservoir; it presents the form of a long, slender, cylindrical, whitish-coloured tube, extends to the anterior third of the body, forming numerous convolutions and loops about the intestine, and its attenuated extremity adheres intimately to the nutrient vessels of the dorsal region of the body. The total length of the seminiferous tube in an ordinary sized *Ascaris lumbricoides* is from two feet and a half to three feet. Its contents, when examined with a high microscopic power, consist of a transparent viscous fluid, in which float an innumerable quantity of round white globules, much smaller than the ova in the corresponding tubes of the female. In the genus *Trichocephalus* the filamentary testis is convoluted around the intestine in the enlarged posterior part of the body. The intromittent organ in the *Trichocephalus dispar* is inclosed in a distinct sheath, which is everted together with the penis, and then presents the form of an elongated cone (*c*, *fig.* 69), adhering by its apex to the enlarged anal extremity of the body, and having the simple filiform spiculum or penis (*d*, *fig.* 69) projecting from the middle of its base.

In the *Strongylus gigas* the bursa or sheath of the penis terminates the posterior extremity of the body, and is a cutaneous production, of a round, enlarged, truncated form, with the spiculum projecting from its centre, as at *B*, *fig.* 71. In other species of *Strongylus,* as in the *Strongylus inflexus,* the *bursa penis* is bifid, and in the *Strongylus armatus* it is divided into four lobes: the obvious functions of these appendages, as of the lateral alæform cutaneous productions which characterize the *Physalopteræ* and *Spiropteræ,* is to embrace the *vulva* of the female, and ensure an effective intromission and impregnation of the ova.

In the genus *Cucullanus,* and in most of the smaller species of *Ascaris,* the intromittent organ consists of a double spiculum.

This is also the case in the *Syngamus trachealis,* the parasitic worm before alluded to as infesting the trachea of the common fowl, and occasioning the disease termed the 'Gapes.' In this species the male individual appears as a branch from the body of the female. The testis begins near the middle of the œsophagus by a slender blind extremity, and winds round

* "Quelques Matériaux pour servir à l'Histoire des Filaires et Strongles, 8vo. Paris, 1836."

the gut, as it descends, gradually enlarging, to the lower part of the *intestine*, where it suddenly contracts and runs down, as a very slender canal, to near the vulva. It is partly covered by two long slender bodies of a horny substance, representing a bifurcate penis.

From this comparison of different genera of the Nematoidea, it is seen that, although there are many varieties of structure in the efferent and copulative part of the male generative apparatus, the essential or secerning portion uniformly consists of a single tube. A like uniformity of structure does not obtain in the essential parts of the female organs: in a few instances the ovary is single, corresponding to the testis in the male, but in the greater number of the Nematoid worms it consists of two filamentary tubes.

The *Strongylus gigas* is an example of the more simple structure above alluded to. The single ovary commences by an obtuse blind extremity close to the anal extremity of the body, and is firmly attached to the termination of the intestine; it passes first in a straight line towards the anterior extremity of the body, and when arrived to within a short distance from the vulva, is again attached to the parietes of the body, and makes a sudden turn backwards (*f*, *fig.* 95); it then forms two long loops about the middle of the body and returns again forwards, suddenly dilating into an uterus (*e*), which is three inches in length, and from the anterior extremity of which a slender cylindrical tube, or vagina, about an inch in length, (*e*, *d*, *fig.* 95) is continued, which after forming a small convolution terminates in the vulva, at the distance of two inches from the anterior extremity of the body. Rudolphi was uncertain as to the termination of the oviduct in the *Strongylus gigas*, and Professor Otto, who appears to have mistaken its blind commencement for its termination, believed that the oviduct opened into the rectum.

Fig. 95.

Anterior extremity of the Strongylus gigas, showing the commencement of the digestive and the termination of the generative tube.

The theory which had suggested itself to Rudolphi of the correlation of a simple oviduct in the female with the spiculum simplex of the male, and of a double oviduct with the spiculum duplex, receives additional disproof from the circumstance of the uteri and oviducts being double in the *Strongylus inflexus* and *Strongylus armatus*. In the former species (which infests the bronchial tubes and pulmonary vessels of the Porpesse, and which I once found in the right ventricle of the heart of that animal,) each of the two female tubular organs may be divided into ovary, oviduct, and uterus: the ovary is one inch in length, commences by a point opposite the middle of the body, and, after slightly enlarging, abruptly contracts into a capillary duct about two lines in length, which may be termed the oviduct, or Fallopian tube, and this opens into a dilated moniliform uterus three inches in length; the divisions here described were constant in several individuals examined, and cannot, therefore, be considered to result from partial contractions. Both tubes are remarkably short, presenting none of the convolutions characteristic of the oviducts of *Ascaris* and *Filaria*, but extend, in a straight line, (with the exception of the short twisted capillary communication between the ovaria and uteri,) to the vulva, which forms a slight projection below the curved anal extremity of the body.

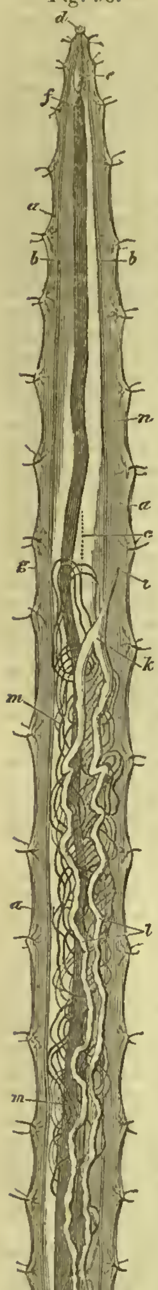
The reason of this situation of the vulva seems to be the fixed condition of the head of this species of *Strongylus*. In both sexes it is commonly imbedded so tightly in a condensed portion of the periphery of the lung as to be with difficulty extracted; the anal extremity, on the contrary, hangs freely in the larger branches of the bronchi, where the coitus, in consequence of the above disposition of the female organs, may readily take place.

In the *Strongylus armatus* the two oviducts terminate in a single dilated uterus, and the vulva is situated at the anterior extremity of the body, close to the mouth.

We find a similar situation of the vulva in a species of *Filaria*, about thirty inches in length, which infests the abdominal cavity of the *Rhea*, or American Ostrich. The single portion of the genital tube continued from the vulva is one inch and a quarter in length; it then divides, and the two oviducts, after forming several interlaced convolutions in the middle third of the body, separate; one extends to the anal, the other to the oral extremities of the body, where the capillary portions of the oviducts respectively commence.

In the *Ascaris Lumbricoides* the female organs (*fig.* 96) consist of a *vulva*, a vagina, a uterus, which divides into two long tortuous oviducts gradually diminishing to a capillary tube, which may be regarded as ovaries. All these parts are remarkable in the recent animal for their extreme whiteness. The vulva (*d*, *fig.* 72,) is situated on the ventral surface of the body at the junction of the anterior and middle thirds of the body, which is generally marked at that part by a slight constriction. The *vagina* is a slightly wavy canal five or six lines in length, which passes beneath the in-

Fig. 96.



Female organs, Ascaris lumbricoides.

testine and dilates into the uterus (*k*, *fig.* 96). The division of this part soon takes place, and the cornua extend with an irregularly wavy course to near the posterior extremity of the body, gradually diminishing in size; they are then reflected forwards and form numerous, and apparently inextricable, coils about the two posterior thirds of the intestine. Hunter has successfully unravelled these convolutions, and each of the tubes may be seen in the preparation in the Hunterian Collection to measure upwards of four feet. The generative organs contained in the female, or longer branch of the *Syngamus trachealis*, have a corresponding structure with those of the *Nematoidea*. The capillary unbranched ovary and uterus are double, as in *Ascaris*, *Spiroptera*, *Filaria*, and most *Strongyli*. The vulva is in the form of a transverse slit, and is situated at the anterior third of the body, immediately below the attachment of the male branch.

In the *Nematoidea* the male individual is always smaller, and sometimes disproportionately so, than the female. At the season of reproduction the anal extremity of the male is attached to the vulva of the female by the intromission of the single or double spiculum, and the adhesion of the surrounding tumid labia; and, as the vulva of the female is generally situated at a distance from either extremity of her body, the male has the appearance of a branch or young individual sent off by gemmation, but attached at an acute angle to the body of the female.*

In the *Heteroura androphora* of Nitzch (Hersch and Grüber's Encyclopædie, th. vi. p. 49, and th. ix. taf. 3. f. 7.) the male maintains an habitual connexion with the female, which has a horny prehensile process for the purpose of retaining the male in this position. Here there is no confluence of the substance of the bodies of the two sexes; the individuals are distinct in their superficies as in their internal organization. But this singular species offers the transitional grade to that still more extraordinary Entozoon, the *Syngamus trachealis*, in which the male is organically blended by its caudal extremity with the female, immediately anterior to the slit-shaped aperture of the vulva, which is situated as usual near the anterior third of the body. By this union a kind of hermaphroditism is produced; but the male apparatus is furnished with its own peculiar nutrient system; and an individual animal is constituted distinct in every respect, save in its terminal confluence, with the body of the female. This condition of animal life, which was conceived by Hunter as within the circle of physiological possibilities, (see Anim. Œconomy, p. 46,) has hitherto been only exemplified in this single species of Entozoon; the discovery of the true nature of which is due to the sagacity and patient research of Dr. Charles Theodore Von Siebold.

The Entozoa of the parenchymatous class are chiefly oviparous, those of the cavitary class for the most part ovoviviparous.

The germinal vesicle has not yet been discovered in the vitelline substance of the ova of the *Acanthocephala*, *Trematoda*, or *Cestoidea;* but it is distinctly discernible in the ova of the *Nematoidea;* I have also observed and have figured it in the highly organized ovum of the *Linguatula tænioides*.

The ova of the *Tæniæ* present considerable varieties of size and form in different species; Rudolphi has figured seven forms of these ova in the *Synopsis Entozoorum*, (tab. iii.)* Some are much elongated and pointed at both extremities, others elliptical: the ova of the *Bothriocephalus latus* are of the latter form, (C, *fig* 89); those of the *Tænia solium* are spherical, as are also the ova of *Tænia filiformis*. In some species the development of the embryo Tape-worm has been observed to have distinctly commenced in the undischarged ova, as in the *Tænia polymorpha*. In dissecting a Touraco infested by the *Tænia filiformis*, we found that the segments of the Tænia in which the ova were most developed had been detached from the rest of the body, a process remarkably analogous to that which takes place in the *Lerneæ* and *Entomostraca*, where the external ovaries are cast off, when charged with mature ova.

A few of the Trematode Entozoa, as the *Monostoma mutabile*, produce the young alive; but these have a very different form from the parent. It would seem that they were destined to pass a transitional state of their existence in a fluid medium permeated by light, since two coloured ocelli have been discovered on the head, and the surface of the body is beset with locomotive vibratile cilia.†

* See Figures of Nematoid Entozoa in copulation, in Bremser, Icones Helminthum tab. iii. fig. 8. 15.; and Gurlt, Lehrbuch der Patholog: Anatomie der Haus-Saügethiere, tab. vi. fig. 35.

* Synopsis Entoz. p. 505, pl. iii. fig. 10, 11.
† See Siebold, in Weigmann's Archiv. 1835.

The ova of the greater part of the *Trematoda* are excluded prior to the full development of the fœtus; they are generally of an oval but sometimes spherical form, and many of them singularly resemble the seeds or capsules of certain mosses, in having a small circular portion of the outer covering separate from the rest, and closing the cavity of the egg like a lid.

Nordmann has studied the development of the young of the *Distoma hians*, which infest the intestines of the perch. According to this excellent observer the fœtus raises, in its endeavours to slip out of the egg, the small lid, and writhes about for some time, being still attached to one point of the egg. In about six hours it succeeds in freeing itself from the egg-coverings; and at this period it differs in every respect from the shape of the parent animal; the body, which is of a mucous consistence and perfectly transparent, is of an oval form; the anterior mouth forms a small square-shaped projection, and the whole surface of the body is beset with many longitudinal rows of short cilia, which are in rapid and incessant motion, and create a vortex in the surrounding water, similar to that which the Polygastric Infusoria produce. The little animal having its anterior extremity diminishing to a point, is well formed for swimming, and by means of its vibratile cilia, quickly darts out of the field of vision when under the microscope. At the distance of one-third of the body from the anterior extremity there is a single coloured eye-speck, from which, when pressed between glass plates, there escapes a brilliant blue-coloured pigment. Thus organized, the young of the intestinal parasite just described move to and fro in water as if this were their natural element, and approximate in form and structure most closely to the Polygastric Infusoria of the genus *Paramæcium*, Ehrenb. In this state, doubtless, they are ejected by the Fish, in the intestines of which they were originally developed, into the surrounding water, and when again received into the alimentary canal undergo their metamorphosis, lose, like the Lerneæ and Cirripedes, the organ of vision which guided the movements of their young and free life, and grow and procreate at the expense of the nutrient secretions with which they are now abundantly provided.

In the *Cœlelmintha* the young cast their integument, and would seem in some species, as the *Filaria Medinensis*, to undergo a change in the form and proportions of the extremities of the body, but they do not possess cilia or ocelli, as in the Trematoda above-mentioned.

The ova of the *Linguatula* are of an oval form: the germinal vesicle is situated near the superficies half-way between the two extremities; the vitelline membrane is surrounded with a strong cortical membrane: the development of the fœtus takes place out of the body. In the *Strongylus gigas*, *Strongylus inflexus*, and a species of *Trichosoma* infesting the intestines of the Goatsucker, we have found the fœtus completely formed in the ova contained in the uterus or terminal segment of the generative tube, while those in the ovary or narrow commencement of the same part were still occupied with the granular matter of the vitellus

The mature ova of the *Strongylus gigas* are of an elliptical form, and the embryo within is plainly seen coiled up through the transparent coats of the egg; the resemblance which these bear to the *Trichina* when inclosed in its inner cyst is very striking: the hypothesis suggested by this resemblance need only be alluded to for the purpose of exciting the attention of those, who may hereafter meet with the preceding minute muscular parasite, to the existence of larger Nematoid Entozoa in other parts of the body.

Cloquet describes the ova in the beginning of the ovaries of the *Ascaris Lumbricoides* as consisting of rounded linear corpuscles, pointed at one extremity, thickened at the other; in the middle of the ovaries they assume an elongated triangular form, and one of their angles frequently supports a small spherical eminence; the base of the ovum adheres to the parietes of the oviduct, the apex projects into its cavity. In the enlarged canals, which he terms the cornua of the uterus, the ova are unattached and of a conoid or irregularly triangular figure. In the uterus itself they have assumed an ovoid or elliptical form, are surrounded by a transparent glairy mucus, and are composed of a transparent cortical membrane, perfectly smooth on the external surface, and filled with a transparent fluid, in which floats a linear embryo, disposed either in a straight line or coiled up. Cloquet never observed the young Ascarides excluded from the egg in the interior of the uterus, and we equally searched in vain for free embryos in the generative tubes of the Strongylus and Oxyurus above-mentioned, although their development in regard to form appeared to be complete in the ovum; the structure of the embryo resembles that of the simpler Vibriones, there being no generative tubes apparent, and the cavity of the body being occupied by a granular parenchyma.

With respect to the exclusion of the ova in these and similar ovo-viviparous Nematoid Entozoa, it would appear to be very commonly accompanied with a rupture of the parietes of the body and of the generative tube. Rudolphi observes, with respect to the Cucullanus, "Ovula, verme quieto, per intervalla ex vulvâ pullulent; quin eodem disrupto, quod sæpe accidit, ovula vel embryones ex ovariis prolapsis parituque ruptis vi quâdam et undatim protroduntur."

The generation of the *Filaria Medinensis* is of the viviparous kind, and the progeny is countless,—"Filariæ nostræ," observes Rudolphi, "prole quasi farctæ sunt, quod si harum longitudinem illius vero minutiem spectas, fœtuum multa millium millia singulis tribuit." What is most remarkable is, that these embryos are not, as in the *Strongylus* and the Nematoid genera above-mentioned, enveloped in an egg-covering, nor are they included in a special generative tube, but float freely along with a granular substance in the common muscular envelope of the cavity of the body.

M. Jacobson,* who has recently published a description and figures of the young *Filaria Medinensis*, compares the body of the mother to a tube or sheath inhabited by the young ones; and, after a careful examination of three individuals, we have equally failed in detecting either generative or digestive tubes within the muscular sac of the body. The external tunic of the body is a firm subtransparent elastic integument, which, examined under a high magnifying power, presents fine transverse striæ, occasioned most probably by adherent muscular fibres. Within this tunic and readily separable from it are the longitudinal muscular fibres, which are arranged in two fasciculi, separated from each other by two well-marked intervals on opposite sides of the body, which are indicated by an impression (or furrow, as the worm dries by evaporation) on the exterior surface. When from long maceration the crisp outer integument has become separated from the longitudinal muscular bands, these might be mistaken for two tubes contained loosely within the cavity. I believe that these muscular bands are the *tubes fibrineuses*, described by Dr. Le Blond † as the alimentary canal and intestine in the fragment of *Filaria Medinensis*, which he dissected. In a small *Filaria Medinensis*, containing no vermiculi, we have also failed to discover any distinct tubes for digestion or generation.

It is interesting to observe that the young of the *Filaria Medinensis* do not resemble the parent in form; one extremity is obtuse, the body slightly enlarges for about one-fourth of its length, then gradually diminishes to within a third of the opposite extremity, which is capillary and terminates in the finest point. The enlarged part of the worm contains a granular substance, and is coiled upon itself, and presents a distinct but minute annulation of the integument: the capillary extremity is smooth, transparent, and generally straight. The *Trichocephalus dispar* closely resembles in its external form the fœtus, if it be such, of the *Filaria Medinensis*.

BIBLIOGRAPHY. — *Redi*, Osservazioni intorno agli animali viventi che si trovano negli animali viventi, Firenze, 1684. *Bloch*, Abhand. von d. Erzeugung Eingewerdwürmer. Berl. 1782. *Goeze*, Versuch einer Naturgeschichte der Eingewerdwürmer, und Nachtrag dazn. Leipz. 1782-1800. *Vallisneri*, Considerazioni ed esperienze intorno alla generazione de vermi ordinarj del corpo umano. Padova, 1782. *Werner*, Vermium intestinalium, &c. brevis expositio. Leipz. 1782. *Retzius*, Lectiones publicæ de Vermibus intestinalibus, Holm. 1786. *Schrank*, Verzeuhniss der bisherigen hinlänglich. bekannten Eingeweidwürmer, Münch, 1788. *Rudolphi*, Observ. circa vermes intestinales, 2 fasc. Greifsw. 1793-95. *Rudolphi*, Entozoorum s. vermium intestinalium historia naturalis, 2 in 3 vol. Amst. 1808-9. *Rudolphi*, Entozoorum Synopsis, Berl. 1819. *Treutler*, Obs. pathol. anat. ad helminthologiam corp. humani. Leipz. 1793. *Zeder*, Anleitung zur Naturgeschichte des Eingeweidwürmer. Bamb. 1803. *Olfers*, De vegetativis et animatis corporibus in corporibus viventibus reperiundis comment. Berl. 1816. *Fischer*, Brevis Entozoorum s. verm. intest. expositio. Viennæ, 1822. *Bremser*, Ueber lebende Würmer in lebenden Menschen. Wien, 1819; trad. en français, par MM. Grundler et de Blainville, Paris, 1825. *Bremser*, Icones Helminthorum Systema Rudolphii illustrantes, Wien. 1823. *Joerdens*, Entomologie und Helminthologie des Mensch. Koerpers. 2 Bde. Hof. 1801-02. *Lidth de Jeude*, Recueil des figures des Vers intestinaux, Leid. 1829. *Cloquet*, Anatomie des Vers intestinaux, Paris, 1824. *Creplin*, Observ. de Entozois, Greifesw. 1825-29. *Schmalz*, De Entozoorum systemati nervoso, Leipz. 1827. *Ejus*, Tabulæ anatomicæ Entozoorum, Dresd. 1831. *Le Blond*, Quelques matériaux pour servir à l'histoire des filaires et des stroogles, Paris, 1836. *Mehlis*, Obs. Anat. de distomate hepatico et lanceolato, Gölting. 1825. *Nordmann*, Mikrographische Beiträge, 2 Bde. Berlin, 1832. *Jacobson*, in Nouv. Annales du Museum d'Hist. Nat. tom. iii. *Klein*, in Philos. Trans. for 1730. *Carlisle*, in Trans. of the Linnean Society, vol. ii. *Laennec*, in Bulletin des Sciences de l'Ecole de Médecine, An xiii. *Home*, in Philos. Trans. for 1793; *Frisch*, in Miscell. Berolinensia, tom. iii.; and for further references to numerous papers on the natural history of particular families and species, vide *Reuss's* Repertorium, &c. Scientiæ Naturalis, tom. i. Zoologia, &c. Götting.; the first vol. of Rudolphi's Entozoorum historia naturalis, and *Wiegemann's* Archiv für Naturgeschichte und Vergleichende Anatomie.

(R. Owen.)

* Nouvelles Annales du Museum d'Histoire Naturelle, tom. iii. p. 80, pl. v.

† Quelques Matériaux pour servir à l'Histoire des Filaires et des Strongles, 8vo. 1836.

ERECTILE TISSUE, *(tela erectilis;* Fr. *tissu erectile;* Germ. *das erectile, oder schwellbare Gewebe,)* a structure composed principally of bloodvessels, intimately interwoven with nervous filaments. This tissue in its ordinary state is soft, flaccid, and spongy; but when influenced by various causes of excitement, whether these consist of stimuli directly applied, or operating through the medium of the sensorium, it exhibits the faculty of admitting an influx of blood much greater in quantity than what is sufficient for its nutrition, and in virtue of which it suffers a state of turgescence giving rise to a swollen condition, with more or less of rigidity and increased sensibility of the organs into the structure of which it enters, and which state has been long known by the name of erection. From the property of undergoing erection peculiar to this tissue, Dupuytren and Rullier first applied to it the term *erectile*, and the propriety of this distinguishing appellation is now very generally admitted by anatomical authors.

The erectile tissue is developed in various degrees in the several parts of the animal economy in which it occurs; it is abundant and particularly evident in the corpora cavernosa penis, corpus spongiosum urethræ, clitoris, nymphæ, plexus retiformis, the nipples of the mammary glands, less marked in the red borders of the lips, &c.; it also enters into the structure of the papillæ of the skin and the villi of the mucous membranes which possess the property of becoming erected in the performance of their functions, as is exemplified in the papillæ of the tongue. These consist of the pulpy terminations of nerves enveloped by this tissue; in their unexcited state they appear small, pale, soft, and shrunken; but when excited to erection, they become increased in size, stiff, red, and distended with blood, at the same time that their sensibility is remarkably exalted. The foregoing remarks apply equally to the cutaneous papillæ, particularly those on the pulpy extremities of the fingers, where the sense of touch is developed in its highest degree of perfection.

Erectile tissue has also been recognised in the callosities on the buttocks of some of the quadrumana, in the comb and gills of the cock, the wattles of the turkey, and in the tongue of the chamelion.* It is not improbable that this tissue enters into the structure of the iris; and Beclard seems disposed to consider that it exists in the spleen, as well from the appearance which that organ presents when a section of it is made, as from the different states in which it is found on opening the bodies of animals; being sometimes contracted and corrugated on the surface, and at other times plump, smooth, and swollen.

In some of the situations above enumerated, the erectile tissue is enclosed in a fibrous sheath which limits its extent and determines the form of the organs in which it occurs; while in other situations it is deployed superficially, as in the tegumentary organs.

It is in the corpora cavernosa penis and corpus spoogiosum urethræ, however, that the erectile tissue has been more especially made the subject of anatomical and physiological research; and the results of the investigations instituted in these organs have been rather inferred from analogy than directly proved as equally applicable to it in all other situations in which its existence has been indicated.

According to De Graaf, Ruysch, Duverney, Boerhaave, Haller, and Bichat, the cavernous bodies of the penis and urethra consist of a loose and elastic spongy tissue formed of innumerable cells, into which, during erection, blood is poured from the arteries, and from which it is afterwards removed by an absorbing power of the veins. Such an opinion would accord with the appearances observed by examining sections of this structure after having been inflated and dried, but careful examination of it when previously prepared by injection, proves the foregoing opinion to be founded in error.

Vesalius, who appears to have directed his attention to the particular nature of this structure in the penis, describes it as composed of innumerable fasciculi of arteries and veins closely interwoven, and included in an investing sheath.

Malpighi considered it as composed of diverticula or appendices of veins.

Mascagni, who at one time believed in the existence of cells interposed between the veins and arteries, in consequence of subsequent researches abandoned that opinion, and demonstrated the fact, that a plexus of veins with arteries corresponding, but smaller and less numerous, formed the corpus spongiosum urethræ, glans, and plexus retiformis, and that the arteries entering this substance terminated in the commencement of veins.

Mr. Hunter remarked that the corpus spongiosum urethræ and glans penis were not spongy or cellular, but made up of a plexus of veins, and that this structure is discernible in the human subject, but much more distinctly seen in many animals, as the horse, &c.

Subsequent researches respecting the structure of the penis and clitoris of man, the horse, elephant, ram, &c. have been instituted by Duverney, Mascagni, Baron Cuvier, Tiedemann, Ribes, Moreschi, Panizza, Beclard, Weber, &c. and the result has been a confirmation of the views developed by Vesalius, Malpighi, and Hunter.

Moreschi, in particular, has shewn that the corpora cavernosa penis, corpus spongiosum urethræ, and glans consist of a congeries of fine vessels in all animals, whether covered by skin, hairs, spines, or scales; and that these vessels, which are principally veins, are characterized by their abundance, tenuity, and softness, which distinguish them from the veins in the muscles and other parts of the body.

The annexed figure (*fig.* 97) from Moreschi

Fig. 97.

* On the structure and mechanism of the tongue of the chamelion, by J. Houston, in Transactions of the Royal Irish Academy, vol. xv.

represents the plexiform arrangement of the veins apparent on the surface of the glans, and which empty themselves into the superficial veins of the penis.

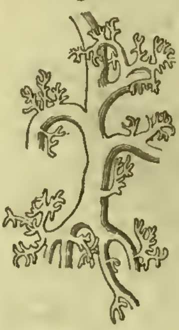
Müller having more recently investigated the structure of the penis, has announced the discovery of two sets of arteries in that organ, differing from one another in their size, their mode of termination, and their use; the first he calls nourishing twigs *(rami nutritii)*, which are distributed upon the walls of the veins and throughout the spongy substance, differing in no respect from the nutritive arteries of other parts; they anastomose with each other freely, and end in the general capillary network.

The second set of arteries he calls *arteriæ helicinæ*. In order to see these vessels, an injection of size and vermilion should be thrown into a separated penis through the arteria profunda: when the injection has become cold, the corpora cavernosa should be cut open longitudinally, and that portion of the injection which has escaped into the cells carefully washed out. If the tissue of the corpora cavernosa be now examined at its posterior third with a lens, it will be seen that, in addition to the nutritious arteries, there is another class of vessels of different form, size, and distribution. These branches are short, being about a line in length and a fifth of a millimetre in diameter; they are given off from the larger branches as well as from the finest twigs of the artery. Although fine, they are still easily recognised with the naked eye; most of them come off at a right angle, and projecting into the cavities of the spongy substance, either terminate abruptly or swell out into a club-like process without again subdividing. These vessels appear most obvious and are most easily examined in the penis of man, to which the following description refers. These twigs branch off from place to place, sometimes alone, and sometimes in little bundles of from three to ten in number; these, as well as the former, project constantly into the cells or venous cavities of the corpora cavernosa penis. When the arteries thus form a bundle, they arise by a common stem. Sometimes such a vessel, whether it proceeds from the artery as a single branch or as part of a cluster, divides into two or three parallel branches, which also either terminate abruptly, or else swell out near their extremity.

Almost all these arteries have this character, that they are bent like a horn, so that the end describes half a circle, or somewhat more. When such a branch so divides itself, there are formed doubly bent twigs inclined one to the other.

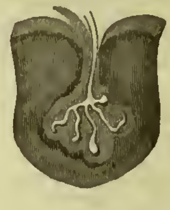
Many of these arteries enlarge towards their end; this enlargement is gradual, and is greatest at some little distance from the extremity, so that the end is somewhat conical, terminating immediately in a rounded point without giving off any branches. The diameter of these arterial twigs, in their middle, is from one-fifth to one-sixth of a millimetre: those which branch off from the trunk of the arteria profunda penis are no larger than those which arise from its finest twigs. It is by no means unusual to observe the finest twigs of the arteria profunda giving off branches of this kind which seem much thicker than the twig from which they arose. The annexed figure *(fig.* 98) (from Müller's Archiv.) represents a portion of the arteria profunda penis of man, with its arteriæ helicinæ somewhat magnified.

Fig. 98.



These remarkable arteries have a great resemblance to the tendrils of the vine, only that they are so much shorter in proportion to their thickness, whence they have received the name arteriæ helicinæ. Their terminations may also be compared to a crosier. By a more minute examination of these vessels either with the lens or with the microscope, it will be seen that, although they at all times project into the venous cavities of the corpora cavernosa, yet they are not entirely naked, but are covered with a delicate membrane, which under the microscope appears granular *(fig.* 99).

Fig. 99.



After a more forcible injection this envelope is no longer visible. When the arteries form a bundle, the whole is covered by a slight gauze-like membrane.

With respect to this investing membrane, Professor Müller appears to consider it as performing an important part in producing the phenomena of erection.

These tendril-like arteries have neither on their surface nor their extremities any openings discoverable with the aid of the microscope; and when the blood, as it is probable, escapes from them in large masses into the cells of the corpora cavernosa during erection, it must either traverse invisible openings, or pass through small openings which become enlarged by the dilatation of these arteries. If the great number of the tendril-like branches of the arteria profunda be compared with the very fine nutritious twigs of the same vessel, it is evident that when the former are filled they must take up the greater part of the blood of the arteria profunda; the diameter of the profunda therefore not only includes its nutritious twigs, but also the tendril-like branches, which derive their blood from it, yet probably allow none to pass except during erection; therefore the blood in the unerected state only traverses the nutritive branches and arrives at the commencement of the venous cells in smaller quantities, while during erection it probably passes in considerable quantity into the cells through these tendril-like vessels.

Professor Müller, after pointing out the difference between the tendril-shaped vessels and the looped vessels discovered by Weber in the villi of the placenta, observes: our vessels are simple; they bend themselves at the end, but do not return to their trunk as a loop, being simply blood-containing processes of the arteries which project freely into the cellular cavities of the veins of the corpora cavernosa. These vessels are most numerous in the posterior part of the corpora cavernosa; they occur but seldom in the middle and anterior parts: they are also present in the corpus spongiosum urethræ, especially in the bulb; here also they become less frequent anteriorly, and as yet they have not been perceived in the glans. They are much more difficult of detection in the corpus spongiosum urethræ than in the corpora cavernosa, where they are very easily exhibited, especially in the human penis. In no other animal have they been found so distinct, or so uniform in their existence as in man. The greater development of these arteries, adds Professor Müller, in the posterior parts of the organ corresponds with the fact of erection being always earlier evident there, as if the blood distributed itself from thence into the venous cells.

During erection blood is accumulated in large quantity in the erectile tissue, but the cause and mechanism of this accumulation are but imperfectly known. Hebenstreit ascribes it to a living power, named *turgor vitalis*, which exists in different degrees in almost all the textures of the animal body, but most distinctly in the erectile tissue. It still remains, however, to be proved how far erection depends on mechanical pressure affecting the veins which convey blood from this structure, and consequent retardation of the venous circulation; and how far it may depend upon an increased flow of blood to its arteries accompanied, or perhaps more correctly, occasioned by an increase of sensibility,* or whether it may not depend upon the influence of both these causes combined.

Erectile tissue appears sometimes to be developed as a morbid production, which has been described under the names of varicose tumour, aneurism by anastomosis, nævus maternus, telangiectasis, &c. Its anatomical characters are of the same kind as those of the normal erectile tissue; it varies in size, being more or less circumscribed, sometimes surrounded by a thin fibrous envelope; presenting internally an appearance of cells or spongy cavities, but consisting, in reality, of an inextricable congeries of arteries and veins which communicate by innumerable anastomoses like capillary vessels, but much larger, especially the veins. It is difficult to inject it from the arteries, more easy from the neighbouring veins, which are sometimes much enlarged. This alteration most commonly exists in the substance of the skin, where it sometimes resembles the comb and other analogous parts of the gallinaceæ. The skin of the face, especially that of the lips, is frequently its seat. It has been observed in the subcutaneous cellular tissue in masses of various dimensions, sometimes so large as to occupy an entire limb. It rarely affects the internal organs; sometimes it extends beneath the mucous membrane of the mouth, mostly in the vicinity of the red borders of the lips. This production is occasionally affected by a vibratory motion amounting sometimes to a pulsation resembling that of an aneurismal tumour, which is increased by all the causes which excite the activity of the general circulation; it cannot be properly said that this structure has the property of undergoing erection. It is often congenital, sometimes it appears to have been produced by accidental causes; it sometimes remains unaltered; but it more usually continues to increase in size until some of its cavities burst, when hæmorrhage of a troublesome description ensues.

Beclard considers the hæmorrhoidal tumours which occur round the anus as constituting a variety of anormal erectile tissue.

[* It must be obvious that the discovery of the *arteriæ helicinæ* by Professor Müller favours this theory of erection, as proving the existence of vessels distinct from the ordinary ones, which receive and transmit the increased supply of blood to the venous cells. What, in other organs, is effected by a diminished tonicity in the arteries, and a consequent enlargement of them, ultimately giving rise to the tortuosity so striking in some cases, is here effected by means of a very peculiar set of arterial processes superadded to the ordinary nutritious arteries of the organ. In the pregnant uterus the increased supply of blood is provided for by the enlargement and consequent tortuosity of its ordinary arteries; there are no sinuous veins here to receive the new supply of blood, and consequently erection is not present; but in the case of the penis this phenomenon occurs in consequence of the existence of the sinuous veins which constitute so large a proportion of the corpora cavernosa. It will be interesting to inquire whether any similar or analogous arrangement of arterial processes exists in other erectile organs.—ED.]

BIBLIOGRAPHY. — *Vesalius* de corp. humani fabrica, lib. v. cap. xiv. Venet. 1564. *De Graaf Regner*, De virorum organis, &c. p. 99 et seq. Lugd. Bat. 1668. *Malpighi Marcelli* opera omnia, tom. ii. p. 221. London, 1686. *Ruysch Frid.*, Observatio, C. Amstel. 1691. *Haller*, Elementa, lib. ii. sect. i. § 24, et lib. xxvii. sect. iii. § 10. *Mascagni*, Prodromo della grande anatomia, Firenze, 1819. *Hunter John*, On certain parts of the animal economy, Lond. 1786. *Moreschi Alex.* Comment. de urethræ corporis glandisque structura, Mediolani, 1817. *Duvernay*, in comment. Petropolit. tom. ii. p. 200. *Cuvier*, Leçons d'anatomie comparée, tom. iv. Paris, 1799—1805. *Tiedemann*, in Journal complémentaire, tom. iv. p. 282. *Hebenstreit, G.* De turgore vitali in Brera Sylloge, tom. ii. *Duverney*, Œuvres anatomiques, tom. ii. Paris, 1761. *Mascagni, P.* Hist. vasorum lymphat. sect. ii. Senis, 1787. *Beclard*, Anat. générale, Paris, 1823. *Weber, H. E.* Allgemeine anatomie, p. 415. Braunschweig, 1830. *Craigie David, M.D.* Elements of general and pathological anatomy, Edin. 1828. *Müller*, in Archiv für Physiologie, Jahr 1835, p. 202. The paper of Professor Müller has been very ably translated in the London Medical Gazette, No. 423.

(J. Hart.)

EXCRETION.—This term is applied to the formation of those fluids in the animal economy, which are destined to no useful purpose in the system, but are intended to be discharged from it, and the retention of which is injurious or even fatal. The term used by the older physiologists was excrementitious secretions. Some general observations may be made on these excretions, with the view both of stating the present extent of our knowledge on this mysterious subject, and of pointing out the importance of an arrangement and combination of facts relating to it, which are usually treated, perhaps, in too unconnected a manner, but the connexion of which is already perceptible, and can hardly fail to be satisfactorily elucidated in the progress of physiology.

When we shall have more precise information as to the peculiar, and hitherto obscure principles, which regulate the chemical changes continually taking place in living bodies, it does not seem unreasonable to anticipate, that a discovery will be made, connecting the excretions of the body with the assimilation of the food, and with the nourishment of the different textures, a discovery which may be equally as important in illustrating the chemical phenomena of the living body, as that of the circulation was in explaining those changes which come more immediately under our observation. In the mean time, we can point out a great deal of contrivance, connected with the general function of excretion, and can state what are the general injurious results, when this contrivance fails of its intended effect; but we are unable to explain how the contrivance effects its purpose, or to point out any general law, by which these injurious results are determined.

I. We may state, in the first place, that the necessity for some kind of *excretion*, or discharge of certain matter from the organized frame, corresponding to the acts of *nutrition*, or of reception and assimilation of external matter, is a law of vital action, applicable to all organized beings without exception. The universality of the excretion of carbon, (whether pure, or in the form of carbonic acid, we need not now inquire,) has been established by the inquiries of Mr. Ellis and others, and the poisonous influence of the carbonic acid, in an undiluted state, to all living beings, is an equally general fact. In all animals, which possess organs of such size and distinctness as to make their economy matter of observation, other excretions are likewise observed; and in vegetables, it is not only certain that various excretions, besides the exhalation of water and of carbonic acid, take place, but it is even believed by De Candolle, that all the peculiar products of vital action, excepting only gum, sugar, starch, and lignine, (which have nearly the same elementary composition, and are convertible into one another,) and, perhaps, fixed oils, are applied to no useful purpose in the economy, and are poisonous to the plants in which they are formed, if taken in by their roots and combined with their sap; so that, although often long retained in individual portions of the plants, they all possess the essential characters of excretions.* And it appears to be well ascertained by the observations of De Candolle and of Macaire, that at least great part of the proper juices of vegetables, which descend chiefly by their bark, and are expelled into the soil, are destined to excretion only, and are noxious to plants of the same species, or even of the same families, if growing in that soil (although often useful to the growth of plants of different families); and this principle has been happily applied by the former author to explain the necessity of rotation of crops of different natural families, to prevent deterioration of the produce.*

As this *necessity of excretion* appears to be so general an accompaniment of the vital action of all organized beings, it seems obvious that there must be some general law, which determines the noxious quality of these products of that action, and imposes the necessity of their expulsion. Yet it is certain that the *chemical elements* which pass off in the excretions, are the same which are found in the textures of the animal body, and in the nourishment, which is essential to animal life.

It would appear, therefore, that the noxious property belongs to certain *combinations* only of these elements, which are formed in the course of the chemical changes in living beings, and which, when once formed, must either be expelled from the body, or else laid up in cells appropriated for the purpose, (as in the case of the resins and volatile oils in vegetables, and of the bile in the gall-bladder in animals,) and kept out of the mass of the nourishing fluid.

There is one general fact, on which much stress has been justly laid by Dr. Prout, which is confirmed by M. Raspail, and which may, perhaps, be concerned in determining the noxious qualities of certain compounds, in living beings, viz. that although the elements which enter into the composition of organized bodies, readily combine, in other circumstances, so as to form *crystals*, yet the peculiar combinations which they form in all the textures which are essential constituents of those organic structures are *never crystalline*. When a crystal occurs in an organized body, according to Dr. Prout,† it is always either the result of disease, or of some artificial process, or it is part of an excretion, separated from the nourishing fluid and from the useful textures.‡ Every one of these textures contains, even in its minutest particles, saline and earthy, as well as animal or vegetable matter; § but the combinations are always so arranged, by the powers of life, that these saline and earthy particles are always diffused through membranes, fibres, or cells, never concentrated in crystals. On the other hand, the elements constituting the peculiar matters of the excretions are generally in such a state of combination as readily to assume the crystalline form, either alone, or in the simplest farther combinations of which they are susceptible; and it seems possible, that this circumstance may be part at least of the cause which necessitates their expulsion. This is only matter of

* Physiol. Veget. p. 217.

* Ibid. p. 249, and p. 1496.

† Lectures in Medical Gazette, vol. viii.

‡ "Jamais je n'ai aperçu," says Raspail, "de cristaux dans le sein d'une cellule vivante et d'accroisement," Raspail, Chimie Organique, § 1378.

§ Ibid. § 1390.

speculation, but that some such general principle determines the incompatibility of the matters of the excretions with the life of the structures in which they are formed, can hardly be doubted.

II. Although the necessity of various excretions is obvious, there is a difficulty, both in the case of animals and vegetables, in fixing on those products of vital action which come exclusively under this denomination; and it appears certain, that some of the organs of excretion (such as the lungs) are at the same time destined to other purposes, particularly absorption; and even that part of certain excreted fluids (such as the bile) is employed likewise in the work of assimilation. But it is certain that the lungs or gills, the skin, the intestines, and the kidneys, are the outlets for excreted matters in all vertebrated animals.

1. There can be no doubt that the watery vapour and carbonic acid which are exhaled from the lungs, are strictly excretions, although it is still doubted by some physiologists, whether the latter substance is truly exhaled, or rather formed at the lungs; on the latter supposition we should say, that the excretions of the lungs are water and carbon. It appears certain, from some experiments of Dr. Gordon, that no animal or saline matter escapes by this outlet. The total amount of loss by this excretion in twenty-four hours, in a middle-sized man, has been stated by Lavoisier and Seguin as averaging about fifteen ounces; and it must be remembered, that as we have good evidence of very considerable absorption at the lungs, the whole quantity of matter excreted must considerably exceed this weight. Indeed, Mr. Dalton estimates the exhalation of watery vapour only from the lungs at twenty-four ounces in the day. Some have estimated the quantity of carbon alone escaping in this way in the day at eleven ounces; but this estimate is probably exaggerated. It seems to be ascertained by the experiments of Dr. Edwards, of Despretz, and Collard de Martigny, that there is at times an obvious exhalation of azote by the lungs; and Dr. Edwards expresses an opinion that there is probably, at all times, both an exhalation and absorption of that gas, but that these processes in general nearly compensate one another. According to Dr. Prout's views, recently, though briefly, announced, we may, perhaps, state the source and cause of the formation of the carbonic acid, and assign the use of the excretion of the water, which escapes by the lungs, with more precision. He supposes the acid to be evolved *in the course of the circulation*, by that "process of reduction," by which the gelatin of the animal textures is formed from the albumen of the blood; and the water to be given off chiefly *from the weak albuminous matters of the chyle*, and to be an essential part of the "process of completion," by which this is converted into the *strong albumen of the blood*.*

2. The excretion by the skin is chiefly watery vapour; the escape of carbon, or carbonic acid, by this outlet appears to be to a very small amount, and to be very variable. In the sensible perspiration or sweat there is an excess of lactic acid, a small quantity of the same animal and saline matters as are contained in the serum of the blood, and a little oily or fatty matter, probably from the sebaceous glands; the whole loss by this excretion in the human adult has been stated as averaging about thirty ounces in the day, but is evidently liable to very great variety. Many experiments prove that there is much less compensating absorption by this texture than by the lungs.

3. The excretions by the bowels are, properly speaking, only those parts of the alvine evacuations, which are secreted within the body itself, and mixed with the residue of the food. It is probable that part of the secretions from all parts of the primæ viæ are thus excreted, but the only one of which it has been ascertained that it is, in part at least, destined necessarily for excretion, is the bile. It is certain that the peculiar animal matter of this secretion, (regarded by some as of pretty simple and by others as of very complicated composition) is never found in the healthy state in the lacteal vessels or thoracic duct—that it is found in full quantity along with the residue of the aliments in the lower intestines,—that it is increased in quantity when the excretion of urine is suppressed in animals by extirpation of the kidneys; and again, that when this secretion is suppressed, the urine is increased and altered; and we can therefore have no difficulty about regarding this part of the bile as strictly an excretion, notwithstanding that we have good evidence, that at least the alkali of the bile is of use in the digestion and assimilation of the food. Of the quantity of matter strictly excreted from the intestines in the day it must of course be very difficult to judge. The chemical elements that escape in the biliary matter must be chiefly carbon and hydrogen.

4. The urine is the most complex of the excretions, particularly as to saline impregnation, containing not only the salts which are detected in the blood, but a portion of every earthy and saline matter that can be found in any part of the body, besides the peculiar and highly azotised animal matters, lithic acid and urea. The average quantity of urine passed in twenty-four hours may be about forty ounces, but is very liable to variation, particularly by temperature, being generally greater, as the excretion by the skin is less. The quantity of solid matter, animal, earthy, and saline, that passes off in this way has been stated at about fifteen drachms on an average, and is evidently much less liable to change, the density of urine, in the healthy state, always diminishing as its quantity increases, and vice versâ. The milk, and the semen, although destined to no useful office in the system in which they are formed, are rather to be called recrementitious secretions than excretions. Yet the former has this property in common with excretions, that its retention within the body, when the conditions of its formation exist, is

* See Bridgewater Treatise, p. 524.

hurtful. The menstrual discharge may be regarded as strictly an excretion, though one which is required only in the human species and for a limited time.

Berzelius stated several distinctions, which he thought important, between the excrementitious and recrementitious secretions in the animal body, particularly that the former are always acid, that each of them contains more than one animal matter, and that their salts are more numerous and varied than those in the blood, while the latter have an excess of alkali from the same saline ingredients as the serum of the blood, and each contains only a single animal principle, substituted for the albumen of the serum. But these distinctions are certainly inapplicable in several instances, and the only one of them which appears to be a general fact, is the more complex saline impregnation of the excreted fluids.

III. It is unnecessary to dwell on the well-known injurious effects, on the animal œconomy, of the suppression of any of these excretions. It may, indeed, reasonably be doubted, whether the rapidly fatal effects of obstructing the exposure of the blood to the air at the lungs are owing to the retention of carbon, or carbonic acid; it seems much more probable that the cause which stops the circulation at the lungs in asphyxia, is the suspension of the *absorption* of free oxygen into the blood, rather than the suspension of the *evolution* of carbon or carbonic acid. But even if the circulation could be maintained, after the exposure of the blood to the air is suspended, we know that the carbonic acid which we have good reason to believe would soon be in excess in the blood, would then act as a narcotic poison. Of the effects of suspension of the excretion by the skin we cannot speak with certainty, because that is a case which probably hardly ever occurs; and if it were to occur, the lungs and kidneys would probably act as perfect succedanea. But it is worthy of notice that at a time when the skin is known to be nearly unfit for its usual functions —during the desquamation that succeeds exanthematous diseases, and especially scarlatina,— the lungs and the kidneys, on which an unusual burden may thereby be supposed to be thrown, are remarkably prone to disease. The effect of suppression of the excretion of urine (i. e. of ischuria renalis), whether occurring as a disease in man, or produced by extirpation of the kidneys in animals, is uniformly more or less of febrile symptoms quickly followed by coma and death; and in these circumstances it is now known, that the urea may be detected in the blood. A variety of morbid affections, and particularly an affection of the nervous system marked by inaptitude for muscular or mental exertion, always follows the obstruction of the excretion of bile, and absorption of bile into the blood constituting jaundice.

There are a few cases of intense jaundice which terminate in coma and death as rapidly as the ischuria renalis does, and with as little morbid appearance in the brain to explain this kind of fatal termination; and in several such cases the remarkable phenomenon has been observed after death, that the bile-ducts have been *pervious and empty*.* It is obvious, that it is this last circumstance only, that can make a case of jaundice analogous to cases of the ischuria renalis. If it shall appear to be a general fact, that the cases of jaundice presenting this remarkable appearance on dissection are those which terminate with unusual rapidity in the way of coma, the analogy will appear to be complete; and when such cases are compared with those, much more frequently occurring, where the excretion of bile is only *obstructed*, not *suppressed*, and where months frequently elapse without any bad symptom occurring,—it appears a reasonable conjecture, that the *retention* in the blood of matters destined for excretion, is more rapidly and certainly injurious than the *re-absorption* of matters which have been excreted from the blood at their ordinary outlet, but not expelled from the body.

Although there is still much obscurity in regard to the intention of the menstrual discharge, yet it may be stated as a general fact, that the suppression of this evacuation is more frequently followed by injurious effects (particularly affections of the nervous system, or vicarious hæmorrhage) than the stopping of an equal amount of hæmorrhage, going on equally slowly, would be; so that the general principle applicable to other excretions is exemplified here likewise.

IV. The next question in regard to the excretions is, in what manner they are effected; and on this question, although we must profess ignorance in the last result, yet it is instructive to observe, what seems now to be well ascertained, that the large size, and apparently complex structure, of several of the organs of excretion, appear to be no part of the contrivance for the formation of these fluids from the blood.

It is stated by Cuvier, as the result of a general review of the structure of glandular organs in different classes of animals, that products very nearly resembling each other, and evidently answering the same ends, are formed in organs where the structure, and the disposition of vessels are very various; and again, that substances the most widely different are formed in organs that are in these respects extremely similar;† and that this should be the case will not appear surprising when we consider the result of the most minute and accurate observations on the ultimate structure even of those secreting organs, which form substances the most dissimilar to the general nourishing fluid, either of animals or vegetables. "Chaque cellule de la structure vegetale," says De Candolle, "peut être considerée comme une vesicule organique et vivante, qui est entourée, ou de cavités dans lesquelles abordent des liquides, ou de cellules remplies elles-mêmes de

* See Marsh in Dublin Hospital Reports, vol. iii. Two cases of exactly the same description have occurred within these few years in the Edinburgh Clinical wards.

† Leçons d'Anat. Comp. t. v. p. 214.

liquides. Cette vesicule, par sa vitalité propre, absorbe une partie du fluide qui l'entoure; ce fluide est ou de l'eau prèsque pure, et alors elle en est simplement impregnée et lubrifiée; ou de l'eau plus ou moins chargée de cette matière gommeuse, elaborée dans les feuilles, et d'autres matières alimentaires qui peuvent se trouver portées avec la seve dans les diverses parties. *La vesicule qui l'a absorbée lui fait subir une action determinée d'après sa propre nature*, et cette action modifie les matériaux contenus dans la cellule, de manière à en faire, ou l'une des matières communes que nous avons considérées, ou l'une des matières que nous aurons bientôt à examiner, telles que les huiles volatiles, les resines, &c. Certains vaisseaux analogues à la nature des cellules jouent le même rôle sous ce rapport. Les matières ainsi localement elaborées peuvent, ou rester dans les cellules ou les vaisseaux qui leur ont donné naissance, ou s'extravaser au dehors et donner lieu, soit à des excretions, soit à des transports des matières d'une partie à l'autre du tissu."*

The description given by Dutrochet of the act of secretion as it may almost be detected in the glands of the lower classes of animals, is exactly similar. "Entre les vesicules qui composent le tissu organique des animaux rampent les vaisseaux sanguins, chez les animaux à circulation: ces vesicules sont appliquées sur les parois des vaisseaux; et il est certain que la cavité des vesicules ne communique point immediatement avec la cavité des vaisseaux, puisque le même fluide n'éxiste point dans leurs cavités. Ce fait est très facile à verifier, en examinant au microscope le tissu d'un organe secretive chez un mollusque gasteropode, celui de la foie par example: on voit toutes les vesicules de cet organe remplies par la bile, que l'on distingue à sa couleur, tandisque les vaisseaux sanguins qui cotoient ces vesicules n'ont que la diaphanieté que leur donne l'etat incolore du sang qui les remplit. Ainsi, les vaisseaux sanguins n'éxistent que comme des moyens d'irrigation pour les vesicules qu'ils cotoient, et ce n'est peut-être que *par filtration* que le fluide sanguin pénètre, *en si modifiant*, jusque dans ces vesicules elementaires. Le système sanguin, consideré dans son entier, forme une cavité sans issue, dans laquelle rien ne peut entrer, et de laquelle rien ne peut sortir, autrement que *par filtration*."†

Any one who is acquainted with the elaborate "Vasorum Lymphaticorum Historia" of Mascagni, will recognize the perfect accordance of this statement with the result of his careful and minute investigation of the structure of the secreting organs in the higher animals.‡

We may consider, then, the act of secretion, "en dernière analyse," as consisting simply in the passage of certain portions of a compound fluid through a thin living membrane, and the exclusion of others; or, according to the fortunate expression of Dutrochet, as a *chemical filtration*. "All that is necessary for any kind of secretion in a living animal," says Mr. Mayo, "is a vascular membrane, and all the arrangements of the glands appear to be merely contrivances for conveniently *packing* a great extent of such a surface in a small compass." And if we are asked, to what cause we can ascribe this escape of certain matters from the circulating fluid through one portion of membrane, and of others through another, we can only answer, in the words of this last author, that it depends on the exercise of certain "*vital affinities*," peculiar to the living state, and the existence of which will always be an ultimate fact in Physiology, although we may attain to a knowledge of the laws according to which they operate.

V. One principle may already be laid down, almost with certainty, as to the exercise of these powers in the present instance, viz. that the peculiar matters characterizing the excretions are not actually *formed* from the blood at the parts where they appear, but only *separated* from the blood at these parts,—their formation, if not actually completed, having been at least considerably advanced, in the blood itself which reaches these parts. Of this we are well assured, chiefly by the following facts.

1. The experiments already mentioned, first made by Prevost and Dumas, have proved that within a short time after the extirpation of the kidneys in animals, urea may be detected in the blood, showing clearly that the existence of these glands is not necessary to the formation of this very peculiar excrementitious matter, and giving us reason to conjecture that the office of the kidneys is, not to form the urea, but to attract it out of the blood as fast as it is formed there. The same existence of urea in the blood has been ascertained in the human body, both in cases of diseased kidneys, when the excretion there was much impeded, and in cases of malignant cholera, when the excretion was suppressed. The cases of rapidly fatal jaundice already mentioned, where the bile-ducts were pervious and empty, would seem to have been cases where the peculiar matter of the bile has been in like manner formed in the blood, without finding the usual vent at the liver. And it will appear under the head of Respiration, particularly from the experiments of Dr. Edwards, and of Collard de Martigny, that there is good reason to believe the carbonic acid of expired air to be formed in the course of the circulation, and only exchanged for oxygen at the lungs.

2. There are various instances in disease, of substances generally found in the secretions of certain glands only, being deposited in situations quite unusual, and where no texture similar to these glands exists; e. g. cholesterine,

* Physiol. Vegetale, p. 215.

† L'agent immediat du mouvement vital devoilé, &c. p. 192.

‡ It must not be considered as ascertained, that the files or tracks of globules of blood seen under the microscope, and usually called capillaries, have really, in all animals, and all parts of these, vascular coats. It seems pretty certain, that in many cases they are only lines or membranes, or channels in a solid parenchyma; but still the observation in the text applies strictly to the escape of any particles of the circulating fluid from them.

which in the natural state is found only in the bile, has been found deposited in diseased structures in the brain, kidneys, pelvis, scrotum, &c.; and lithic acid, naturally existing only in the urine, is deposited in cases of chalkstone in the textures immediately surrounding the joints of the fingers and toes. It seems to be nearly in like manner that purulent matter, when mixed in unusual quantity with the blood, as by inflammation of a vein, is frequently deposited in individual parts of the body, with little or none of the usual symptoms, or of the other accompaniments, of inflammation at these parts.

3. There are a considerable number of cases recorded on unexceptionable evidence, where excretions have passed off *per aliena cola*, i. e. by organs which in the natural state yield no such products, and the structure of which is widely different from that of the glands where they are usually secreted. This has been most frequently observed of the milk and of the urine, and of the latter, both in cases where the secretion at the kidneys had been suppressed, and in cases where its discharge by the urinary passages has been obstructed, so as to occasion its re-absorption. In both cases it is obvious that the peculiar matter of this excretion must have been first mixed generally with the blood, and then deposited in individual parts of the system, widely different as well as distant from those where it usually appears.

In cases of this kind collected by Haller,* the vicarious discharge of urine is stated to have occurred from the skin, from the stomach, from the intestines, and from the nipples; and in cases recorded by Dr. Arnold and Dr. Senter in America, it is stated to have been passed by vomiting, by stool, from the nose and from the mammæ, as well as other parts.† Both in cases given by Haller, and in one recorded in Magendie's Journal de Physiologie, (vol. vii.) milk is stated to have been evacuated in quantity from pustules that formed on the thigh; and among the former are instances of its having passed off from the salivary glands, the kidneys, and the uterus. Such statements were formerly considered as fabulous, but since the facts already mentioned (and particularly the appearance of urea in the blood after extirpation of the kidneys) have been ascertained, this scepticism seems no longer reasonable.

It must be here observed, that the healthy blood is easily shown to contain in itself matters more nearly akin to all the solid textures and to the other secreted fluids of the body, than to the bile and the urine; and hence, if we are satisfied that the elaboration of these latter fluids is effected in the blood itself, and does not essentially require any special action of the organs in which they usually appear, there can be little hesitation about extending this inference to other acts of secretion and to nutrition. It appears, therefore, at least highly probable, that the whole processes of assimilation and elaboration of the fluids in the living body are carried on, as other chemical changes on fluids are, in the interior of these fluids themselves, and that the solids of the body are concerned in these changes only in two ways: *first*, by securing the complete subdivision and intimate intermixture of the fluids necessary to their chemical changes; and *secondly*, by determining the parts of the body where peculiar matters, already existing in the blood, shall be deposited from it, or attracted out of it.

* Elem. Phys. lib. vii. ch. 1.

† London Med. and Phys. Journal, 1828.

VI. We may next enquire, what is the most probable *original source* of the matters which are thrown out of the body in the way of excretion. As it is generally believed, and on strong grounds, that the solid textures, as well as prepared fluids of the body, are liable to continual decay and renovation, it has long been the general belief, that the materials for the excretions are supplied chiefly from those substances which have formed part of the textures, and, after fulfilling their office there, have been taken back into the circulation with a view to their discharge from the body. And it has been conjectured, certainly with much probability, by Berzelius and by Autenrieth, that the animal matters thus mixed with the blood on their way to the excretories, are distinguishable from the albuminous or nutritious parts of the blood, by their solubility both in hot and cold water, and constitute the *animal matter of the serosity*, or uncoagulable animal matter of the blood. This is supported by the observation, that, when the kidneys are extirpated, this part of the blood is first observed to increase in amount, and afterwards it is here that the urea is detected.* And the connexion of the excretions with absorption from all parts of the body seems farther illustrated by the phenomena of diabetes, which may be held to be the disease in which there is the strongest evidence of increased absorption in all parts of the body, from the rapid digestion, the rapid recurrence of thirst after drinking, the dryness of the surface, and the progressive emaciation notwithstanding the excessive amount of ingesta; and in which the quantity of the urine is often ten times, and the solid contents of the urine often twenty times, the average quantity in health.†

But it should not be too hastily concluded, that *all* the solid constituents of the animal body are liable to continual absorption and renovation. The permanence of coloured marks on the skin, noticed by Magendie, is sufficient evidence, that, in some of the textures, any such change must go on very slowly; and some of the best observers doubt whether any such process of alternate deposition and absorption takes place in vegetables, in which, nevertheless, as we have seen, excretion is a necessary process.

* Prevost et Dumas in Ann. de Chimie, t. xxiii. p. 97.

† The change of nature of the animal part of this solid matter, (viz. the disappearance of part of the urea, and substitution of an excessive quantity of sugar,) is evidently connected with the singular fact ascertained by Dr. Prout, that sugar differs from urea simply in containing no azote, and a double quantity of carbon and oxygen: a discovery which will, probably, acquire a greatly increased importance in the progress of organic chemistry.

Dr. Prout has lately stated strong reasons for thinking, that great part of the contents of the lymphatic vessels are not excrementitious, but destined for useful purposes in the animal economy; remarking particularly on the way in which hybernating animals appear to be nourished *by absorption of their own fat.**

And it is obviously possible, that the excretions may be required to purify the blood of matters taken in *from without*, or evolved *in the course of the circulation* and its abundant changes, as well as to purify it of what has been absorbed *from the system itself*. Now that we know, that great part of the ingesta into the stomach are taken up by the veins, and pass through the liver on their way to the heart; and, likewise, that the venous blood is the chief source of the excretions of bile, it seems probable, that one important use of this excretion is, to subject a part of the ingesta to a second filtration, or rejection of part of their ingredients, subsidiary to that which they undergo in the primæ viæ. This may also be probably one principal reason why the great mass of the chyle, and other products of absorption in the body, should be mixed with the blood just before its concentration at the heart, and subsequent diffusion through the lungs; and thus participate in a purification, by the rejection of water and carbonic acid, before they are applied to the purposes of nutrition. We know, that in birds, reptiles, and fishes, there is a venous circulation similar to that of the vena portæ, through the substance of the kidneys, of most of the blood coming from the lower half of the body; a part of the ingredients of that blood will, therefore, be evolved with the urine; and, in the case of the reptiles, it has been lately ascertained, that this venous blood receives, before entering the kidneys, the contents of numerous and large lymphatics.†

At all events, if we are right in supposing, that, in the higher animals, all the great chemical changes which are wrought on the blood, even the formation of the excretions, are effected during its circulation in the bloodvessels themselves, we can thereby acquire a general notion of the intention of several contrivances, the use of which is otherwise very obscure. We can understand, that the object of the concentration of the blood at the heart may be not merely mechanical, but, partly, also chemical; and we can see the intention of the heart being so admirably adapted, by the articulated structure of its internal surfaces, not only to receive and propel, but also most effectually to *intermix*, all the component particles of the blood, both before and after its exposure to the air; the most perfect illustration of which power of the heart is afforded by the effect it produces on any compressible and elastic fluid which is received in a mass of any considerable volume into its cavities, and which is necessarily subdivided into so many minute globules, and compressed in so many directions, that it cannot escape from the heart, and so stops the circulation.

* Bridgewater Treatise, p. 515, et seq.
† Müller, in Phil. Transactions, 1833.

Again, when we attend to the manner in which substances foreign to the circulation are absorbed into it, whether from the system itself, or from without, we see a great deal of contrivance, evidently adapted, and probably intended, to secure the most *gradual introduction*, and the most *perfect intermixture* possible, and to allow the escape of certain parts of the compound fluid formed. Thus of the contents of the primæ viæ, part are absorbed into the veins, and sent through the capillaries of the liver and those of the lungs, (both admitting of excretion,) before they are admitted into the arteries. What is taken up by the lacteals has already undergone much elaboration by living fluids; this portion passes through the mesenteric glands, and is, probably, so far intermixed with the blood there, and partly received into the veins passing from them to the liver;* and the rest is mixed with much matter flowing from other parts of the system by the lymphatics; and, according to the views of Dr. Prout† as to the nature of absorption, is so far assimilated by this mixture also, before it is poured into the great veins in the state of chyle, to undergo the thorough agitation at both sides of the heart, and to participate in the changes at the lungs. What is absorbed from other parts of the body seems to be partly taken up by the veins, partly also by lymphatics which immediately convey it into adjacent veins; the remainder passes through lymphatic glands, and is there pretty certainly subjected to an intermixture and an interchange of particles with blood; after which it has necessarily much further admixture, and two thorough agitations at the heart, as well as the exposure at the lungs, to undergo, before arriving at the left side of the heart.

In those of the vertebrated animals which have no lymphatic glands, the thorough intermixture of the fluids contained in the lymphatic vessels is provided for by numerous plexuses,‡ and, in the case of reptiles, by distinct lymphatic hearts communicating with veins;§ and we are sure, that much of the matters absorbed in these animals, whether by veins or lymphatics, passes through the capillaries of the kidneys or liver, as well as the lungs, before reaching the arteries.

When we see so much contrivance, evidently adapted for giving every facility to the gradual operation of the vital affinities subsisting among the constituents of the blood, before it reaches the scene of any of the acts of nutrition, secretion, or excretion, we cannot be surprised to find, that these acts themselves should appear to be so simple as the observations already quoted would seem to indicate.

It must be admitted, that if we consider these contrivances in the higher animals as important agents in the elaboration of the blood, and consequent formation of the textures and prepared fluids of the body, there is a difficulty in understanding how these objects can be accomplished

* Tiedemann et Gmelin, Recherches, &c.
† Bridgewater Treatise, *ubi supra*.
‡ Cuvier, Leçons, &c. t. iv. p. 98.
§ Müller, *ubi supra*.

in the lowest classes, particularly the insects and zoophyta, where the nourishment of various textures, and formation of secretions and excretions, has been thought to be merely in the way of imbibition from a central cavity.* But it is to be observed, that in several of these tribes, in insects, and even in the infusory animals, recent observations have disclosed a much more complex apparatus for the movement of the fluids, than was previously suspected. And, in regard to the lowest zoophyta, it may be said in general, that if there is little apparent provision for the elaboration of the fluids, there is also little occasion for it,—*first*, because there is little variety of textures to be nourished, and *secondly*, because the simplicity of their structure is such, that all the particles of their nourishing fluid, — admitted into a central cavity, flowing thence towards their surface, and acted on by the air at all parts of that surface,— are similarly situate in regard to all the agents by which they can be affected, and must be equally fitted for the changes which the vital affinities there acting on them can produce, so that the same necessity for gradual intermixture, and repeated agitation, of heterogeneous materials, does not probably exist in them, as in the animals of more complex structure. The analogy of their economy, therefore, is not a serious objection to the inference we have drawn from so many other facts, as to the numerous changes which are wrought in the blood of the higher animals, while circulating in the vessels, and as to the function of excretion being a necessary accompaniment of the *assimilation* of aliment, and *nutrition* of textures, even independently of their *renovation* by processes of ultimate deposition and absorption.

(W. P. Alison.)

EXTREMITY, (in human anatomy), *membrum, artus;* Gr. μελος, κωλον; Fr. *extremité, membre;* Germ. *Gliedmassen;* Ital. *membro.* This term is used to denote certain appendages most manifest in the vertebrated classes of animals, employed as instruments of prehension, or support, or motion, also occasionally employed for other purposes sufficiently indicated by the habits of the animal. In familiar language we apply the word, limb, synonymously, and the superior and inferior limbs of man, or the anterior and posterior ones of the Mammiferous Quadrupeds, are the best examples by which we can illustrate our definition. When these appendages exist in their complete number, i. e. four, they are distinguished either by the appellatives already mentioned, anterior and posterior, or superior and inferior, or more precisely *pectoral*, and *pelvic* or *ventral*, or again *atlantal* and *sacral*.

In Fishes we find that in most instances the anterior limbs (pectoral fins) are larger than the posterior (ventral fins): and sometimes the posterior are absent altogether, as in the common eel. In Fishes we look for the simplest form of the skeleton of the more highly developed limbs in Man and Mammalia: and here we find, more or less obviously in different instances, the same elements which subsequently appear in a more distinct and complete form. Thus, in the case of the *Lophius piscatorius*, we find very distinctly the scapula and clavicle forming the bond of connection of the other bones of the limb to the trunk. We can also recognize the radius and ulna, what seems to be a very rudimentary humerus, and the bones of the carpus, as well as the phalanges, which generally greatly exceed in number any arrangement that is to be found in the higher classes. The ventral fins, however, the analogues of the posterior extremities, are not so developed: while bones analogous to the phalanges of the feet are found in it, we meet no trace of the femur, tibia, or fibula.

In all the other Vertebrata we find the anterior and posterior extremities developed on a plan similar to that in man, with such variations as the manner of life of the animal requires. We must, however, notice an exception in the case of serpents and Cetacea. In the former there are no limbs, or at least the merest trace of them; in the latter the posterior are absent, although the anterior exhibit very perfectly all the elements of the human upper extremity.

We propose to devote the present article to the detail of the descriptive anatomy of the osseous system of the extremities in Man, in whom, by reason of his erect attitude, the terms superior and inferior are substituted for anterior and posterior, as applied to the extremities of the lower animals.

Superior extremity.—The superior extremity is connected to the trunk through the medium of two bones, which, as being intimately connected with the motions of the limb, first demand attention. These bones are the *clavicle* and *scapula*, and are commonly called the bones of the shoulder.

Clavicle (from *clavis*, a key;) *collar-bone;* syn. *ligula, jugulum, os furcale;* Germ. *Schlusselbein.* This bone is situated at the upper and anterior part of the thorax, and forms the anterior part of the shoulder: its direction is from within outwards, so that its external end, which is articulated with the scapula, is posterior, and on a plane superior to its internal end, which is articulated with the sternum. It thus constitutes the key to the bony arch formed at the shoulder, and hence its integrity is especially necessary to the integrity of the motions of the shoulder.

The clavicle is a long bone, cylindrical, and so curved as to resemble the italic *f* placed horizontally. Its internal extremity is thick and rounded, while its external one is flattened; of its two curves one is internal, with its convexity directed forwards; the other external, with its convexity directed backwards.

The internal extremity, also called sternal, is formed by a gradual expansion of the shaft of the bone, which, however, still preserves the general cylindrical form, but is flattened a little on its superior surface: in size this exceeds all other parts of the bone. The inner surface of this extremity of the clavicle is

* Cuvier, Leçons, &c. 27.

destined for articulation with the sternum, and accordingly we find on it a considerable articular facet, which is convex from above downwards, and concave from before backwards. The outline of this surface is triangular, and each angle is easily distinguishable by the degree of its prominence: thus, one angle is situated anteriorly and inferiorly, it is the least prominent; a second is posterior and inferior, it is the most prominent; and the third is superior, and may easily be felt under the integuments in the different motions of the bone.

The external or acromial end of the clavicle is at once distinguished by its flattened appearance; it is flattened on its superior and inferior surfaces. At its extremity we find an elliptical articular surface adapted to a similar one upon the acromion process; this surface is nearly plane, its long axis is directed horizontally from before backwards.

The body or shaft of the bone presents several points deserving of notice. The superior surface is smooth and rounded, expanding towards the sternal end, where it affords attachment to the clavicular portion of the sternomastoid muscle. It expands likewise towards the acromial end, but loses the cylindrical form and becomes flattened: the central part is the most contracted and the most cylindrical; here the bone is almost subcutaneous, being covered only by the common integument, some fibres of the platysma, and crossed by the supra-clavicular filaments from the cervical plexus of nerves.

On the inferior surface of the clavicle we notice towards its sternal end a rough surface for the insertion of the costo-clavicular or rhomboid ligament: external to this and extending outwards is a superficial excavation along the inferior surface of the bone, which lodges the subclavius muscle. This groove terminates at the commencement of the external fourth of the bone, where we notice a rough and prominent surface for the insertion of the coraco-clavicular or conoid and trapezoid ligaments; in the articulated skeleton this surface corresponds to the root of the coracoid process, immediately over which it lies. On the inferior surface, near its middle, is the orifice of the canal for the transmission of the nutritious artery, the direction of which is outwards.

The anterior edge is thicker and more rounded towards the inner than towards the outer end, where it partakes of the general flattened appearance of the bone at that part; in the former situation it affords attachment to the pectoralis major muscle—in the latter to the deltoid. The two internal thirds of this edge are convex, its external third is concave.

The posterior edge is smooth and thin upon its two internal thirds, thicker and rougher at its external third, where the trapezius muscle is inserted into it; in the former situation this edge is convex, in the latter it is concave. The relations of the clavicle in this situation are interesting: it forms the anterior boundary of a space somewhat triangular in form, through which a communication is formed between the axilla and the neck. The posterior boundary of this opening is formed by the superior border of the scapula, and the internal by the inferior vertebra of the cervical region of the spine, while the first rib constitutes a sort of floor, over which pass the various vessels, nerves, and other parts which enter the cavity of the axilla. The anterior third of the first rib passes beneath the sternal end of the clavicle, but its two posterior thirds lie on a plane superior to it. Consequently we find that the cone of the pleura passes up behind this end of the clavicle so as to be on a level with it, hence the sonoriety elicited by percussion of the clavicle, and hence likewise the possibility in many instances, where embonpoint does not interfere, of hearing the respiratory murmur in the supra-clavicular region.

The great importance of the clavicle in the motions of the upper extremity is rendered abundantly evident by observing how completely synchronous are its movements with even the slightest change of position in the arm. But this is illustrated in a more striking manner by reference to the comparative anatomy of this bone. Those animals only possess a well-developed clavicle whose habits of life require extensive and varied movements of the shoulder. Where the anterior extremity is employed merely as an instrument of progressive motion on a plane surface, we have no clavicle; hence this bone is absent from the skeletons of Pachydermata, Ruminantia, Solipeda, and the motions of the shoulders are only such as are required for the flexion and extension of the limb. In the Carnivora, where there is a slight increase in the range of motion of the anterior extremities, a rudimentary clavicle exists, and in this class we observe that the size of the bone in the different orders bears a direct relation to the extent of motion enjoyed by the limb. Thus it is smallest in the Dogs and largest in the Cats; in these animals it has no attachment to either the sternum or the scapula, but is enclosed in the flesh, and does not occupy much more than half the space between the two bones last named. "But, however imperfect," says Sir C. Bell, "it marks a correspondence in the bones of the shoulder to those of the arm and paw, and the extent of the motion enjoyed. When the bear stands up, we perceive, by his ungainly attitude and the motion of his paws, that there must be a wide difference in the bones of his upper extremity from those of the ruminant or solipede. He can take the keeper's hat from his head and hold it; he can hug an animal to death. The ant-bear especially, as he is deficient in teeth, possesses extraordinary powers of hugging with his great paws; and, although harmless in disposition, he can squeeze his enemy the jaguar to death. These actions and the power of climbing result from the structure of the shoulder, or from possessing a collar-bone however imperfect."*

In those Mammalia that dig and burrow in the ground, or whose anterior extremities are so modified as to aid them in flight, or who are skilful in seizing upon and holding objects

* Bridgewater Treatise, p. 48.

with their paws, the clavicle is fully developed, and extends the whole way from the scapula to the sternum. Thus in the Rodentia this bone is very perfect, as, for example, the Squirrel, the Beaver, the Rabbit, the Rat, &c. The Bat affords an example of a very strong and long clavicle, as also the Mole and the Hedgehog among the Insectivora.

Among the Edentata those tribes possess a clavicle whose habits are fossorial, as the Ant-eater, the Armadillos, and even the Gigantic Megatherium, in which animal, however, the clavicle presented the peculiarity of being articulated with the first rib instead of with the sternum. In the Quadrumana the clavicles are strong and curved as in the human subject.

In Birds, the bone which is analogous to the clavicle presents similar variations in its developement, according to the range of motion required in the anterior extremity, or in other words, in proportion to the extent to which the powers of flight are enjoyed. Thus, in some these bones are anchylosed along the mesial line, and constitute the furculum; in others they are cartilaginous internally; and in others they do not reach the sternum.*

In women the clavicle is in general less curved than in men; the diminution in the incurvation is most manifest in the external portion. According to Cruveilhier, the clavicles are often unequally developed in the same individual according as one limb is more used than the other, and sometimes the difference is sufficiently obvious to enable one to ascertain from the relative size of the clavicles, whether the individual is right or left-handed.

Structure.—The clavicle contains a considerable proportion of compact tissue in its shaft, and a cylindrical medullary canal; at the extremities the compact tissue greatly diminishes, and is replaced by the reticular, which likewise fills up the bone and obliterates the medullary cavity.

Developement.—A strong argument as to the great importance of this bone to the motions of the shoulder, is derived from its precocious developement; for although the cartilaginous nidus of the vertebræ as well as that of the ribs appear before that of the clavicle, yet the latter bone begins to ossify sooner and is completed more rapidly than any other bone in the body, excepting perhaps the lower jaw, which sometimes takes the precedence in the process of ossification. It is remarkable too for the diversity in its proportional size, which it presents at different periods; thus, according to Meckel, about the middle of the second month of pregnancy, the clavicle is four times longer than the humerus or femur, and it is not until the fourth month that the humerus exceeds it in length. The clavicle has but one primitive point of ossification: a supplementary point is developed under the form of a very thin lamella at the anterior part of the sternal extremity.†

Scapula, scapulum, omoplata, (ωμος, humerus, πλατυς, latus.) Fr. *omoplate;* Germ. *das Schulterblatt.*—This bone forms the posterior and principal portion of the shoulder; it is placed on the posterior and outer part of the thorax, and occupies a space which extends from the second to the seventh rib.

The scapula is very thin in the greatest part of its extent, quite papyraceous in some places. It is triangular in form, and anatomists commonly describe its sides or borders, its angles, and its surfaces.

The borders, or *costæ,* of the scapula are three in number, and are named according to the position they occupy or the relation they bear: thus there are the superior border or *cervical,* the posterior or *vertebral,* and the anterior or *axillary.* The cervical border (also called the *coracoid)* is the shortest, being somewhat less than a fourth of the length of the vertebral border; it is connected posteriorly with the vertebral at an angle the apex of which is rounded off; it is slightly concave, and the bone for some way below it is very thin, and the border itself is acute. Anteriorly it terminates in a notch which is bounded in front by one root of the coracoid process, *(incisura semilunuris, lunula, coracoid notch.)* This notch is converted into a foramen by a ligament which is often ossified, and thus the suprascapular nerve, which is lodged in the notch, is separated from the artery of the same name, which passes over the ligament. The extent, therefore, of the cervical border is from the posterior superior angle to this notch. The levator anguli scapulæ and the omo-hyoid muscles are attached to this border.

The vertebral border, also called the base of the scapula, is the longest, being in an average-sized bone from seven to eight inches in length; it is sharp in its whole extent, which is limited above by the posterior superior angle, and below by the inferior angle. At the junction of the superior fourth with the remaining portion there is an inclined surface, triangular in form, the base confounded with the margin of the bone, the apex continued to the spine. This surface is smooth, and the ascending fibres of the trapezius muscle glide over it. To that part of this edge, which is above the surface, the levator anguli scapulæ is attached, and below it the rhomboidei.

The anterior or axillary border is limited above by the glenoid cavity, and below by the inferior angle of the scapula. It is much thicker than either of the others, and its thickness increases towards its upper extremity, where, close to the glenoid cavity, there is a rough surface which gives attachment to the long head of the triceps muscle; inferior to this, the edge affords insertion to the teres minor muscle, and still lower down to the teres major.

The superior and posterior angle is formed by the junction of the cervical and vertebral borders; it is a little less than a right angle, and is chiefly remarkable for affording insertion to the levator anguli scapulæ muscle. The inferior angle, formed by the union of the axillary and vertebral borders, is very acute; the bone here is very thick and spongy; part of the latissimus dorsi glides over this angle, and sometimes some of its fibres are inserted into it. It is

* See Aves, p. 285, vol. i.

† Cruveilhier, Anat. Desc. t. i. p. 219.

only this portion of the muscle which separates this part of the scapula from the common integuments, and to this superficial position is attributed the more frequent occurrence of fractures from direct violence in this than in any other portion of the bone.

The angle between the cervical and axillary borders is truncated, and presents many points of great interest. We here notice an articular concavity, destined to contribute to the formation of the shoulder-joint, commonly known under the name of the *glenoid cavity*, *(sinus articularis.)* This cavity, which is a very superficial one, is oval; the long axis of the oval being vertical in its direction, the acute extremity of the oval is situated superiorly, and here the edge of the bone is cut and rounded off towards the posterior part, where is inserted the tendon of the biceps. The cavity is surrounded by a thick lip of bone, to which in the recent state the fibro-cartilage, called *glenoid ligament*, is applied. At the internal or anterior part of this border, is a notch for the passage of the tendon of the subscapularis muscle. The aspect of the glenoid cavity when the scapula is quiescent is outwards and slightly upwards and forwards. This cavity is connected with the rest of the bone by a thick but contracted portion denominated the *neck of the scapula*. The neck of the scapula is surmounted by a remarkable curved process, called the *caracoid process*, (*κοραξ*, *corvus*.) This process, well compared to a semiflexed finger, is directed forwards and outwards, it is connected to the scapula by a thick portion, which seems to arise by two roots, one posterior, thick and rough, lying immediately in front of the notch in the cervical border, the other anterior and thin, and connected with the apex of the glenoid cavity. The concave surface of the coracoid process is directed downwards and outwards, and in the recent state projects over the upper and internal part of the shoulder-joint: its convex surface is rough, and has inserted into it the ligaments by which the clavicle is tied to it. The coracoid process affords attachment by its internal edge to the pectoralis minor muscle; to its outer edge is affixed the ligament which, with the acromion process, completes the osseo-ligamentous arch over the shoulder-joint, and by its summit it gives insertion to the short head of the biceps and to the coraco-brachialis.

It remains only to examine the surfaces of this bone. The *anterior* surface forms in the greatest part of its extent a shallow fossa, *fossa subscapularis*, which is limited above and behind by the superior and posterior margins of the bone, and in front by a smooth and rounded ridge, which extends from the glenoid cavity to the inferior angle. This fossa is frequently intersected in various directions by bony ridges. Cruveilhier remarks, that in a well-formed person, this surface ought to be exactly adapted to the thorax; but when the chest is contracted, as in phthisical patients, the scapula not participating to a proportionate extent in the contraction, there follows such a change of relation that the scapulæ become very prominent behind, and are in some degree detached from the ribs like wings, whence the expression *scapulæ alatæ*, applied to the projection of the shoulders in phthisical patients. The whole fossa has lodged in and inserted into it the subscapularis muscle, whence its name. At the superior posterior angle and the inferior one, are rough surfaces into which are inserted the superior and inferior fibres of the serratus magnus muscle.

The *posterior* surface is remarkable for its division into two portions by a large process which projects from it nearly horizontally backwards and slightly upwards. This process, called *the spine of the scapula*, is fixed to the bone at the line of union of its superior and middle thirds; it commences at the triangular surface already noticed at the termination of the superior fourth of the vertebral border of the scapula, thence it proceeds outwards, inclining a little upwards, and just where the neck of the scapula is united with the rest of the bone, this spine ceases to be connected with the scapula, and is continued outwards in a slightly arched form, as a broad and flattened process, denominated the *acromion process*, (*ακρος*, *summus*, *ωμος*, *humerus*.) The spine presents posteriorly a thick and rough edge, which by its superior border gives attachment to the trapezius muscle, and by its inferior to the deltoid, the intervening space being covered by the aponeurotic expansion which connects the muscles last-named. The superior surface of the spine looks nearly directly upwards; it is concave, and contributes to form the fossa supra-spinata. The inferior surface, on the other hand, forming part of the fossa supra-spinata, is convex anteriorly and slightly concave posteriorly, and looks downwards and backwards; on each surface we observe a large nutritious foramen. The posterior edge of the spine is quite subcutaneous, and the physician often finds it desirable to practise percussion upon it.

Above the spine of the scapula is the *fossa supra-spinata*, which lodges the muscle of the same name, formed in front by the scapula, behind by the spine, both surfaces being slightly concave. Below the spine is the fossa supra-spinata much larger than the preceding, slightly convex, except towards its anterior part. This fossa is formed by the scapula below and the inferior surface of the spine above; it is limited in front by a ridge which proceeds downwards and backwards, from the glenoid cavity to the inferior angle, and bounds behind a surface which gives attachment to the teres major and minor muscles. Into this ridge itself is inserted a fibrous fascia, which separates the attachment of the last-named muscles from the fossa infra-spinata and the insertion of the muscle of the same name. The two fossæ, thus separated by the spine, communicate through a channel formed on the posterior part of the neck of the scapula and bounded behind by the spine; through this channel pass the arterial and nervous ramifications from the superior to the inferior fossa.

The acromion process is evidently continuous with the posterior thick edge of the spine of the scapula, and viewed from above appears to be merely an expansion of it. The narrowest part of the process is where it seems to spring from the spine, forming a sort of pedicle. Its posterior surface is convex, rough, covered with fibrous tissue in the recent state; its aspect is upwards and backwards. Here the process is quite subcutaneous as the posterior part of the spine of the scapula. The anterior surface is concave, smooth, looks downwards and forwards to the posterior and superior part of the shoulder-joint. The posterior or inferior edge of the process continuous with the corresponding edge of the spine of the scapula forms a curve, convex downwards and outwards, and terminates in the pointed extremity or apex of the process; all this edge affords attachment to the deltoid muscle. The superior edge is concave; near the apex we observe upon it a plane oval articular surface to which the acromial extremity of the clavicle is articulated; into this edge the trapezius muscle is inserted. The apex of the acromion, which is immediately in front of the articular surface for the clavicle, gives insertion to the apex of the ligament, whose base is attached to the outer edge of the coracoid process.

The scapula is connected to the trunk through its articulation with the clavicle, but chiefly through the intervention of muscles, so that muscles are inserted into all its edges, and its surfaces are "cushioned with muscles." It is, then, as might be anticipated, a very moveable bone, and its motions consist in more or less extensive revolutions round an axis through its centre. This bone, then, being the medium of connexion between the pectoral extremity and the trunk, it is evident that the great movements of the former must depend upon the movements produced in the scapula by the muscles which pass to it from the trunk; moreover, when some of these muscles fix the scapula, it becomes the point whence the others act in producing the motions of the ribs. The scapula, then, is an essential element in the upper extremity, and it exists wherever we find that limb in a perfectly developed state, but it experiences various modifications in position and shape according to the uses to which the upper extremity is applied. In quadrupeds the position of the scapula is more forwards and on the side of the chest, for in them the anterior extremity is employed as an instrument of support. It is interesting to observe the variation in the aspect of the glenoid cavity, according to the oblique or upright position of the scapula, indicating whether the pectoral extremities are used chiefly as instruments of support or as instruments of prehension, &c. When freedom and rapidity of motion are required conjoined with strength, we find the scapula placed obliquely over the ribs, and a corresponding obliquity between the humerus and scapula. "In the horse, as in most quadrupeds, the speed results from the strength of the loins and hinder extremities, for it is the muscles there which propel the animal. But were the anterior extremities joined to the trunk firmly and by bone, they could not withstand the shock from the descent of the whole weight thrown forwards; even though they were as powerful as the posterior extremities they would suffer fracture or dislocation. We cannot but admire, therefore, the provision in all quadrupeds whose speed is great, and whose spring is extensive, that, from the structure of their bones, they have an elastic resistance by which the shock of descending is diminished.

"If we observe the bones of the anterior extremity in the horse, we shall see that the scapula is oblique to the chest, the humerus oblique to the scapula, and the bones of the fore-arm at an angle with the humerus. Were these bones connected together in a straight line, end to end, the shock of alighting would be conveyed through a solid column, and the bones of the foot or the joints would suffer from the concussion. When the rider is thrown forwards on his hands, and more certainly when he is pitched on his shoulder, the collar-bone is broken, because in man this bone forms a link of connexion between the shoulder and the trunk, so as to receive the whole shock; and the same would happen in the horse, the stag, and all quadrupeds of great strength and swiftness, were not the scapula sustained by muscles and not by bone, and did not the bones recoil and fold up."

"The horse-jockey runs his hand down the horse's neck in a knowing way and says, 'this horse has got a heavy shoulder, he is a slow horse.' He is right, but he does not understand the matter; it is not possible that the shoulder can be too much loaded with muscle, for muscle is the source of motion and bestows power. What the jockey feels and forms his judgement on is the abrupt transition from the neck to the shoulder, which, in a horse for the turf, ought to be a smooth undulating surface. This abruptness or prominence of the shoulder is a consequence of the upright position of the scapula; the sloping and light shoulder results from its obliquity. An upright shoulder is the mark of a stumbling horse—it does not revolve easily to throw forward the foot."*

A comparison between the skeleton of the anterior extremity in the elephant and in one of the stag kind illustrates how the oblique position of the scapula is favourable to rapidity of motion, while the upright position is that most calculated for supporting weight. In the elephant the glenoid cavity of the scapula is placed vertically over the head of the humerus, and all the other component parts of the limb are similarly disposed, so as to form a complete pillar of support for the trunk. Hence the attitude of standing in the elephant requires but slight muscular effort, and in this position he is in such complete repose as often to obtain sleep. In this animal, then, the angle between the scapula and humerus is nearly obliterated, but in the stag it approaches closely to a right angle, the scapula is oblique to the ribs, and

* Sir Charles Bell, Bridgewater Treatise.

the humerus to the scapula. The rule seems to be that where the pectoral extremity is chiefly a pillar of support, the aspect of the glenoid cavity is nearly vertically downwards. If freedom and rapidity of motion be required in addition to strength as a member of support, the trunk being lighter, the scapula is oblique, and consequently the glenoid cavity looks downwards and forwards; or if the limb be not used to support the trunk, then the aspect of the glenoid cavity is no longer downwards but outwards, as in man.

Structure.—The greatest part of the scapula is composed of very thin almost papyraceous compact substance; but its processes, and the enlargements at its edges and angles, contain reticular tissue.

Developement.—This bone is developed by six points of ossification; one for the body, and five supplementary ones, viz. one for the coracoid process, two for the acromion, one for the posterior border of the bone, and one for its inferior angle. The ossification of the body commences about the second month, and the spine appears in the third month as a growth from the posterior surface of the scapula. The union of the several epiphyses is not completed till late, and it is not until after the fifteenth year that the ossification is finished.

The bones of the upper extremity, properly so called, are the humerus, radius, ulna, and bones of the hand.

Humerus, (os brachii; Fr. *l'os du bras;* Germ. *das Oberarmbein).* This is the longest bone of the upper extremity; it is situated between the scapula and forearm, being, as it were, suspended by muscle and ligament from the former.

Like all long bones, the humerus consists of a shaft and two extremities. The superior extremity is formed by a smooth and rounded convexity, rather less than half a sphere; a slight depression in, or constriction of, the bone, most manifest above, marks the limit of this articular eminence. The eminence is called the head of the humerus; the constriction indicates what is denominated *the anatomical neck of the bone,* being that portion which connects the head to the shaft, and analogous to the more developed neck of the thigh-bone. The axis of the neck is but a continuation of that of the head, and passes in a direction from within outwards and downwards, forming an obtuse angle with the axis of the shaft. The head of the humerus is entirely covered by articular cartilage, and articulates with the glenoid cavity of the scapula, to which, however, it obviously does not at all correspond in dimensions.

The inferior part of the anatomical neck of the humerus is very slightly marked, and is continued in a smooth declivity slightly concave from above downwards, into the shaft of the bone. Its superior part is more distinct, and the depth of the groove here seems in a great degree owing to the prominence of two bony protuberances, one situated anteriorly, called *the lesser tuberosity,* and the other posteriorly, denominated *the greater tuberosity.*

The lesser tuberosity of the humerus *(tuberculum minus)* is somewhat conical in shape, and inferiorly it ends in a smooth, rounded bony ridge *(spina tuberculi minoris),* which extends downwards and inwards, gradually diminishing in prominence till it is lost in the shaft of the bone at the inner part of its anterior surface. The lesser tuberosity gives insertion to the tendon of the subscapularis muscle, and the ridge or spine last described forms the anterior and internal boundary of the bicipital groove.

The greater tuberosity *(tuberculum majus, externum s. posterius)* forms a considerable prominence on the upper and outer part of the humerus, being the most external part in that situation and easily to be felt under the integuments. Superiorly the constriction corresponding to the anatomical neck separates it from the head of the humerus; inferiorly it is continued into and gradually lost in the shaft of the bone at its outer part. A very distinct and prominent ridge *(spina tuberculi majoris)* is continued from its anterior extremity downwards and inclining very slightly inwards, which terminates about the middle of the anterior surface of the bone, just internal to the deltoid ridge. This ridge is most prominent but smooth in its upper third, in its inferior two-thirds it is less prominent but rough; it forms the posterior boundary of the bicipital groove. On the greater tuberosity three distinct surfaces are marked, to the anterior of which the supra-spinatus muscle is attached, to the middle the infra-spinatus, and to the posterior the teres minor.

The *bicipital groove* commences above between the two tuberosities, and passes downwards and slightly inwards, bounded before and behind by the spines which proceed from those tubercles. This groove, very distinct at its commencement, ceases to be so a little above the termination of the superior third; in the recent state it is lined by the tendinous expansion of the latissimus dorsi and teres major muscles, and lodges the tendon of the biceps muscle, whence its name.

From the anatomical neck the bone gradually tapers down and becomes more cylindrical in its form; this upper portion is, for the convenience of description, distinguished by the name of *surgical neck of the humerus.* The middle third of the shaft of the bone is prismatic in form; the external spine which commences at the greater tuberosity is continued down, forming a prominent ridge all down the front of the bone to the termination of its flattened inferior third. The outer part of the middle third of the humerus is remarkable for the rough surface into which the deltoid muscle is inserted, *the deltoid ridge,* situated nearer the upper than the lower part of this portion, and directed downwards and very slightly forwards. The inner part of the middle third presents a smooth, flattened, and inclined surface, which is continued down in this form to within a very short distance of the inferior extremity of the bone. The posterior surface is rounded and very smooth.

At the junction of the middle and inferior thirds we notice a very slight and superficial groove passing downwards and inwards, and very much resembling what one would imagine might be produced by an attempt to twist the bone while yet in a yielding condition, the inferior third having been twisted inwards and the two superior thirds outwards. This groove indicates the spiral course from above downwards and from without inwards of the musculo-spiral or radial nerve. Below this groove is the inferior third of the humerus, the anatomical characters of which are very distinct from those of the remaining parts of the bone. A prominent and rounded ridge, continuous with that already noticed in connexion with the greater tuberosity, passes vertically down in front of it; from each side of this ridge a smooth surface inclines backwards, forming an inclined plane on each side of it, the external being larger and more distinct than the internal.

The posterior surface of the upper part of this portion is flat and very smooth. As the bone descends it expands considerably laterally, so as to present in front a broad surface slightly convex from side to side, bounded on either side by prominent edges, continued from the edges of the inclined planes above described. Each edge terminates in a prominence, the inner one being the largest; the inner edge itself being thicker, more prominent, and describing a slight curve as it descends. The posterior surface is limited below by a deep depression, to be further described hereafter. Thus, by its gradual expansion laterally, the inferior portion of the humerus, being about one fifth of the entire length of the bone, has a triangular figure, the base being formed by the inferior articular extremity of the bone.

The whole shaft of the humerus is completely clothed with muscle. We have already indicated the place of insertion of the deltoid muscle on the outer surface of the bone; all that portion of the outer and anterior surface below the deltoid ridge, and for a little way on each side of its inferior extremity, is covered by the brachiæus anticus muscle. Internal to the bicipital groove, on the inner surface of the humerus, about its middle, the coraco-brachialis muscle is inserted. The external edge below the spiral groove affords attachment to the brachiæus anticus, supinator longus, extensor carpi radialis longior, and the triceps muscles.

The internal edge below the insertion of the coraco-brachialis has the brachiæus anticus and triceps muscles inserted into it, and both edges afford insertion to intermuscular aponeuroses, which separate the muscles connected with the anterior from those on the posterior part of the bone. The posterior surface is completely covered by the triceps muscle, excepting in the line which corresponds to the groove already referred to, in which the radial nerve and musculo-spiral artery pass.

The foramen for the nutritious artery is found upon the internal surface at the inferior extremity of its middle third; the direction of the canal is downwards; sometimes this foramen exists upon the external, or upon the internal surface.

The inferior extremity of the humerus is terminated by an articular cylinder, which projects into a plane anterior to that of the shaft of the bone, *(processus cubitalis)*. This cylinder is placed transversely, but in transverse extent it falls short of the widest part of the inferior third of the humerus. Various depressions and elevations are marked upon the surface of this cylinder. Proceeding from without inwards, we notice a convexity or rounded head, limited externally by the margin of the cylinder and internally by a groove, which passes in a curved direction from before backwards, the concavity of the curve corresponding to the rounded head. This head is properly denominated the external condyle of the humerus; it articulates with a cavity on the head of the radius; the anatomist should notice that the axis of this head passes in a direction downwards and forwards. On the anterior surface of the humerus immediately above this head, we observe a slight and very superficial depression which receives the edge or lip of the cavity of the radius, when the forearm is in a state of complete flexion. Internal to the groove which bounds the condyle on the inner side, we have a pulley-like surface, which is destined for articulation with the ulna. The concavity which forms the central part of this pulley is deep, but deeper and wider behind than before; its anterior extremity terminates in communicating with an oval depression on the anterior surface of the bone *(fovea anterior minor)*, which in flexion of the forearm receives the anterior projecting angle of the coronoid process of the ulna; the posterior extremity terminates in a similar depression, *(fovea posterior* v. *sinus maximus,)* but a much deeper one, and of greater dimensions generally, occupying, in short, nearly the whole posterior surface of the bone; this depression receives the olecranon process of the ulna, when the elbow-joint is in extension. The trochlear concavity, in passing from before backwards, takes a curved direction, so that its posterior extremity is much nearer the external part of the articular cylinder than the anterior. This has an important influence on the direction of the motions of the forearm. These two depressions are separated from each other by a thin osseous lamina, almost transparent. We sometimes meet with instances in which this lamina is perforated in consequence of a defect of ossification; and Meckel states that he has found this perforation more frequently in the bones of Negroes and Papuas than in those of the superior races of mankind. It is the permanent condition of many pachydermata, rodentia, carnivora, and quadrumana. On the inside the trochlear concavity is bounded by a thick and projecting lip, which, when the bone is placed at right angles with a horizontal plane surface, descends lower down than any other part, so that this part comes in contact with the plane surface, while the remaining portion of the articular cylinder is raised considerably above it. This arrangement accounts for the hollow angle manifest on the outer side of the elbow-joint when the forearm is extended.

We have yet to describe two processes which are connected in great measure with the outer and inner extremities of the articular cylinder, and to which we have already referred, as being the points in which the margins of the bone terminate. The external one is triangular and thick, rough upon its surface, and projects slightly. It is improperly called the external condyle—more correctly it should be designated *epicondyle*, being applied to the outer surface of what is properly the external condyle. This process affords attachment to the external lateral ligament of the elbow-joint and to the principal supinator and extensor muscles on the forearm, whence it has been called *condylus extensorius*. The internal process is very prominent, distinctly triangular, terminating the inner edge of the humerus and connected with the trochlea; it is more correctly denominated *epitrochlea*. It affords insertion to the internal lateral ligament, and to the pronator and flexor muscles of the forearm. Its posterior surface is slightly hollowed at the line of its junction with the rest of the bone; the ulnar nerve passes behind it.

The humerus is the principal lever of the pectoral extremity; hence in all animals its strength is proportionate to the force and power which is required in the limb. In the elephant it is a massive pillar of support; and here we may notice a variety following the same law which influences the difference in the aspect of the glenoid cavity of the scapula, already noticed; namely, that the angle between the axes of the head and shaft of the humerus, is at its maximum when the arm-bone is mainly an instrument of support, and diminishes as that bone is more used for prehension and other purposes; and as this use is found for this bone chiefly in the human subject, we may presume that in man the angle in question is the least removed from a right angle. When this limb is used mainly for support and progression, a considerable range of motion in the shoulder-joint is not required, the tuberosities at the upper extremity of the bone project and limit the motions of the joint. When, however, a considerable motion is necessary, these tubercles are depressed as in man, so as not to interfere with these motions. The lower extremity of the humerus likewise affords marks indicative of the mobility of the fore-arm and hand; thus, in the one case one or both of the edges of the bone which terminate in the epitrochlea and epicondyle are prominent and strong in proportion as the muscles which arise from it are frequently called into play, as when the pronating and supinating motions of the forearm are extensive: in the other case this ridge is imperfectly developed, and the principal modification of the lower end of the bone is to be seen in the articular cylinder, where greater depth is given to the trochlea, in order to afford increased strength and security to the elbow-joint.

One of the most singular instances of the developement of bony processes in accordance with muscular power is in the case of the mole. In this little animal the whole anterior extremity is constructed entirely with reference to its burrowing habits; its short, thick, and almost square clavicle and its elongated lever-like scapula tend to the same end, as its amazingly strong humerus. The upper extremity of this latter bone is extremely broad; it presents two articular surfaces, being articulated with the clavicle as well as with the scapula, and the tuberosities which give insertion to the muscles of rotation are enormously developed. The body of the bone is short, thick, and strong; the inferior extremity is nearly as large as the superior; both the epicondyle and epitrochlea are very highly developed, especially the latter, which is accounted for by the fact that the muscles of pronation are those most called into action, in order to enable the animal to employ the accessory bone on the radial side of the hand, in scraping up the earth. This large size of the humerus, and great developement of its muscular eminences, is found in all fossorial animals, as the megatherium, the pangolins, beavers, ant-eaters, moles, and monotremata. In the two last the developement is the most remarkable.

In the class of Birds, the humerus is developed as regards the prominence of its muscular protuberances, in proportion to the powers of flight. In birds which fly, those eminences are strong and prominent, and the bone itself is proportionally strong; but in those which do not fly, the bone is weak and generally short. In the common pigeon, for example, the enlargement of the scapular extremity of the humerus, and the developement of the tubercles is very manifest, as well as the strength and thickness of the shaft of the bone.

Structure.—The structure of the humerus is characteristic of that of long bones in general. In a vertical section we observe that the reticular texture is chiefly accumulated towards the extremities; the shaft being mainly formed of compact tissue. At the upper extremity we notice the mark of union of the epiphysis of the head, which corresponds to the line of the anatomical neck of the bone. The canal, when a transverse section of it is viewed, appears somewhat quadrilateral in form. Its walls are formed of very dense compact tissue.

Developement.—The ossification of the humerus begins in its shaft, and that very early, according to Meckel about the second month; the shaft goes on enlarging, but the extremities are still cartilaginous during the whole of intra-uterine life, and for the first year after birth. The superior extremity is developed by two points of ossification, one for the head, the other for the great tuberosity; about the beginning of the second year the ossification of the head of the bone commences, and from the four-and-twentieth to the thirtieth month the ossification of the great tuberosity begins. According to Beclard, a small ossific point for the lesser tuberosity is visible in the fifth or sixth year; from the eighth to the ninth year the ossific elements of the head of the humerus become united and the head is completed.

The inferior extremity of the humerus, according to Cruveilhier, begins to ossify later than the superior. The first point of ossification noticed in it is for the external condyle: this appears at the age of two years and a half; at seven years a second point of ossification commences for the epitrochlea; at twelve a third point appears for the internal edge of the trochlea; and at sixteen years a fourth point for the epicondyle. These four points of ossification, Cruveilhier states, are united in the following order: first, in the second year, the two points of the trochlea are united; and, secondly, at sixteen years the trochlea, epicondyle, and the condyle form a a single piece.* The union of the extremities with the shaft of the bone takes place from the eighteenth to the twentieth year; and all observers agree in stating that the union of the inferior extremity with the shaft always precedes that of the superior extremity, although the ossification of the latter is prior.

Forearm.—The bones of the forearm are the ulna and radius, of which the former constitutes the second essential element in the elbow-joint, the radius being chiefly an accessory bone to provide for the wider range of motion of the hand. The ulna therefore is the principal lever of the forearm, and the motions of flexion and extension of that segment of the limb upon the arm depend upon it; at its superior extremity it forms a very firm hinge-joint with the trochlea of the humerus, but inferiorly its connexion with the carpus at the wrist-joint is very slight, and it forms by no means an essential element of that joint. On the other hand, the radius at its inferior extremity forms a very important part of the wrist-joint, but at its superior its connection with the elbow-joint is due to its necessary articulation with the outer side of the ulna.

Ulna (*κυβιτον, cubitus;* Fr. *os du coude;* Germ. *das Ellenbogenbein.*†) This bone is situated on the inner side of the forearm. It is the longest and the largest bone of that region, and in the vertical position of the limb it is directed downwards and a little outwards, the obliquity being occasioned by the greater projection downwards of the inner lip of the trochlea of the humerus, as already alluded to in describing that bone.

The upper or humeral extremity of the ulna is at once distinguished by its great size from the inferior extremity. It consists of two processes joined to each other at a right angle, and so that that angle opens forwards. One of these processes is vertical, and is continued in the direction of the long axis of the bone, and is little else than a continuation of the shaft; this is the *olecranon:* the other is horizontal, anterior to the olecranon, as it were placed upon the superior extremity of the bone, so as to project considerably beyond the plane of its anterior surface: this is the *coronoid process.*

The olecranon, (*ωλενη, cubitus, κρανον, caput,*) also called *processus anconæus,* may be said to begin from the angle of junction of the coronoid process with it; there the bone appears slightly constricted, for above that point it expands. We notice five surfaces upon it. The *superior* surface is horizontal; it presents posteriorly a muscular impression affording insertion to the triceps extensor, and anteriorly it ends in a remarkable beak, which, in the state of complete extension, is received into the olecranon cavity of the humerus. The *posterior* surface is rough with a very obviously triangular outline; this surface gives insertion to the triceps muscle. The *internal* surface is also rough, and covered by the fibrous expansion from the tendon of the triceps, and at its anterior margin affords insertion to the superior fibres of the internal lateral ligament. The *external* surface is smooth, and also is covered by the fibrous expansion from the tendon of the triceps. The *anterior* surface is articular; it presents the appearance of having been covered by articular cartilage; it is divided by a rounded vertical ridge into two unequal portions, of which the internal is larger than the external. This surface is limited below by a transverse depression, non-articular, in which some fatty matter is deposited in the recent state. The surface is convex from side to side in the centre, and each of its lateral portions is concave; the whole surface is concave from above downwards. In the extended state of the forearm this articular surface of the olecranon is applied to the posterior part of the trochlea of the humerus; it forms the posterior part of the *great sigmoid cavity* of the ulna.

The coronoid process is wedge-shaped, attached by its base to the anterior surface of the ulna, the sharper edge projecting forwards and free. This edge is convex, and sometimes forms a point; it is received into the coronoid cavity of the humerus. On the *external surface* of the coronoid process is an oval articular facet, concave from behind forwards, whose long axis is horizontal; this is the *lesser sigmoid cavity,* and is articulated with the inner side of the head of the radius; *the internal surface* is rough, and has a projecting lip, which affords attachment to the anterior fibres of the internal lateral ligament. *The anterior surface* is inclined from above downwards and from before backwards, so that its aspect is downwards and forwards; it is slightly hollowed transversely, and is rough, the roughness being continued down for a little way in front of the bone, thus forming a rough surface triangular in form, the base corresponding to the anterior edge of the coronoid process; this surface affords insertion to the brachiæus anticus muscle. *The superior surface* forms the anterior portion of the great

* Cruveilhier, Anat. Descr. tom. i. p. 231.

† The term *focile* was applied to this bone as well as to the radius by some of the ancient anatomists, in imitation of the Arabians, who used the word *zend,* sc. an instrument analogous to our tinder-box, which consisted of two sticks, similar in appearance and proportions to the bones of the forearm. *Focile majus* was the ulna, *focile minus* the radius. Blumenbach, Beschreibung der Knochen, p. 395.

sigmoid cavity; like the similar surface on the olecranon, it is divided by an obtuse ridge directed from before backwards, into two unequal portions; these portions correspond in shape and size with those already noticed on the olecranon.

The shaft of the ulna gradually tapers from above downwards; it is triangular in its entire extent, excepting for about an inch above the inferior extremity, where the bone is distinctly cylindrical. On the shaft anatomists commonly describe three surfaces. *The anterior* surface is broader in the middle than at its extremities; it is slightly concave in the transverse direction in its middle third; on this surface, at its upper part, we notice the orifice of the nutritious canal, which is directed upwards towards the coronoid and olecranon. By its three superior fourths this surface affords attachments to the flexor digitorum profundus, and by its inferior fourth to the pronator quadratus; the place of attachment of this latter muscle is limited above by an oblique line which passes from without inwards and from above downwards. *The internal* surface is smooth, and convex in its entire extent; widest above, it gradually tapers to the inferior extremity. In its inferior fourth it is subcutaneous, and to its three superior fourths is attached the deep flexor muscle of the fingers; the aspect of this surface is backwards as well as inwards.

The third surface is *posterior*. The two inferior thirds of this surface are smooth, the middle being flat and the lowest rounded; here are attached the extensor muscles of the thumb and that of the index finger. In the superior third we distinctly notice two surfaces, easily distinguishable by the difference of aspect; the internal one, which is continued up on the olecranon process, looks backwards and slightly outwards; to it the anconæus muscle is attached superiorly, and inferiorly the extensor carpi ulnaris. The external of these two surfaces looks directly outwards, and is separated from that last described by a line which passes obliquely downwards and inwards; to this surface, which commences just below the lesser sigmoid cavity, the supinator brevis is attached, and below it, commences the line of attachment of the extensor muscles already alluded to.

Three edges separate the surfaces above described; of these the external is at once distinguished by its greater prominence; it is sharp in nearly its two inferior thirds, and superiorly is lost on the surface to which the supinator brevis is attached; all that part of this edge which is prominent and sharp gives insertion to the interosseous ligament. The anterior edge commences just below the coronoid process, and terminates, inclining a little backwards, in front of the styloid process of the ulna: it is rounded and smooth in its entire extent, and has the deep flexor of the fingers and the pronator quadratus inserted into it. The posterior edge commences at the apex of the posterior surface of the olecranon, and terminates insensibly towards the inferior fourth of the bone.

The inferior or carpal extremity of the ulna is very small; it forms a slightly rounded head; on its posterior and internal part is a small process, projecting vertically downwards and ending in a point, to which the internal lateral ligament of the wrist-joint is attached: this process is the *styloid process*; external to this is a depression or pit, into which is inserted the triangular cartilage of the wrist-joint, and external to this depression is the rounded head, which is smooth on its inferior surface, covered with cartilage in the recent state; the triangular cartilage glides upon this surface. On the outer side of the head is an articular convexity which articulates with a concave surface on the inner side of the carpal extremity of the radius. On the posterior surface of the head, immediately external to the styloid process, there is a slight channel, in which is lodged the tendon of the extensor carpi ulnaris.

Structure. — The olecranon and coronoid processes are completely cellular in structure, excepting the external cortex of compact tissue. The inferior extremity of the ulna is likewise cellular, but the shaft is mainly composed of compact tissue, hollowed by a medullary canal, which commences a little below the coronoid process, and terminates just above the inferior extremity.

Radius, (Germ. *die Speiche*,) so called from its being compared to the spoke of a wheel; it is the shorter of the two bones of the forearm; its proportion to the ulna being as 11 to 12.

The superior extremity or *head* of the radius is a cylindrical head excavated on its superior surface so as to form a superficial cavity, *cavitas glenoidea*, which is articulated with the external condyle of the humerus. The circumference of this head consists of a deep lip of bone presenting a smooth surface covered by cartilage in the recent state, the depth of which, measured vertically, is greatest on the inner side, so as there to form an oval convex articular facet which is adapted to the lesser sigmoid cavity of the ulna; the remainder of the circumference is embraced by the annular ligament of the radius. The head of the radius is connected to the shaft by a short and cylindrical *neck*, which passes obliquely downwards and inwards; the neck of the radius is limited inferiorly and on the ulnar side by a rounded tubercular process, into the internal posterior and rough part of which the biceps muscle is inserted, *the bicipital tuberosity* or *tubercle* of the radius; the anterior part of this tubercle, over which the tendon of the biceps glides, is smooth. For about an inch below this process the bone retains the cylindrical form, being here embraced by the inferior fibres of the supinator brevis muscle; but below this the bone becomes distinctly prismatic in its form, and begins to expand to its inferior or carpal extremity. We here describe three surfaces as in the ulna; the *anterior* is inclined inwards, its aspect is forwards and inwards; about its middle this surface is slightly hollowed from above downwards; at the junction of its middle and inferior third it is convex, and in its inferior third, where it attains its greatest lateral expansion, it is concave again. At the superior third of the bone we notice on this surface the nutritious foramen, the canal following the same direction as that of the ulna, namely upwards. The muscles attached to the anterior surface of the radius are the flexor pollicis proprius, connected with the two superior thirds of the bone, and the pronator quadratus occupying the inferior third. The *posterior* surface of the radius is likewise inclined, and looks backwards and inwards, very narrow in its whole extent, but broadest at its inferior extremity, convex in its superior and inferior thirds, and slightly concave from above downwards in its middle third. This last portion of the bone affords attachment to the two inferior extensor muscles of the thumb; the superior third is embraced by the supinator brevis, and the inferior third has applied to it the tendon of the common extensor of the fingers, the indicator, and the extensor tertii internodii pollicis. The *external* surface is convex in its whole extent, and like the others expands inferiorly; about its middle we observe a rough surface, which gives insertion to the pronator quadratus; in its upper portion the surface is embraced by the supinator brevis, and inferiorly the radial extensors of the wrist are applied to it.

Of the three edges which separate these surfaces, the *internal* is sharp, and extends from about an inch below the bicipital tuberosity to about the same distance above the carpal extremity of the radius; at this latter point the edge seems to bifurcate and form a plane triangular surface above the inferior extremity of the radius. This edge gives attachment in its entire extent to the interosseous ligament. The *anterior* edge is rounded; it distinctly originates from the bicipital tuberosity, and terminates at the outer side of the carpal extremity of the radius in front of the styloid process. The supinator brevis, the proper flexor of the thumb, and the flexor sublimis of the fingers, have attachments to this edge above, and below the pronator quadratus and supinator longus are inserted into it. The *posterior* edge is very imperfectly defined, being distinct only in its middle.

The inferior or carpal extremity of the radius is the largest part of the bone; it is irregularly quadrilateral in form. Its inferior surface forms an articular excavation, the outline of which is triangular, the apex being external and the base internal; this surface is divided into two by a slightly prominent line which passes from before backwards; the outer of these two portions retains the triangular form, and is articulated with the scaphoid bone of the carpus; the internal is quadrilateral, and articulated with the lunar bone. At its inner margin, this surface is continuous with a slightly excavated articular facet on the ulnar side of the inferior extremity of the bone, which is articulated with the convex surface on the corresponding part of the ulna. The inferior extremity of the radius presents, at its outer part, a pyramidal process projecting downwards and slightly outwards; this is the *styloid* process, which by its apex gives attachment to the external lateral ligament of the wrist-joint. The anterior margin of the inferior extremity is slightly concave from side to side; it gives attachment to the anterior ligament of the wrist-joint, and the tendons of the flexor muscles of the fingers pass over it into the palm of the hand. On the posterior margin of this extremity we observe two grooves: the internal one, wide and very superficial, lodges the tendons of the common extensor of the fingers and the indicator; the external, deeper and oblique, lodges the extensor tertii internodii pollicis. Externally we notice likewise two superficial grooves, of which the posterior lodges the radial extensors of the wrist, and the anterior is traversed by the extensores primi et secundi internodii pollicis.

Structure.—The central canal extends upwards into the neck of the bone; it is cylindrical at the extremities, and prismatic in the centre. Both extremities are composed of cancellated structure.

Developement of the bones of the fore-arm.—Both bones appear about the same time, and if not synchronously with the humerus, at least a very little later. With both bones the ossification begins on the shafts, which are very early completed; the ossific point of the shaft of the radius is said, by Beclard and Cruveilhier, to begin some days before that of the ulna. In the radius the inferior extremity begins to ossify before the superior, about the end of the second year. The ossification of the superior extremity begins between the seventh and ninth year; it is united to the shaft about the twelfth year, whilst the inferior extremity, whose ossification begins earlier, is not united till the eighteenth or twentieth year. The progress of the ossification of the ulna is very similar. The inferior extremity developed by a single point of ossification begins first about the sixth year. A little later the olecranon begins to ossify; the coronoid is formed by an extension of ossification from the shaft. The union of the superior extremity of the ulna with the shaft takes place about the fifteenth or sixteenth year; that of the inferior about the eighteenth or twentieth.

It is important to observe that the articulation of the radius with the ulna, in the manner in which it is effected in man, has reference to the motions of the hand. *Pronation* and *supination* of the hand are effected by the rotation of the head of the radius within the coronary ligament and on the lesser sigmoid cavity of the ulna. The hand is so connected with the radius that it follows the motions of that bone; when, therefore, the radius rotates in such a direction that its inferior part crosses the ulna, the posterior edge is directed outwards, and its anterior surface inwards and backwards; the palm of the hand is turned backwards and the dorsum forwards; the forearm and hand are then said to be in *pronation*. On the contrary, when the rotation is such that the ulna and radius are placed on the same plane, the dorsum of the hand is directed backwards and the palm forwards; this is *supination*.

In the lower animals we never find this mode of articulation of the radius with the ulna, unless there be also present the motions of supination and pronation of the hand. In such animals, evidence of the existence of these motions is afforded by certain points in the conformation of the radius and ulna themselves, such as the peculiar form of the head of the radius, and the concave articular surface on the ulnar side of its lower extremity, as well as the lesser sigmoid cavity of the ulna, and the convexity on the radial side of the head of the same bone. This is found in many of the Carnivora, but chiefly in the Quadrumana.

In the Ruminants and Solipeds the radius and ulna are consolidated together so as to form one bone; they can, however, be distinguished at the humeral end, where the latter bone is conspicuous by its elongated olecranon, which not only affords insertion to the extensor muscles of the arm, but also increases the security of the elbow-joint. The radius, which is the principal bone of the fore-arm, is so articulated with the humerus as to admit of free flexion and extension, but it is fixed in the state of pronation. In many of the other Mammalia the radius and ulna are distinct throughout, but do not admit of the rotation of the one on the other; this is the case in Rodentia, many Carnivora, Pachydermata, Edentata, Insectivora, and Cetacea. In the Sloth, however, among the Edentata, the motions of pronation and supination are conspicuous, and the olecranon is imperfectly developed; on the contrary, in the Edentata proper, as the Armadillo, Megatherium, &c. these motions do not exist, and the olecranon is very much developed. In the Cheiroptera the radius is the principal bone of the fore-arm, the ulna being developed only as to its humeral extremity consisting sometimes of little more than its olecranon; and in some, as the *Vespertilio vampyrus*, the olecranon exists in the form of a patella, connected with the upper extremity of the ulna.

In Birds the radius and ulna are distinct throughout, but do not admit of motion between them; they are fixed in a state intermediate between pronation and supination.

The Hand.—The third division of the upper extremity is the hand: for the description of the bones which compose it, we refer to the article HAND.

Inferior extremity.—The bones which form the skeleton of the inferior or pelvic extremity are the femur, tibia, fibula, and the bones of the foot, occupying subdivisions of this member, which correspond to the arm, forearm, and hand in the pectoral extremity.

Femur (thigh-bone, os femoris v. *cruris, os coxæ.* Fr. *os de la cuisse, le femur.* Germ. *das Schenkelbein.)* This is the largest and longest bone of the skeleton; it constitutes the upper part of the inferior extremity, and is articulated with the pelvis above and the tibia inferiorly. The femur exhibits very obviously the characteristic marks of the class of long bones in its elongated and cylindrical shaft, and its swollen extremities.

The superior extremity of the femur consists of a spherical head, connected to the shaft of the bone by a neck. The head is very regularly spheroidal, being nearly two-thirds of a sphere; it is limited towards the neck by a waving line which passes all round, and corresponds to the margin of the acetabulum. The whole head of the femur is incrusted in the recent state with articular cartilage, excepting at one point, where there is a depression or pit, varying in depth in different subjects. The precise situation of this depression is just inferior and posterior to the point at which the axis of the head of the femur would pass out: into this depression the ligamentum teres is inserted.

From the head of the femur is prolonged outwards and downwards to the upper end of the shaft the neck *(cervix* v. *collum femoris).* This portion of bone, cylindrical where it is connected to the head, gradually expands as it proceeds outwards, and is flattened in front and behind. That portion of the neck of the femur which is connected with the shaft may be called *its base;* here we observe two lines, by which the demarcation between the neck and shaft is indicated; one of these lines is anterior, being simply a rough line extending from the great trochanter obliquely downwards, inwards, and slightly backwards to the lesser trochanter, and thence called the ***anterior inter-trochanteric line***, into which the capsular ligament of the hip-joint is inserted; the other line may be more correctly designated a prominent ridge; it is situated at the posterior part of the base of the neck, and extended also between the trochanters, ***the posterior inter-trochanteric line.*** The anterior surface of the neck of the femur is for the most part plane, but slightly concave just external to the line of junction of the head. The superior surface of the neck is concave, being limited on the outside by the great trochanter; the posterior surface is likewise concave, being, as it were, hollowed from within outwards. The inferior surface is slightly concave from above downwards, but rounded from before backwards: this surface inclines downwards and outwards, and at its termination is connected with the trochanter minor behind, and the inner side of the shaft of the bone in front; in length it exceeds all the rest; the superior surface is the shortest, and the posterior is longer than the anterior. On all the surfaces of the neck we observe numerous foramina for the transmission of vessels into the substance of the bone; these foramina are largest and most numerous on the superior surface.

At the superior angle of the base of the neck of the femur, and at the upper aod outer part of the shaft of the bone, we observe a large and thick process, *the trochanter major*, (from τϱοχαω, *roto*,) *processus exterior femoris;* it is a prolongation upwards of the shaft of the bone, but its most elevated point is below the level of the head of the bone, corresponding to the upper part of the line of junction of the head with the neck. "This eminence," says Cruveilhier, "whose size is considerable, and which makes a very manifest prominence under the skin, ought to be studied with care in its relations as to its relative position; first, with the crista ilii, beyond which it projects externally; secondly, with the external condyle of the femur; thirdly, with the malleolus externus, because these relations are constantly valuable guides, as well in the diagnosis as in the reduction, of the luxations of the femur and of the fractures of the neck or shaft of the bone."

The external surface of the great trochanter is convex and rough, and the tendon of the glutœus maximus muscle covers it in the recent condition; this surface is terminated below by a projecting line, into which is inserted the upper extremity of the vastus externus muscle. The internal surface is of much less extent: it is placed at right angles with the superior surface of the neck of the bone, and at its posterior part it is excavated so as to form a deep pit or depression, *the digital cavity* or *fossa trochanterica*, into which are inserted the tendon of the pyriformis, the gemelli, and the obturatores internus and externus. The anterior edge is thick and irregular; the glutœi medius and minimus are inserted into it, the former into its inferior, the latter into its superior part. Superiorly the trochanter forms a thin edge, more or less pointed, into the interior half of which the glutœus minimus is inserted, and into its posterior or pointed portion the glutœus medius; it may in general be observed, that the size of this pointed part of the superior edge of the great trochanter is proportionate to the developement of the glutœus medius muscle. The posterior edge is convex and thick, and gives attachment to the quadratus femoris muscle.

At the inferior angle of the base of the cervix femoris, and on the internal and posterior part, we notice a short conical process, *trochanter minor, (processus interior femoris,)* attached to the bone by its base, its apex directed downwards, inwards, and backwards, smooth on its whole surface. This process affords insertion to the tendon of the psoas and iliacus muscles.

In the male adult, the axis of the head and neck of the femur passes downwards, outwards, and slightly backwards, and forms an obtuse angle with the shaft, an angle of about 135 degrees. In the female this angle is somewhat smaller, and approaches more nearly to a right angle, which contributes with the greater lateral dimensions of the pelvis, to increase the distance of the trochanters of opposite sides from each other, and to cause that projection of these processes which forms a peculiarity of the female form. In early age, when the neck of the femur is imperfectly developed, the angle between the neck and shaft is not defined; in the earliest condition the connexion of the head and shaft very much resembles the permanent condition of the corresponding parts in the humerus; as the neck becomes developed, the angle is rendered apparent, at first, however, little removed from a right angle, but subsequently it increases up to the adult period; after that time we often find that the neck of the bone diminishes in its dimensions, and the angle is consequently altered, so as to approximate to a right angle.

The following may be given as the mean measurements of the different parts of the neck of the femur. In the centre it measures about one inch, its posterior surface about fifteen lines, its inferior edge about twenty lines, and its superior about eleven lines; its vertical diameter, in its most contracted part, is about seventeen lines, and its antero-posterior about ten.

The shaft of the femur forms a slight curve from above downwards, convex anteriorly and concave posteriorly, the excavation thus formed behind being filled up by the powerful muscles on the back of the thigh. It likewise presents the appearance as if it had been twisted, like that which we have noticed in the humerus, the inferior extremity being twisted inwards, the superior in the contrary direction. Cruveilhier remarks, that this curvature of torsion is in relation with the disposition of the femoral artery, which in its spiral course passes from the anterior to the posterior surface of the bone.

In the greater part of its extent the shaft of the femur is prismatic; at the superior extremity it is expanded laterally and flattened; at the inferior it is likewise very considerably expanded.

The anterior surface of the shaft is smooth and rounded; at the upper part it is a little rough: this surface is covered completely by the triceps extensor muscle. The posterior surface is divided along the middle into two, which are inclined, the one forwards and inwards, the other forwards and outwards; the external surface is covered by the vastus externus, the internal by the vastus internus. In the middle, separating these two surfaces, is a rough ridge, *linea aspera*, which occupies two-fifths of the shaft of the bone about its middle, but is bifurcated above and below. Superiorly the bifurcation takes place about the termination of the superior fifth; two lines proceed, the external, rough and prominent, to the great trochanter; the internal, rather indistinct, to the lesser trochanter. The external line gives insertion to the vastus externus, the adductor magnus, and the glutœus maximus; the pectinæus and the vastus internus are inserted into the internal line. Inferiorly, the bifurcation takes place at a point corresponding to the commencement of the two inferior fifths; each line proceeds down to the corresponding condyle, and a triangular space is thus enclosed, the base of which is formed by the posterior extremities of the condyles, and the apex is at the point of bifurcation of the linea aspera. This space, which presents a smooth surface, slightly concave in both the vertical and transverse directions, forms the floor of the popliteal region. The external line, from the inferior bifurcation, is more prominent than the internal, and gives insertion to the vastus externus and to the short head of the biceps. The internal is very faint superiorly where the femoral artery passes over it, and inferiorly the vastus internus and the adductor magnus are inserted into it.

The nutritious foramen of the femur is found either upon, or on one side of, the linea aspera.

The direction of the canal is upwards towards the head of the femur.

The inferior extremity of the femur is much more considerable than the superior. We notice upon it two articular processes of large size, united in front, but separated by a deep depression posteriorly. These processes are the *external* and *internal condyles;* at the point of union of these two condyles in front, we observe a transversely concave surface, which extends for a little distance upwards upon the anterior surface of the bone; this is the *trochlea* of the femur, on which the patella moves. The deep notch which separates the condyles posteriorly is denominated the *intercondyloid notch.*

Each condyle is ovoidal in its outline and convex. The external condyle is placed directly under the external part of the femur; it projects more forwards than the internal condyle; its antero-posterior diameter is less than that of the internal condyle, but its transverse is greater. On the other hand, the internal condyle projects inwards out of the plane of the internal surface of the bone; its posterior extremity extends much further backwards than that of the external, and if the bone be placed at right angles with a plane surface, it will be seen that this condyle alone touches that surface, a circumstance which arises from the internal condyle projecting downwards more than the external. It is also worthy of notice, as resulting from this conformation of the internal condyle, that in order to bring both condyles in contact with a plane surface, the bone must be made to incline with the inferior extremity inwards. Above the posterior extremity of each condyle there is a depression for the insertion of the two heads of the gastrocnemius muscle.

The external surface of the external condyle is continuous with the outer surface of the shaft; it is rough and convex, and is called by some anatomists the external tuberosity. At its posterior part there is a prominent tubercle to which the external lateral ligament is attached, and below and a little posterior to this is a depression into which the tendon of the popliteus is inserted. The internal surface of this condyle forms the outer wall of the depression which separates the condyles behind; it is concave, and has the anterior crucial ligament inserted into it. The inner wall of this notch is formed by the external surface of the internal condyle, which is likewise concave, and into it are implanted the fibres of the posterior crucial ligament. The internal surface of this condyle, or the internal tuberosity, is rough, much more convex than the external tuberosity; the internal lateral ligament and tendon of the adductor magnus are inserted into it. Both the tuberosities are perforated by a number of minute foramina for the transmission of vessels to the cancellated texture.

Structure.—A vertical section of the femur demonstrates its structure to be the same as that of all the long bones, composed of cancellated texture at the extremities and compact in the shaft, which is bored by a cylindrical canal. Posteriorly the compact tissue is of great density and hardness, especially where it forms the linea aspera or spine of the bone. When the section of the femur is made so as to divide the neck vertically in its long axis into two equal portions, we observe how admirably the arrangement of the osseous texture in this part is adapted to the function which it has to perform. The head is entirely composed of reticular texture surrounded by a thin cortex; this cortex gradually increases in thickness on the upper surface of the neck till it reaches the great trochanter. On the inferior surface of the neck, however, the compact tissue, although thin near the head, becomes very much increased in thickness as it curves downwards and outwards to the lesser trochanter. We observe, moreover, that although the principal portion of the head and neck are composed of reticular texture, in certain parts this texture is more loose than in others. From the upper part of the head to the thick part of the compact tissue on the inferior surface of the neck, a series of parallel fibres proceed in an oblique course, and closely applied to one another; these fibres receive and transmit the weight to the arch of the neck. Again, the reticular texture is loose and rare, external to these fibres and in all the inferior part of the head of the bone where no stress is laid upon the bone.

Developement.—According to Beclard, the femur begins to ossify before the humerus; its ossification commences about the thirtieth day by a point for the shaft. A second point of ossification is for the inferior extremity, and this consists in a single osseous nucleus which is formed within the last month of fœtal existence, and is situated between the two condyles, occupying the centre of the cartilage. According to Cruveilhier this osseous nucleus appears during the last fifteen days of intra-uterine life. "The constant presence," adds this author, "of this osseous point in the inferior extremity of the femur is a fact of great importance in legal medicine; because from the knowledge of this circumstance alone, namely, that this nucleus exists in the epiphysis of the inferior extremity of the femur of a fœtus, we can pronounce that fœtus to have arrived at its full period."

The neck of the femur is formed by an extension from the body. The head has a distinct point of ossification which begins to form at the end of the first year. The trochanters have each a separate point of ossification; that of the great trochanter is formed about the third or fourth year, that of the lesser from the thirteenth to the fourteenth year. These several osseous points are united to the shaft about the period of puberty in the following order; first, the trochanter minor, next the head and trochanter major, and lastly the inferior extremity.

In the skeleton the femur is articulated so that its inferior extremity approximates the corresponding part of the bone of the opposite side, while the superior extremities are separated from each other to a considerable extent. One object of this oblique position of the femora has been already referred to, namely, to bring both condyles of each femur in contact with the articular surfaces of the vertical tibiæ. In women, in consequence of the more horizontal position of the neck of the femur and the greater width of the pelvis, the obliquity is more manifest, and hence they are naturally more *in-kneed* than men, as from the greater projection of the internal condyle that surface alone would come in contact with the tibia if the position of the femur were vertical. The separation above is effected by the neck of the bone, and the advantage of this arrangement is to give a more favourable insertion to the muscles of rotation; they thus acquire a lever power proportionate to the length of the neck, a fact which is abundantly manifest by comparing the relative powers of rotation in the shoulder and hip joints; in the former these motions are more extensive, because, from the peculiar form of the joint, the obstacles to extent of motion are fewer; in the latter they are effected with greater power at a less expense of muscular force.

In comparing the femur of man with that of the lower mammalia, we notice the imperfect developement or the non-developement of the cervix in the latter, the head in some being placed nearly vertically over the shaft of the bone, and also the small size of the trochanters, and the magnitude of the trochanter major in some classes. The curved form of the shaft of the femur is much less in the lower mammalia than in man; in some the femur is perfectly straight, and as a consequence the linea aspera or spine is indistinctly marked. The proportionate length of the femur to the other bones of the inferior extremity differs also: in man it exceeds that of the tibia; in the inferior mammalia, although in most cases the strongest bone, the femur is shorter than the tibia, and shorter even than the foot, although longer than each segment of this portion of the limb. The trochlea in the inferior extremity is deeper, and the transverse dimensions of the condyles are less than in man.

Patella, (rotula, knee-pan, *os sesamoideum maximum,* Bertin; Fr. *la rotule;* Germ. *die Kniescheibe).* This bone, although belonging to the class of sesamoid bones, is yet so fully developed in the adult human subject, and is so essential to the integrity of the knee-joint, that it is usual to examine its anatomical characters along with those of the other bones of the inferior extremity. Its developement in the tendon of the rectus femoris leads to its being classed among the sesamoid bones.

The patella is of a triangular form, the apex being directed downwards and the base upwards; the former is connected with the tibia by the continued tendon of the rectus, under the name of ligamentum patellæ; the tendon of the rectus and the tendinous expansions of the triceps extensor are inserted into the base, which expansions are likewise implanted into the margins of the bone, so that the whole circumference and anterior surface of the patella are invested with tendinous fibres.

The anterior surface of the patella is very slightly convex, and exhibits a fibrous appearance produced by vertical and parallel fibres, with narrow fissures between, into which the fibrous expansion which invests this surface is implanted. The posterior surface is articular and adapted to the trochlea of the femur. A vertical ridge, which inclines a little outwards in its descent, divides this surface into two lateral portions; each of these portions is a concave articular facet for adaptation to the anterior part of each condyle of the femur, and consequently there is between these surfaces the same inequality which exists between the condyles. In the recent condition these surfaces are covered by a soft and very elastic cartilage.

Structure and developement.—The patella is entirely composed of cancellated texture, the anterior surface being covered by a thin lamella of very fibrous compact tissue already referred to. This bone is developed by a single point of ossification, which commences about the second year.

The patella exists pretty generally among Mammalia, also among Birds. It is most developed in the Pachydermata and the Solipeds, and also in the Monotremata; and least so in the Carnivora and Quadrumana. It is absent in Cheiroptera and Marsupiata.*

Leg.—The bones that form the second segment of the inferior extremity are the *Tibia* and *Fibula.*

Tibia, (shin-bone; Germ. *das Schienbein.)* This bone is situated between the inferior extremity of the femur and the astragalus. Its length is to that of the femur as five to six. It forms the principal support of the leg, on the inside of which it is placed, and its volume is five times that of the fibula. After the femur, it is the longest bone in the body, being longer than the humerus.

The upper or femoral extremity of the tibia is thicker and broader than the remaining parts of the bone, and is properly the head of the bone. Its transverse extent is much greater than its antero-posterior. Its superior surface presents two bony processes lying on the same plane, denominated *condyles of the tibia.* Each of these has upon its superior surface a superficial concave articular facet, oval with long axis from before backwards; to these surfaces the term condyle has been improperly applied; but they are more correctly called the *glenoid cavities* of the tibia, *(cavitates glenoideæ, externa et interna).* These cavities correspond to the condyles of the femur, having the semilunar cartilages interposed; the outer cavity approaches more to the circular form than the internal one; it is likewise much less deep, and at its posterior part it is even convex. The internal one, on the other hand, is uniformly concave, and its antero-posterior axis greatly exceeds its transverse. These surfaces are separated in the centre by a pyramidal eminence whose apex appears bifurcated, the subdivisions of which are separated by a narrow rough space. This is the *spine* of the tibia, *(acclivitas intercondyloidea);* it corresponds to the intercondyloid fossa of the femur

* Meckel, Anat. Compar.

where the crucial ligaments are attached. Anterior and posterior to this spine are two rough depressions, the posterior more hollowed than the anterior: into the former the posterior crucial ligament is inserted, and the latter receives the anterior crucial ligament.

The circumference of the head is rough and perforated by a vast number of minute vascular foramina. Each condyle projects laterally beyond the plane of the corresponding surface of the shaft, the internal to a greater extent than the external. These lateral projections are distinguished by the name of *Tuberosities.* The internal tuberosity gives insertion at its lower part to the internal lateral ligament of the knee-joint; posteriorly this tuberosity is grooved, and one of the tendons of the semi-membranosus is inserted into the groove, and separates the internal lateral ligament from the bone in this situation. At the posterior part of the external tuberosity there is a small articular facet, nearly circular and plane, with which the fibula is articulated.

In front of the head of the tibia there is a rough triangular surface, the apex of which is directed downwards and forms a prominence, which is smooth at its superior part, but rough inferiorly. The ligamentum patellæ is inserted in the latter situation; the smooth portion indicates the position of a bursa which intervenes between the ligament and the bone. This prominence is called *the anterior tuberosity*, and by some anatomists *the spine.* From the inferior rough portion of this tuberosity there passes upwards and outwards a prominent line, most prominent at its termination, where the tibialis anticus muscle has one of its attachments.

The shaft of the tibia has the form of a triangular prism in almost its whole extent: at its inferior third this form is less distinct, in consequence of the angles being rounded off. Of the three surfaces *the anterior* is that which presents the greatest dimensions: it is smooth and slightly convex in its entire extent, inclined backwards and inwards, subcutaneous, except at its upper part, where an aponeurotic expansion connected with the tendons of the semi-tendinosus, sartorius, and gracilis muscles. The inferior fourth of this surface is much more convex than the upper portion, and looks directly inwards. *The external surface* is inclined backwards and outwards, and is concave in its three superior fifths, convex in the rest of its extent. The depth of the superior concave portion is proportionate to the developement of the tibialis anticus muscle, to which it gives insertion. The inferior convex portion is of less extent than the superior, and as it descends it experiences a change of aspect so as to look directly forwards. This change is in accordance with the altered direction of the tendons of the tibialis anticus and extensor muscles of the toes, which lie in contact with the bone in this situation. *The posterior surface* is expanded at its extremities and contracted in the centre. At its superior part a triangular surface is marked off from the rest, towards the upper extremity by an oblique line, which proceeds from below upwards, and from within outwards; into this line are inserted the poplitæus, solœus, tibialis posticus, and the long flexor muscle of the toes. The space which intervenes between this line and the posterior margin of the head of the bone is covered by the poplitæus muscle and forms part of the floor of the popliteal space. Immediately below this oblique line, the orifice of the nutritious canal is situated, penetrating the bone obliquely downwards; this canal is the largest of the medullary canals of the long bones; and Cruveilhier states that he has traced a nervous filament passing into it in company with its artery. All that portion of the posterior surface which is below the oblique line is smooth and divided by a vertical line, which is variously developed in different subjects; the tibialis posticus muscle and the long flexor of the toes are attached to this surface.

Three distinct edges separate these surfaces. The *anterior edge (crista tibiæ)* is very prominent and sharp in its three superior fourths, but rounded off below: in its upper part it is quite subcutaneous, and may be felt under the skin. *The external edge* forms a very distinct line of demarcation between the internal and posterior surfaces; it gives attachment to the interosseous ligament, and at its inferior extremity it bifurcates and encloses a concave triangular surface, in which the fibula rests. *The internal edge* is more rounded than either of the others; more distinct inferiorly than superiorly. At its upper end it gives insertion to the internal lateral ligament of the knee-joint and the popliteus muscle, and lower down to the solœus and the common flexor of the toes.

The inferior or *tarsal extremity* of the tibia is of larger dimensions than the shaft, although much smaller than the superior. On its inferior surface we notice a quadrilateral articular cavity, of greater dimensions transversely than from before backwards, concave in this latter direction, and slightly convex transversely, in consequence of the existence of a slight ridge in the centre, which passes from before backwards. This surface is for articulation with the superior part of the body of the astragalus to form the ankle-joint.

The anterior surface of the inferior extremity of the tibia is convex and rough; it gives insertion to the anterior ligamentous fibres of the ankle-joint, and the tendons of the extensor muscles pass over it. The posterior surface is very slightly convex; sometimes a very superficial groove exists upon it for lodging the tendon of the flexor pollicis longus; and internal to that, and lying behind the internal malleolus, a more distinct and constant groove, which passes obliquely downwards and inwards, and lodges the tendons of the tibialis posticus and flexor communis.

On the inside of the inferior extremity, we observe that the bone is prolonged downwards and slightly inwards, forming a thick and flattened process, quadrilateral in form, called *malleolus internus.* The internal surface of this process is rough and convex; it is quite subcutaneous; its external surface is smooth, and exhibits a triangular articular facet, which is united at a little more than a right angle with the articular surface on the inferior extremity of the tibia; by this facet the internal malleolus moves on the inner surface of the body of the astragalus. The apex of the malleolus has the internal lateral ligament of the ankle-joint inserted into it; the anterior edge gives insertion to ligamentous fibres, and the posterior edge, much thicker than the anterior, is closely connected with the posterior surface of the inferior extremity of the tibia, and has upon it the oblique groove already referred to. In comparing the position of the malleolus internus with that of the internal tuberosity of the tibia, (which may best be done by laying the bone on its posterior surface on a horizontal plane,) it will be observed that the malleolus is considerably anterior to the tuberosity, a fact which is attributable to the same cause which occasions the change of aspect in the inferior part of each of the three surfaces of the shaft, namely, a torsion of the bone similar to that already noticed in the other long bones of the extremities. This torsion is manifest at the junction of the inferior and middle thirds, the lower part having the appearance of being twisted inwards, and the upper part outwards. The outer side of the tarsal extremity of the tibia is excavated so as to form a triangular surface, rough in its entire extent, to which the fibula is applied, and into which are implanted the strong ligamentous fibres by which that bone is tied to the tibia.

Structure.—The cancellated texture is accumulated in large quantity at the extremities, where, especially at the superior, a line is very frequently apparent on the whole circumference, indicating the place of junction of the epiphysis and shaft. The medullary canal is large, approaching the cylindrical form, and surrounded by a dense compact tissue.

Fibula (Fr. *peroné;* Germ. *Wadenbein).*—This bone is situated on the outer and posterior part of the tibia. It is about the same length as that bone, but as its upper extremity is applied to the under surface of the external tuberosity, its inferior extremity projects below that of the tibia. There is a slight obliquity in its direction, and in consequence, its inferior extremity advances more forwards than its superior.

The fibula is a very slender bone in its entire extent, however its extremities are a little enlarged. *The superior extremity* or head of the fibula (capitulum) is somewhat rounded on its inner side, flattened on its external surface, terminating superiorly in a point into which the external lateral ligament of the knee-joint is inserted, anterior and posterior to which the edge of the bone receives the tendon of the biceps muscle. At the upper and anterior part of its internal surface there is a small surface nearly plane, which is articulated with a similar one on the external tuberosity of the tibia. On the shaft of the fibula we may distinguish three surfaces, but in consequence of the great extent to which the fibula appears to have undergone torsion, it is at first difficult to detect the lines of demarcation between these surfaces. *The external surface* is very narrow and convex in its upper third, gradually expands as it descends, and becomes hollowed out in its middle third, where it receives the peronæi muscles; in both these portions the aspect of this surface is outwards and slightly forwards. In the inferior third it is quite flat, and its aspect is outwards and backwards. *The internal surface* has a longitudinal sharp ridge upon it, which gives insertion to the interosseous ligament. This crest divides the internal surface into two portions; the anterior, very small, in some cases not exceeding two or three lines, gives attachment to the extensor muscles of the toes and the peronæus tertius; the posterior, much more considerable and slightly concave longitudinally for about its two superior thirds, has the tibialis posticus inserted into it. This surface, which above looks nearly directly inwards, looks forwards in its inferior third. *The posterior surface* is also very narrow above, and expands as it descends; upon it the twist in the bone is very obvious. In its superior third this surface looks outwards and backwards; in its middle third, where it is much more expanded, it looks directly backwards; and in its inferior third its aspect is inwards, and here it terminates in forming a rough surface which is adapted to the similar one on the fibular side of the inferior extremity of the tibia. Superiorly the posterior surface of the tibia gives attachment to the solœus muscle, and lower down to the flexor pollicis proprius. The orifice of the nutritious canal, directed downwards and forwards, is found here.

A knowledge of the edges which separate these surfaces will assist the student in understanding the position of the surfaces themselves. *The anterior edge* begins just below the head, passes down in front of the bone as far as the middle, then becomes external and bifurcates, enclosing a triangular surface on the outside of the inferior extremity of the bone, which is quite subcutaneous. *The external edge* is at first external, and about the commencement of the inferior third it begins to wind round so as ultimately to become posterior. *The internal edge*, which is the most acute, and is more prominent in the centre than at its extremities, passes forwards inferiorly, and terminates in front of the inferior extremity of the bone: below it gives attachment to the interosseous ligament.

The inferior extremity is long and flat, and terminates in a point; it extends entirely below the inferior articular surface on the tibia, and, as Cruveilhier aptly remarks, it forms externally *the pendant* to the malleolus internus, which it exceeds in length and thickness; it is consequently called the *malleolus externus.* The internal surface of the external malleolus presents in its anterior two-thirds a plane triangular surface for articulation with the astragalus; behind this surface there is an excavation, which is rough, and gives insertion to the posterior external lateral ligament. The external surface is convex and subcutaneous, and the posterior surface is grooved for the passage of the tendons of the peronæi muscles. The apex of the malleolus is directed downwards, and is the point of attachment of the middle external lateral ligament.

Structure.—This bone is very light and elastic, a property rendered necessary by the antagonist muscles which are inserted into its opposite surfaces. Its extremities are composed of cancellated structure, which extends some way to the shaft of the bone. The medullary canal, very narrow and irregular, is found only in its middle third.

Developement of the bones of the leg.—The tibia begins to ossify somewhat earlier than the fibula. Both bones begin to ossify in their shafts; the ossific point of the shaft of the tibia appears about the middle of the second month. According to Meckel, in the embryo of ten weeks, the fibula is not above half the length of the tibia; after the third month the two bones are nearly equal. Both bones have an ossific point for each extremity. The superior extremity of the tibia begins to ossify towards the termination of the first year after birth. The inferior extremity is ossified in the course of the second year: the external malleolus is a prolongation of the inferior extremity. The union of the extremities with the shaft commences by the inferior, and is completed from the eighteenth to the twenty-fifth year. The ossification of the fibula follows nearly the same course, excepting that the superior extremity does not begin to ossify till the fifth year.

The tibia constitutes the principal pillar of support to the leg. It is placed perpendicularly under the femur, and as the latter bone is inclined inwards, it follows that there must be an angle formed between these two bones at the knee-joint, a very obtuse one, with its apex inwards.* It is then by the strength and direction of the tibia that the leg firmly supports the body in the erect attitude; the fibula seems not to contribute at all to the solidity of the limb, but is chiefly employed to increase the surface of attachment for the muscles of the leg.

The developement of the tibia and fibula in the inferior mammalia is pretty similar to that of the radius and ulna. The tibia is always fully developed, and, as in man, is the principal bone of the leg, its size being proportionate to the weight and strength of the animal. Admitting the fibula to be the analogue of the latter bone, we find that, as it is rudimentary in the Solipeds and Ruminants, so the fibula is in a similar condition in these animals. In the former animals this bone is applied to the external side of the head of the tibia in the form of an elongated stilet, terminating less than half way down in a fine point. On the other hand, in Ruminants it is only the inferior part of the fibula that is developed; it appears under the form of a small narrow bone, extending a very little way upwards, and forming the external malleolus.

* A preternatural obliquity of the femur causes a corresponding divergence of the tibia from the perpendicular. When the femur is directed unusually inwards, the tibia is directed downwards and outwards.

In Pachydermata the fibula is fully developed and quite distinct from the tibia, and very small in proportion. In Edentata the two bones are fully developed, and in the Sloths the inferior extremity of the fibula contributes to form the articular surface for the astragalus. In Rodentia the two bones are united together in the inferior half, as also with the Insectivora, particularly in the Mole. In many Carnivora these bones are fully developed and detached: this is particularly manifest in the Phocidæ and the Felidæ. In the Dogs, however, the fibula is attached to the posterior part of the tibia.

For the description of the bones composing the foot, we refer to the article under that head; and for further details on the osseous system of the extremities, we refer to the articles Osseous System (Comp. Anat.) and Skeleton.

Abnormal condition of the bones of the extremities.—A congenital malformation of one or more of the extremities is classed by Isidore Geoffroy St. Hilaire among what he denominates "Monstres Ectromeliens," of which he has three subdivisions: 1st, where the hands or feet appear to exist alone, and seem to be connected with the trunk without the intervention of all or some of the intermediate segments; these he denominates *Phocomeles*, (φωκη, *Phoca*, and μελος, *membrum*,) from their resemblance to the permanent condition of the aquatic mammalia: 2d, cases in which there are one or more incomplete limbs terminating in the form of stumps: to these he gives the name *Hemimeles:* and, lastly, where the limb or limbs are wholly absent or scarcely at all developed. An interesting case of Phocomelia is recorded by Dumeril; all the limbs were in this condition, owing to the absence of the humerus, and forearm bones in the upper extremity, and the presence of a very imperfect femur, developed only as to the head and trochanters, and a very imperfect tibia in the lower extremity. The clavicle and scapula were present, but presented some irregularities of form.* The congenital absence of these last bones is rare excepting where the other bones of the limb are also absent.

It would be inconsistent with the objects of this article to prosecute this subject further; we therefore refer for further details to the article Monstrosity.

For Bibliography, see that of Anatomy (Introduction).

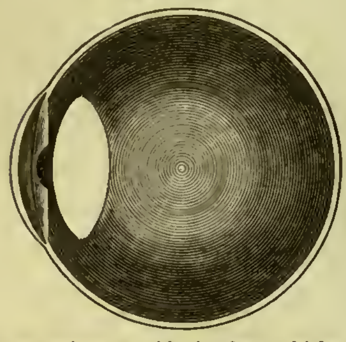
(R. B. Todd.)

EYE, (in human anatomy), οφθαλμος, *organon visus; oculus.* Fr. *Œil;* Germ. *das Auge;* Ital. *Occhio.*—The human eye is a hollow sphere, about one inch in diameter, with a circular aperture in the anterior part about one-fifth of this sphere in breadth, filled by a transparent convex portion called the cornea, through which the light is transmitted. Within this hollow

* Bull. de la Soc. Philomath. t. iii., quoted in Geoff. St. Hilaire's Anom. de l'Organization, t. ii. p. 211.

sphere, and at a short distance behind the transparent convex portion or cornea, is fixed a double convex lens, called the crystalline lens or crystalline humour; and between this cornea and crystalline lens is interposed a partition or screen called the iris, with a circular aperture in its centre called the pupil. The inner surface of this hollow sphere, as well as the back of the iris or screen, are covered or stained with a black material. The space between the cornea and crystalline lens, in which the iris is placed, is filled with a transparent fluid, called the aqueous humour, and the space between the crystalline lens and the bottom of the sphere is filled with a similar fluid, called the vitreous humour. The annexed figure represents a section of this simple piece of optical mechanism, much larger than natural to render the parts more distinct.

Fig. 100.

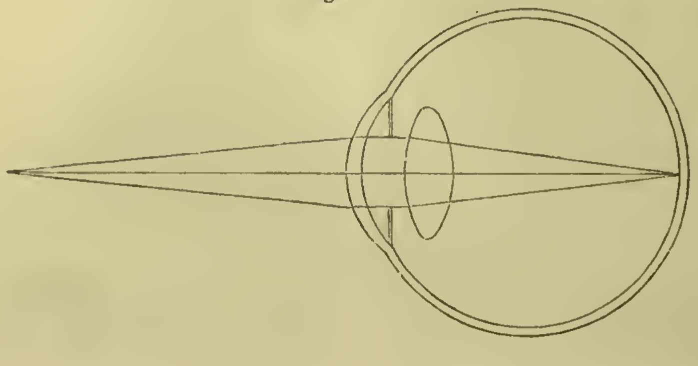


An acquaintance with the laws which regulate the transmission of the rays of light through transparent bodies, and with the manner in which the lenticular form changes the direction of these rays, teaches that a correct image of external objects is formed in the bottom of the eye in consequence of the above adjustment of its parts. First, the rays of light acquire a convergence in their passage through the cornea and aqueous humour, then the central portion of the pencil of rays is transmitted through the pupil, and, finally, the rays in their passage through the crystalline lens acquire such additional convergence, that they are brought to a focus on the bottom as represented in the annexed diagram.

Such are the essential component parts of the eye, considered as a piece of optical mechanism, but viewed as a piece of anatomical mechanism, its construction is much more complicated, and the materials of which it is composed are necessarily totally different from those of any human contrivance of a similar nature. It lives in common with the body of which it forms a part, it grows and is repaired; consequently, the animal organisation destined for such functions must constitute an essential part of its construction.

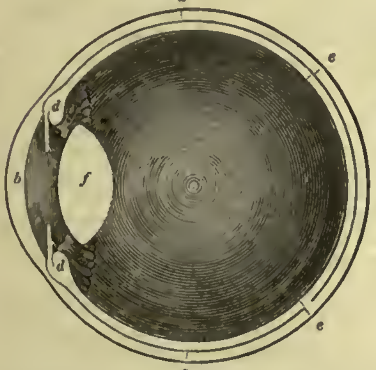
The organ derives its permanent spherical form, its external strength, and the support of the delicate parts within it, from a strong opaque membrane called the sclerotic coat; while the convex portion, called cornea, in front, equally strong, being transparent, allows the rays of light to pass without interruption. The interior of the portion of the sphere formed by the sclerotic coat is lined throughout by a soft membrane called the choroid, necessarily constituting another hollow sphere, accurately adapted and adhering to the inside of the former. This also has its circular aperture anteriorly, into which is fitted the screen called iris, as the cornea is fitted into the aperture in the sclerotic. While the external surface of this choroid coat is comparatively rough and coarse in its organization, as it adheres to the equally coarse surface of the sclerotic, the interior is exquisitely smooth and soft, being destined to embrace the retina, another spherically disposed membrane of extreme delicacy. The screen called iris, which is fitted into the circular aperture anteriorly, is as different from the choroid coat in its organization as the cornea is from the sclerotic: it is perfectly plane, and therefore forms with the concave surface of the cornea a cavity of the shape of a plano-convex lens, called the anterior chamber. In or on the choroid coat the principal vessels and nerves, destined to supply the interior of the organ, are distributed, and in its texture and upon its inner surface is deposited the black material, which in this part of the chamber, as well as on the back of the iris, is so essential a provision. At the anterior margin the choroid is more firmly united to the corresponding margin of the sclerotic by a circular band of peculiar structure called the ciliary ligament, and on its inner surface, in the same place, it is fur-

Fig. 101.



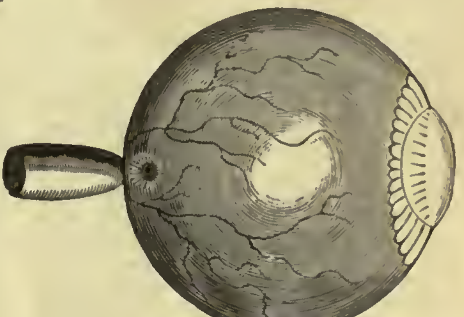
nished with a circle of prominent folds called ciliary processes, by means of which it is united to the corresponding surface of the hyaloid membrane of the vitreous humour. The annexed figure represents a section of this hollow sphere lodged within the sclerotic sphere. The external circle, *a a*, between the two black lines represents a section of the strong opaque membrane called the sclerotic, which constitutes the case or resisting sides of the organ; *b* is the transparent lenticular window called cornea, which fills the aperture left in the anterior part of the sclerotic for its reception; *d d* is the place of union between the sclerotic and cornea, to which the ciliary ligament on the outside of the anterior margin of the choroid sphere corresponds; *e e* the circle bounded by the line marking the inner surface of the sclerotic externally, and by the shaded part internally, represents a section of the hollow sphere called choroid. At the point *d d*, corresponding to the place of union between the sclerotic and cornea, this choroid projects externally, encroaching upon the sclerotic in a peculiar manner, to be presently described as the ciliary ligament; while at the same point it projects internally in the shape of a series of folds, to be described as the ciliary processes. The white productions extending from the same points in a vertical direction into the chamber of the aqueous humour, between the cornea and crystalline lens, represent a section of the screen called the iris. *f* is a section of the crystalline lens.

Fig. 102.



Through a small aperture in the sclerotic and choroid membranes in the bottom of the eye, the optic nerve is transmitted, and immediately expands into a texture of the most exquisite delicacy, called the retina. This constitutes a third spherically disposed membrane, not however of the same extent as the sclerotic or choroid, being discontinued at a distance of about an eighth of an inch from the anterior margins of these membranes. This is the nervous expansion endowed with the peculiar description of sensibility which renders the animal conscious of the presence of light. The globe of the eye, as above described, is obviously divided by the iris into two chambers of very unequal dimensions; that in front bounded by the cornea being very small, and that behind bounded by the retina being very large. This large posterior chamber is distended by a spherical transparent mass, called the vitreous humour, which does not, however, fill this posterior chamber completely, but is discontinued or compressed at a short distance behind the iris, leaving a narrow space between it and that membrane, called the posterior chamber of the aqueous humour. This spherical mass is of extremely soft consistence, and is composed of a delicate transparent cellular membrane called the hyaloid membrane, the cells of which are distended with a transparent fluid. In the small space between the anterior part of the vitreous humour and the back of the iris, called the posterior chamber of the aqueous humour, and lodged in a depression formed for its reception in the vitreous humour, is placed the double convex lens called the crystalline lens. The relation of these parts to each other may be seen in the last figure, and the one below represents the optic nerve expanded in the form of a spherical membrane over the sphere of vitreous humour, with the crystalline lens lodged in a depression on the anterior part of that sphere, and surrounded by a circle of radiating lines, which are delicate folds corresponding to the folds of the choroid, called the ciliary processes.

Fig. 103.



The piece of animal optical mechanism thus constructed is lodged in an open cavity of the skull called the orbit, and is furnished with six small muscles for its motions inserted into the outside of the sclerotic coat. The transparent cornea through which the light is transmitted is necessarily exposed, and not being in its nature suited to such exposure, is covered with a membrane called *conjunctiva*, which also extends over the sclerotic, where that membrane constitutes the anterior part of the globe, and then being reflected, lines the eyelids, and finally becomes continuous with the skin of the face.

The human eye is, as has been stated above, probably a sphere of about one inch in diameter. Petit, however, who appears to have first made the attempt to determine the proportions of the organ accurately, describes the axis to be to the diameter as 135 to 136, and the younger Sömmerring, apparently from his own observations, as 10 to 9.5. This belief in a slight difference in dimension may, however, have been adopted from not making allowance for the projection of the cornea, which is a portion of a smaller sphere than the globe itself, and consequently projects beyond its circumference. From the flaccid state of the eye even shortly after death, it must be very difficult to measure it accurately. The question is, however, fortunately of little practical importance. The eyeball of the male is generally a little larger than that of the female; and if a close inquiry be made into the matter, much difference in this respect might probably be detected in different individuals. I have seen the eyeball in an adult of full size not larger than that of a child of five years old; and there is much apparent difference in consequence of the difference in the depth of the orbit, and in the gape of the eyelids. Although the human eyeball is nearly a perfect sphere, that precise form is obviously not an essential requisite in the construction of a perfect organ of vision. In all the vertebral animals the bottom of the eye, where the retina is expanded, is probably a portion of a correct sphere, but in many the anterior part is compressed, or in other words the sphere is truncated, to adapt it to the form and dimensions of the head, or to bring the cornea and lens nearer to the retina. In the mysticete whale the axis is to the diameter as 20 to 29; in the swan as 7 to 10; in the turtle as about 8 to 10; and in the cod as 14 to 17. This deviation from the spherical form demands a corresponding provision in the construction of the sclerotic, to be noticed when describing that membrane. For a fuller account of the comparative proportional measurements of the eye, the student is referred to the works of Cuvier and D. W. Sömmerring, as quoted at the end of this article; the limits of which do not admit of a greater detail of facts derived from comparative anatomy than the illustration of the description of the human organ absolutely demands.

Having attempted to give a general notion of the mechanism of the eye in the preceding paragraphs, it remains to consider each component part separately, and to determine its organization, properties, and application, as well as the changes to which it is liable from age, disease, or other circumstances.

Of the sclerotic membrane.—This, as has been stated, constitutes, with the transparent cornea, the external case upon which the integrity of the more delicate internal parts of the organ depends, otherwise incapable of preserving their precise relations to each other: without such support the component structures must fall to pieces, or be crushed by external pressure. The name is derived from the Greek σκληροω, and it has also been called *cornea* and *cornea opaca* in contradistinction to the true or transparent cornea, a structure to which it bears no resemblance whatsoever; it is the same animal material which exists in all parts of the body where strength with flexibility is required, the material which in modern times has been denominated fibrous membrane. When carefully freed from all extraneous matter by clipping with a pair of scissors under water, it presents the brilliant silvery-white appearance so characteristic of the fibrous membranes. The white streaks which give the fibrous appearance appear arranged concentrically as the lines on imperfectly polished metallic surfaces. It is inelastic as other fibrous membranes, and so strong that it does not tear or yield unless exposed to the greatest violence. Although penetrated by the vessels going into and returning from the internal parts of the eye, it does not appear to have much more red blood circulating through its texture than other tendinous expansions distinguished for their whiteness. The vascularity of the anterior part, however, where it is exposed in the living body, constituting the *tunica albuginea*, or white of the eye, is different from that of the rest of the membrane. The four straight muscles are penetrated by small branches of the ophthalmic artery, the delicate ramifications of which converge to the circumference of the cornea, for the nutrition of which membrane they appear to be destined. In the natural state they can scarcely be detected, but when enlarged by inflammation, present a remarkable appearance, considered by practical writers one of the most characteristic symptoms of inflammation of the eyeball, or, as it is called, iritis. They then appear as numerous distinct vessels, and as they approach the margin of the cornea, become so minute and subdivided, that they can no longer be distinguished as separate vessels, but merely present a uniform red tint, described as a pink zone. The colour of this inflammatory vascularity is also characteristic. Whether from the vessels being more arterial than venous, or from their distribution in so white a structure, they present a brilliant pink appearance very different from the deep red of conjunctival inflammation, which often enables the practitioner to pronounce an opinion as to the nature of the disease before he makes a close examination.

The inner surface of the sclerotic where it is in contact with the choroid, does not present the same brilliant silver-white appearance that it does externally, being stained with the black colouring matter; it is also obscured by a thin layer of cellular membrane, by means of which it is united to the external surface of the choroid.* This layer of cellular membrane was described by Le Cat, and more particularly by Zinn, as a distinct membrane, and considered to be a continuation of the pia mater; it is, however, obviously nothing more than the connecting material applied here as in other parts of the body where union is requisite.

The thickness of the sclerotic is greater in the bottom of the eye than at its anterior part, where it is so thin that it allows the black colour of the choroid to appear through it, giving to this part of the eye a blue tint, particularly remarkable in young persons of delicate frame. The attachments of the four straight muscles, however, appear to increase the thickness in this

* [Arnold and others describe and figure a serous membrane in this situation (*Spinnwebenhaut, arachnoidea oculi*). See the figure of a vertical section of the eye in Arnold über das Auge, tab. iii. fig. 2, and copied into Mr. Mackenzie's work on the Eye.—Ed.]

situation; but that there is no general thickening in this part from this cause is proved by the thinness of the membrane in the intervals between and beneath these tendons. The consequence of this greater thinness of the membrane anteriorly is, that when the eyeball is ruptured by a blow, the laceration takes place at a short distance from the cornea. In animals in whom the eyeball deviates much from a true sphere, as in the horse, ox, sheep, and above all, in the whale, the sclerotic is much thicker posteriorly than anteriorly, being in the latter animal from three quarters to an inch in thickness, while it is not more than a line at its junction with the cornea. The reason for the existence of this provision is, that the form of the perfect sphere is preserved by the uniform resistance of the contents, but when these contents are spherical in one part, and flattened in another, the external case must possess strength sufficient to preserve this irregularity of form. It is remarkable that this strength is conferred in the class mammalia by giving to the sclerotic increase of thickness, the fibrous structure remaining nearly the same in its nature, while in birds, reptiles, and fishes, the requisite strength is derived from the presence of a cartilaginous cup or portion of sphere, disposed within a very thin fibrous sclerotic. This cartilaginous sclerotic, as it is often called in the books, exists, as far as I have been able to ascertain, in these three classes, and is in some individuals very remarkable. In birds it is thin and flexible, giving a degree of elasticity, which distinguishes the eyeball in this class. In fishes, as has been observed by Cuvier and others, the cartilage is always present, and is particularly thick in the sturgeon; it is even osseous in some, as the sea-bream, from the eye of which animal I have often obtained it in the form of a hard crust by putrefactive maceration. Among the reptiles the turtle presents a good example of this structure. Where the deviation from the spherical form is very great, as in birds, additional provision is made to sustain the form of the organ. This consists of a series of small osseous plates arranged in a circle round the margin of the cornea, lapping over each other at the edges, and intimately connected with the fibrous and cartilaginous layers of the sclerotic. A similar provision exists in the turtle, and also in the chameleon, and many other lizards, but not perhaps so neatly and perfectly arranged as in birds. It is found in the great fossil reptiles Ichthyosaurus and Plesiosaurus.

The sclerotic, like other fibrous membranes, being inelastic and unyielding, does not become stretched when fluids accumulate in the eyeball in consequence of inflammation, or in other words, the eyeball does not become enlarged from effusion of serum or secretion of purulent matter into its chambers. To this probably may be attributed the intolerable torture and sense of tension experienced when the eyeball suppurates, as well as the severe pain extending to the temple in some forms of inflammation. The pain in such cases must not, however, be wholly attributed to this distension of an unyielding membrane. The fibrous membranes in general, when affected by rheumatic or arthritic inflammation, become acutely sensible, and the cause of much suffering; and the sclerotic, when similarly affected, acquires the same description of painful sensibility, apparently independent of distension from effusion. In certain forms of inflammation and other morbid changes of the eyeball, the sclerotic appears to yield to distension, as in scrofulous inflammation and hydrophthalmia; but this is not a mechanical stretching, but an alteration in structure attended with a thinning of the membrane, and consequent alteration in the shape of the globe. It appears that the cornea and sclerotic are peculiarly, if not in many instances almost exclusively, the seat of the disease in chronic scrofulous inflammation of the eyeball. This inference may, I think, be justly drawn from the fact, that in such cases the sclerotic becomes so much thinned that the dark choroid projects in the form of a tumour, and the eye loses its spherical form; yet the pupil remains regular, the lens transparent, and the retina sensible to light. When the cornea is destroyed by slough or ulceration in severe ophthalmia, allowing the lens and more or less of the vitreous humour to escape, the sclerotic does not accommodate itself to the diminished contents by a uniform contraction, but merely falls in; and when the eye has been completely emptied, it is found many years after the injury folded up into a small irregular mass in the bottom of the orbit. When the organization of the eye is completely destroyed by idiopathic, rheumatic, or syphilitic inflammation, the sclerotic becomes flaccid, and the whole eyeball soft, allowing the contraction of the four straight muscles to produce corresponding depressions, and thus convert the sphere into a form somewhat cubical.

Of the cornea.—This is the transparent body which fills the circular aperture in the anterior part of the spherical sclerotic; it is called cornea from its supposed resemblance to transparent horn, and *cornea transparens* in contradistinction to the sclerotic, which, as has been stated, is called *cornea opaca*. It is generally described as a transparent structure, serving to the eye the same purpose as the crystal to the watch; but this is not a correct comparison: the crystal merely transmits the light without changing the direction of the rays; the cornea, whether it be considered in itself a lens, or as the spherical surface of the aqueous humour, refracts the rays and causes them to converge to a focus. Haller, although he does not directly say that it is a lens, yet states that if held over a book it magnifies the letters, which of course results from its lenticular form; and Cuvier and Biot distinctly call it a meniscus. On the other hand, the Sömmerrings, both father and son, describe it as a mere segment of a sphere, the curve of the convexity corresponding to that of the concavity, as in the watch crystal. I consider it to be a lens and a meniscus. If it be removed from the eye a short time after death with a portion of the sclerotic, and dipped in water to smooth its surfaces, it magnifies objects when held between them and the eye, as stated by Haller; and sections of the cornea of the eye of the horse, ox, sheep, or other large animals, shew that the part is much thicker in the centre than at the circumference. It is also to be observed that it has the same provision for the preservation of its lenticular form in a correct state as the crystalline lens, as will presently be explained. The statements made by authors respecting the measurements of the curvatures of the surface of the cornea can be considered only as an approximation to the truth. It is obvious that there must be much difficulty in accurately ascertaining the matter during life, and after death the form is so speedily altered by evaporation that the curve cannot remain the same as during life, hence the measurements differ. Haller says it is a portion of a sphere seven lines and a half in diameter; Wintringham that the chord is equal to 1.05 of an inch, the versed sine of this chord 0.29, and consequently the radius is equal to 0.620215 of an inch. Mr. Lloyd, in his Optics, states, on the authority of Chossat, that the surface of the cornea is not spherical but spheroidical. He says, "the bounding surfaces of the refracting media, however, are not spherical but *spheroidical*. This remarkable fact was long since suspected by M. Petit, but of late has been placed on the clearest evidence by the accurate measurements of Chossat. This author has found that the cornea of the eye of the ox is an *ellipsoid* of revolution round the greater axis, this axis being inclined inwards about 10°. The ratio of the major axis to the distance between the foci in the generating ellipse he found to be 1.3; and this agreeing very nearly with 1.337, the index of refraction of the aqueous humour, it follows that parallel rays will be refracted to a focus by the surface of this humour with mathematical accuracy." Whether we consider the cornea as a distinct lens, or as constituting the spherical surface of the aqueous humour, there can be no doubt of its importance as an agent in causing the convergence of the rays of light to a focus on the retina in conjunction with the crystalline lens. If other proof were wanted, it is afforded by the comparatively perfect optical mechanism of the eye after the crystalline lens has been removed by the operation for cataract. The vision in such cases, especially in young persons, is often so good that individuals are satisfied with it for the common purposes of life, and do not resort to the use of the usual convex glasses. The circumference of the cornea is not perfectly circular externally, although it is internally; the sclerotic laps a little over it both superiorly and inferiorly, so that it appears a little wider than it is deep, the vertical being to the horizontal diameter as fifteen to sixteen.

Although the cornea is in general description considered a simple and uniform membrane, it is undoubtedly composed of three forms of animal structure, as different from each other as any other three in the animal. These are the conjunctiva, which constitutes the exposed surface; the proper cornea, upon which the strength of the part depends; and the elastic cornea, which lines the inner concave surface. The conjunctiva is evidently a continuation of the skin, which, reflected in the form of a vascular membrane, lines the eyelids, from which it is continued as a delicate transparent membrane over the anterior part of the globe, adhering loosely to the sclerotic, and closely to the cornea. The existence of conjunctiva on the surface of the cornea proper admits of easy demonstration, and its identity of character with the rest of the conjunctiva and skin of satisfactory proof. If the surface, shortly after death, be scraped with the point of a needle, the soft texture of the conjunctiva is easily torn and detached, and the tough, firm, polished surface of the cornea proper exposed; and if the eye be allowed to remain for forty-eight hours in water, the whole layer may by a little care be turned off in the form of a distinct membrane. During life, patches of the conjunctiva are frequently scraped off by accident, or by the point of the needle of the surgeon as he attempts to remove foreign bodies implanted in the cornea proper; it is also occasionally accidentally removed by lime or other escharotics. When the vessels of the conjunctiva over the sclerotic become enlarged, and filled with red blood in consequence of preceding inflammation, that over the cornea at length becomes equally red, and has its transparency greatly impaired by the vascular ramifications. In pustular ophthalmia, the pustules form on the conjunctiva over the cornea as well as on that over the sclerotic; and in small-pox, vision is frequently destroyed by this part of the tegumentary membrane participating in the general disease. In cases where the surface is constantly exposed to the atmosphere in consequence of prominent staphyloma or destruction or eversion of the eyelids, the conjunctiva of the cornea occasionally becomes covered with cuticle in common with the rest of the membrane. In animals over whose eyes the skin is continued without forming eyelids, the continuity of it over the cornea is obvious. In the mole-rat *(Aspalax zemni.)*, where the skin is uninterruptedly continued over the eye, the hairs grow from the part over the cornea as well as from the rest. When snakes cast their covering, the cuticle is detached from the cornea as well as from the rest of the body; and when the skin is drawn off the body of an eel, it is detached with equal ease from the cornea as from the rest of the eye.

The cornea proper, upon which the strength of this part of the eye depends, is the structure to which the appellation *cornea* is generally exclusively applied; it is, as might very reasonably be expected from the office which it performs, a material of peculiar nature and organization, not identical with any other of the simple membranes. During life, and before it becomes altered by the changes which take place after death, it is perfectly transparent, colourless, and apparently homogeneous. This perfect transparency, however, depends upon the peculiar relation of the component parts of its texture, for if the eyeball of an animal recently dead be firmly squeezed, the cornea is rendered completely opaque, by altering that relation of parts, and as speedily recovers its transparency upon the removal of the pressure. The chemical composition of the cornea is similar to that of the fibrous membranes in general and the sclerotic in particular: like the latter structure, it is converted into gelatine by boiling; but Berzelius states that it contains also a small quantity of fibrine or coagulated albumen, as proved by the formation of a precipitate upon adding the cyanuret of ferro-prussiate of potass to acetic acid, in which the membrane has been digested. The cornea possesses great strength, being seldom or never ruptured by blows on the eyeball, which frequently tear the sclerotic extensively. It does not yield to distension from increased secretion, effusion, or suppuration within the eyeball in consequence of inflammation, but it becomes extended and altered by growth both in shape and dimensions, as may be observed in prominent staphyloma, hydrophthalmia, and that peculiar alteration called *staphyloma pellucidum*, in which the spherical form of the membrane degenerates into a cone, but retains its transparency.

The cornea is destitute of red vessels, yet it affords a signal example of colourless and transparent texture possessing vital powers inferior to no other. No structure in the body appears more capable of uniting by the first intention. The wound inflicted in extracting a cataract is often healed in forty-eight hours, yet the lips are bathed internally with the aqueous humour, and externally with the tears. Ulcers fill up and cicatrize upon its surface; and although the vessels, under such circumstances, frequently become so much enlarged as to admit red blood, yet there can be no doubt that ulcers do heal without a single red vessel making its appearance. Abscesses form in the cornea, and contain purulent matter of the same appearance as elsewhere; they are generally said to be between the layers of the cornea, but they are evidently distinct cavities circumscribed by the inflammatory process as in other cases; occasionally, however, the whole texture of the cornea becomes infiltrated with purulent matter, as the cellular membrane in erysipelas. The rapidity with which this membrane is destroyed by the ulcerative process is another proof of its superior vitality. In a few days a mere speck of ulceration, the consequence of a pustule, extends through the entire thickness, and permits the iris to protrude; and in gonorrhœal and infantile purulent ophthalmia, the process is much more rapid and extensive. It is true that in the latter case the destruction is attributed to gangrene or sloughing, and to a certain extent correctly; but an accurate observer must admit that the two processes co-operate in the production of the lamentable consequences which result from these diseases. Ulcers of the cornea fill up by granulation and cicatrize as in other parts of the body, but the repaired part does not possess the original organization, and is consequently destitute of that transparency and regularity of surface so essential for its functions; hence the various forms and degrees of opacity enumerated under the technical titles of *albugo*, *leucoma*, *margarita*, *nebula*, &c. which are probably never remedied, however minute they may be, notwithstanding the general reliance placed in the various stimulating applications made for this purpose. Slight opacities, or *nebulæ* as they are called, if confined to the conjunctival covering of the cornea, gradually disappear after the inflammation subsides, as does also diffused opacity of the cornea itself, the consequence of scrofulous inflammation; but I believe opacities from ulceration and cicatrix are seldom if ever removed. The effect of acute inflammation is to render this, and perhaps all transparent and colourless membranes, white and opaque without producing redness; this may be seen in wounds, where the edges speedily become gray; and in the white circle which frequently occupies the margin of the cornea in the inflammations of the eyeball commonly called iritis.

The cornea in a state of health is destitute of sensibility. Of this I have frequently satisfied myself by actual experiment in cases of injury of the eye, where the texture of the part is exposed. When foreign bodies, such as specks of steel or other metals, are lodged in its structure, the surgeon experiences much difficulty in his attempts to remove them, from the extremely painful sensibility of the conjunctiva as he touches it with his needle; but the moment he strikes the point of the instrument beneath the foreign body into the cornea itself, the eye becomes steady, and he may touch, scrape, or cut any part of the membrane uncovered by conjunctiva without complaint.

It has already been stated that the cornea, as it constitutes the transparent medium for the passage of the rays of light, is composed of three distinct forms of structure altogether different from each other, the conjunctiva, the cornea proper, and the elastic cornea. The latter membrane is now to be described. In many of our books this membrane is vaguely alluded to as the membrane of the aqueous humour; but with this it must not for a moment be confounded. It is a distinct provision for a specific purpose, totally different from that for which the other is provided. It was known to and described by Duddell, Decemet, Demours, and latterly by Mr. Sawrey; but all these authors having unfortunately published their accounts in separate and probably small treatises, not preserved in any journal, I have not been able to consult them. It is, however, distinctly recognized by Clemens, D. W. Sömmerring, Blainville, and Hegar; and in a paper on the anatomy of the eye in the Medico-Chirurgical Transactions, I endeavoured to direct attention to it without effect. The structure here alluded to is a firm, elastic, exquisitely transparent membrane, exactly applied to the inner surface of the cornea proper, and separating it from the aqueous humour. When the eye has been macerated for a week or ten days in water, by which the cornea proper is rendered completely opaque, this membrane retains its transparency perfectly; it also retains its transparency after long-continued immersion in alcohol, or even in boiling water. When detached, it curls up and does not fall flaccid or float loosely in water, as other delicate membranes. It also presents a peculiar sparkling appearance in water, depending upon its greater refractive power; in fact it presents all the characters of cartilage, and is evidently of precisely the same nature as the capsule of the crystalline lens. When the cornea proper is penetrated by ulceration, a small vesicular transparent prominence has been repeatedly observed in the bottom of the ulcer, confining for a time the aqueous humour, but ultimately giving way, and allowing that fluid to escape, and the iris to prolapse; there can be little doubt that it is this membrane which presents this appearance. In syphilitic iritis, this membrane becomes partially opaque, appearing dusted or speckled over with small dots altogether different in appearance from any form of opacity observed on the conjunctiva or cornea proper. When it has been touched by the point of the needle in breaking up a cataract, an opacity is produced closely resembling capsular cataract. There is no difficulty in preparing and demonstrating this membrane in the eye of the sheep, ox, and especially the horse, and it may with a little care be exhibited in the human and other smaller eyes. The eye of a horse having been macerated in water for six or eight days, or until the cornea proper becomes white, should be grasped in the left hand so as to render the anterior part plump, and then inserting the point of a sharp knife into the structure of the cornea at its junction with the sclerotic, layer after layer should be gradually divided by repeated touches round the circumference, until the whole thickness is cut through and the transparent elastic cornea appears, after which the cornea proper may be turned off by pulling it gently with the forceps. The use of the elastic cornea does not appear to me doubtful. The crystalline lens is lodged in a capsule of precisely the same nature, evidently destined to preserve correctly the curvature of each surface of that body, a condition obviously necessary to secure the perfection of the optical mechanism of the organ. The elastic cornea in the same way, by its firmness, resistance, and elasticity, preserves the requisite permanent correct curvature of the flaccid cornea proper.

The cornea proper is closely and intimately connected to the sclerotic at its circumference. There does not appear to be any mechanical adaptation resembling the fitting of a watch-glass into the bezel, as stated in books; but a mingling of texture, as in many other instances in the body. The two structures cannot be separated without anatomical artifice and much violence. If the eye be macerated in water for a month, and then plunged into boiling water, the cornea may be torn from the sclerotic; but these destructive processes prove little with regard to animal organization. The conjunctival covering of the cornea is, as has been already stated, continuous with the rest of the conjunctiva, and the elastic cornea is continued for a short distance beneath the sclerotic, as if slipped in between it and the ciliary ligament.

The cornea, thus composed of three different structures, varies in appearance at different periods of life. In the fœtus at birth it is slightly cloudy, and even of a pinkish tint, as if it contained some red particles in its blood; this is, however, more apparent on examination after death than during life; it is also thicker in its centre. In old age it is harder, tougher, and less transparent than in youth, and frequently becomes completely opaque at its circumference, presenting the appearance denominated in the books *arcus senilis*. How far the alteration in the power of adaptation to distance, which occurs in advanced life, is to be attributed to change in curvature of the cornea, is not settled.

If the foregoing account be correct, the apparently simple transparent body which fills the aperture in the anterior part of the sclerotic, is composed of three distinct varieties of organic structure, liable to changes from disease equally distinct and varied. When the aqueous humour becomes the subject of description, I will endeavour to shew that there is good reason for believing that a fourth may be added to these three, the membrane which lines the chamber in which this fluid is lodged, and by which it is secreted. Let it not be supposed that this division of an apparently simple piece of organization into so many distinct parts, is merely an exhibition of minute anatomical refinement. The distinction is essentially necessary to enable the surgeon to account for the appearances produced by disease in this part, and to guide him in the diagnosis and treatment.

Of the choroid coat.—This membrane has been so called from its supposed resemblance to the chorion of the gravid uterus; it has also sometimes been called *uvea* from its resemblance to a grape, a term, however, which is now more frequently applied to the iris. It has already been stated that the spherical external case of the eye called the sclerotic embraces another spherically disposed membrane, called the choroid coat, accurately fitted and adhering to it throughout. This spherically disposed membrane has also its circular aperture anteriorly, into which is fitted the screen or diaphragm called the iris. This choroid membrane cannot be considered essential to the perfection of the organ considered merely as a piece of optical mechanism, as a spherical *camera obscura*, but is obviously an important part of its anatomical organization, and an essential provision for the perfection of its vital functions. It appears to be destined to secure the requisite mechanical connexion between the coarser and more rigid sclerotic case and the parts within, as well as to secure these delicate parts in their situation, and preserve their form, at the same time affording a medium for the distribution and support of the vessels and nerves.

This membrane is of a deep brown or black colour, being stained with the colouring matter called the black pigment; but when this is removed, it exhibits a high degree of arterial and venous vascularity. Its external surface is comparatively rough, coarse, and flocculent, and obscured by the cellular membrane which connects it to the sclerotic. The inner surface, which is in contact with the retina, presents a very different appearance. It is soft and smooth, and when minutely injected, resembles the more delicate mucous membranes, and exhibits a remarkable degree of minute villous vascularity. The external surface being composed of the larger branches of arteries, veins, and nerves, may be torn away from the soft, smooth, and more closely interwoven inner layer, or the inner layer may be partially dissected up from it, with some care, especially in the eyes of the larger quadrupeds. This manœuvre having been executed by Ruysch, and preparations so formed displayed by him, the inner layer has been denominated the tunica Ruyschiana. But this is a mere anatomical artifice. There is no natural division into two layers, the soft, smooth, and highly vascular inner surface being formed by the ultimate subdivision and distribution of the larger branches of vessels, which exhibit themselves separately on the outside. It is a condition somewhat analogous to that of the skin, where the soft, smooth, villous external surface presents so remarkable a contrast to the rough internal surface with its layer of cellular membrane uniting it to the subjacent parts.

The choroid is supplied with blood from the ophthalmic artery by the short ciliary arteries, which penetrate the sclerotic at a short distance from the entrance of the optic nerve, and are distributed to it in nearly twenty small branches. These branches ramify and inosculate freely on the outside of the membrane, and are visible as distinct vessels, especially on the posterior part of the sphere. They finally terminate on the inner surface, forming a beautiful vascular expansion. The long ciliary arteries give scarcely any twig to the choroid, being distributed to the iris, and the anterior branches furnished to the sclerotic, as described in speaking of that membrane, do not penetrate to the choroid. The veins of the choroid present a peculiar appearance. The ramifications are arranged in the form of arches or portions of a circle, bending round to a common trunk like those of certain trees with pendulous branches. They discharge their blood into four or five larger branches which penetrate the sclerotic at nearly equal distances from each other behind the middle of the eyeball. On account of this peculiar arrangement they have received the name of *vasa vorticosa*. They lie external to the ciliary arteries, but the ultimate ramifications pervade the inner surface in the same manner as the arteries; and if the venous system of the eye be minutely injected, the same beautiful uniform villous vascularity is displayed as in the arterial injections.

The annexed figure is a copy of Zinn's representation of the vasa vorticosa.

Fig. 104.

The numerous nerves which pierce the sclerotic and run forward between that membrane and the choroid, called ciliary nerves, being distributed almost exclusively to the iris, are to be noticed when that organ is described; small branches of them are, however, probably distributed to the choroid and its appendages, and possibly even to the retina and hyaloid membrane.

The inner villous surface of the choroid, which in man is stained with the black pigment, in several other animals presents a brilliant colour and metallic lustre. This is called the *tapetum*. It is not a superadded material nor dependent on any imposed or separable colouring matter, but is merely a different condition of the surface of the choroid or tunica Ruyschiana, by means of which rays of light of a certain colour only are reflected. It exists in the form of a large irregular patch, occupying the bottom of the eye toward the outside of the entrance of the optic nerve. It is of a beautiful blue, green, or yellow colour, with splendid metallic lustre, and sometimes white as silver. It is not obscured by the black pigment which covers the rest of the surface and even encroaches a little on its margin, and consequently it acts most perfectly as a concave reflector, causing the rays of light previously concentrated on the bottom of the eye by the lens to be returned, and to produce that remarkable luminous appearance observed in the eyes of cats and other animals when seen in obscure situations. This provision is absent in man, the quadrumanous animals, bats, the insectivorous order, perhaps all the *rodentia*, the sloths and many other of the class *mammalia;* while it is present in the majority if not all of the ruminants, as well as in the horse, the cetacea, and most of the carnivorous tribe. It does not appear to exist in birds or reptiles, and is absent in the osseous, although present in the cartilaginous fishes. I must here, however, state that I am obliged to speak loosely respecting this matter, as the subject has not yet been thoroughly investigated. The use of this tapetum has not been ascertained, or the reason why it exists in some and is absent in other animals explained. It is obvious that where it is present the rays of light are transmitted through the retina, and again when reflected by the tapetum are returned through the same retina, thus twice pervading that structure.

On the outside and anterior part of the choroid, where the margin of that membrane corresponds to the place of union between the sclerotic and cornea, a peculiar and distinct formation exists apparently for the purpose of securing a firm union between the two membranes. It is commonly called the ciliary ligament, also *orbiculus ciliaris*, *circulus ciliaris*, by Lieutaud *plexus ciliaris*, by Zinn *annulus cellulosus*, and by Sömmerring gangliform ring. It is a gray circle of soft cellular membrane about two lines broad, applied like a band round the margin of the aperture into which the iris is fitted. It adheres closely to the choroid, and almost equally closely to the sclerotic, especially in the groove where the cornea joins that membrane. It contains few red vessels, and is not stained by the black pigment; consequently it is of a whitish colour. The ciliary nerves penetrate it and subdivide in its structure. Hence it has been considered by Sömmerring as a ganglion, and had been previously described by Lieutaud as a nervous plexus. The ciliary nerves, however, merely pass through, and may easily be traced on to the iris. It is evidently a mere band of cellular membrane serving to bind the choroid and sclerotic together at this point, and is obviously a provision essentially necessary for the perfection of the anatomical mechanism of the eye, as without it the aqueous humour must, from pressure on the eyeball, be forced back between the two membranes. In man it is broader in proportion than in the larger quadrupeds, and in birds it is particularly large and dense, adhering more closely to the circle of osseous plates than to the choroid, and consequently presents a very remarkable appearance when the latter membrane is pulled off with the ciliary processes and iris, an appearance to which the attention of anatomists was first drawn by Mr. Crampton. From its position and appearance the ciliary ligament has often been suspected to be a muscular organ, destined by its contraction to alter the form of the cornea, and thus adapt the eye to distance. There is not, however, sufficient evidence to sustain such an opinion. The plate introduced to represent the ciliary nerves, as well as that which represents the iris, exhibit this part of the organization of the eyeball in connexion with the choroid.

On the inside of the choroid, surrounding the aperture into which the iris is fitted, and corresponding in position within to the ciliary ligament without, exists another peculiar provision destined to establish a connexion between this part and the hyaloid membrane of the vitreous humour, as the ciliary ligament establishes a similar connexion between the sclerotic and choroid. This is the *corpus ciliare* or ciliary processes, called sometimes incorrectly ciliary ligament, and by Sömmerring *corona ciliaris*. It is composed of a number of distinct folds or productions of the choroid, having their anterior extremities extended to the back of the iris, while the posterior gradually diminish until lost in the membrane from which they originate. Each fold or ciliary process is a production or continuation of the choroid, and cannot be separated from it unless clipped off by the scissors. They appear to be composed altogether of a remarkable interlacement of arteries and veins derived from those of the choroid, and exhibit no appearance whatsoever of muscular organization, although considered by Porterfield and others as endowed with that function. These are sixty or seventy in number, fifty-seven being enumerated by Sömmerring, and seventy by Zinn. They are about two lines in length, but are not equally so, every alternate one being shorter than the next to it. The free internal margin of each ciliary process is buried in the hyaloid membrane of the vitreous humour at its anterior part, round the circumference of the crystalline lens, and a corresponding production of the hyaloid membrane projects into the space between these processes so as to establish a most perfect bond of union between the two structures. The ciliary processes appear to be attached to the circumference of the lens, and are often described as having such connexion. This, however, is not the case. The anterior extremities do not touch the circumference of the lens; they project into the posterior chamber of the aqueous humour up to the back of the iris, and consequently constitute the circumferential boundary of that cavity. When the eye becomes flaccid from evaporation after death, the ciliary processes fall down to the margin of the lens and appear to adhere; but if the cornea and iris be removed from the eye of a subject recently dead, a circle of hyaloid membrane may distinctly be seen occupying the space between the ciliary processes and lens, through which the observer can see to the bottom of the eye. This space is represented and pointed out in Sömmerring's plates. The annexed figure from Zinn's work represents the *corpus ciliare* or circle of ciliary processes on a large scale.

Fig. 105.

The choroid, in common with several other parts of the eye and its appendages, is stained by a black colouring matter secreted in and upon different textures. In man it is of a dark-brown colour, but in other animals is generally black, and so loosely connected with the structure in which it is deposited, that in dissecting the eyes of our common graminivorous animals under water it becomes diffused, and colours the fluid as the ink of the cuttle-fish obscures the water into which it is shed. It is not confined to any one particular structure, but is deposited in every situation where it is necessary for the purpose for which it is destined. It is found in considerable quantity on the inner surface of the choroid, where it appears as if laid on in the form of a paint, and is frequently so described; but it is much more probable that it is deposited in the interstices of the exquisitely fine cellular membrane which connects the choroid with the delicate covering of the retina. In this situation it often, especially in infants, presents the appearance of a perfectly distinct black membrane, which may be peeled off in flakes or allowed to remain on the retina in patches, as noticed by Haller. It also pervades the structure of the choroid, at least in the adult, and even stains the inner surface of the sclerotic and the cellular layer which connects these two membranes. It is deposited in larger quantity in the ciliary processes and upon the back and in the texture of the iris. In many animals it is found forming a black ring round the margin of the cornea and in the edge of the third eye-lid, as well as in the pecten or marsupium nigrum in birds. It is even sometimes found scattered, as if accidentally, as in the texture of the sclerotic in hogs, and within the sheaths of the optic nerve in oxen; it is obvious that it does not require any special form of organization for its production, but is merely secreted into the cellular membrane, where necessary, as the colouring matter is secreted with cuticle on the skin.

It is darker in the earlier periods of life, and in the infant is more confined to the inner surface of the choroid and to the posterior surface of the iris, than pervading the texture of either of these membranes. In old age it evidently fades, and even appears as if absorbed in patches. It is sometimes altogether absent, as in those animals called albinos, where all the parts usually coloured are unstained. Its use is obviously to prevent the rays of light from being reflected from surfaces where they should be absorbed, a provision as essential to the perfection of the animal eye as to the artificial optical instrument. It is also applied to give complete opacity to prevent the transmission of light, and hence is deposited in large quantity in and on the iris, as well as in the ciliary processes which correspond in situation to the exposed part of the sclerotic, through which the light might otherwise pass to the bottom of the eye, and disturb correct vision. The layer of black pigment on the inner surface of the choroid has undergone a careful microscopic investigation, especially by Mr. T. W. Jones, the results of which are stated in a short account of the anatomy of the eye prefixed to the second edition of Mr. M'Kenzie's work on Diseases of the Eye. He says that it possesses organization and constitutes a real membrane, and when examined with the miscroscope "is seen to consist of very minute flat bodies of a hexagonal form, joined together at their edges. These bodies, which are about $\frac{1}{1000}$th of an inch in diameter, consist of a central transparent nucleus, surrounded by an envelope of colouring matter, which is most accumulated at their edges. The centre, indeed, of each hexagonal plate is a transparent point, and appears somewhat elevated, the elevations on the inner surface corresponding to depressions to be described in the membrane of Jacob. That part of the membrane of the pigment situated on the *pars non plicata* of the ciliary body around the ciliary processes, and on the posterior surface of the iris, is composed of irregularly rounded bodies, analogous to the hexagonal plates. In albinos the same membrane exists, but contains no pigment. The bodies composing it are but little developed, being nothing but the central nuclei separated from each other by large intervals, and not hexagonal, but circular, or even globular." The annexed figure represents this membrane of the pigment as described.

Fig. 106.

Sometimes the black pigment is totally or partially deficient, not only in inferior animals, but also in man, constituting the variety denominated albino, of which the white rabbit affords a good example. The circumstance has attracted considerable attention, and has been the subject of particular observation by Mr. Hunter, Blumenbach, and many others. Dr. Sachs has given a curiously elaborate account of himself and his sister, who are both albinos. The eye in such cases appears of a beautifully brilliant red, in consequence of the blood being seen circulating through the transparent textures unobscured by the pigment, but the individual suffers from the defect in consequence of the light being transmitted through all the exposed part of the organ; proving that the covering of black pigment is deposited on the back of the iris and in the ciliary processes to obviate this injurious consequence. In human albinos the eyes have often a tremulous oscillating motion, and the individual is unable to bear strong light.

The colour of the black pigment does not appear to depend on the presence of carbon or other dark material, and the minute quantity of oxide of iron contained in it is obviously insufficient for the production of so deep a tint. It is insoluble in water, either hot or cold, or in dilute sulphuric acid; but strong nitric or sulphuric acids decompose it, and are decomposed by it. Caustic potash is said to dissolve it, though with difficulty, but as ammonia is evolved during the process, and the nature of the pigment necessarily altered, it cannot be considered a case of simple solution. By destructive distillation it affords an empyreumatic oil, inflammable gases, and carbonate of ammonia. It is, therefore, obviously an animal principle *sui generis*, its elements being oxygen, hydrogen, carbon, and nitrogen. One hundred parts in a dry state leave, when incinerated, 4.46 of a calx, consisting of chloride of calcium, carbonate of lime, phosphate of lime, and peroxide of iron. For these particulars I am indebted to Dr. Apjohn.

Of the iris.—This is the circular partition or screen interposed between the cornea and crystalline lens, filling up the aperture in the anterior part of the sphere of the choroid, and consequently exactly fitted to the place of union of the ciliary ligament and choroid with the sclerotic round the cornea. It has an aperture in the centre called the pupil, through which the central portion of the pencil of rays incident upon the cornea is transmitted, while the extreme rays are intercepted; and appears to answer the same purpose as the diaphragm or eye-stop in the telescope, but with this advantage, that it is enlarged or diminished according to the quantity of light, the distance of objects, or even the will of the individual. The iris is frequently called *uvea*, a term also applied to the spherical choroid; or the anterior part is called iris, and the posterior *uvea*. To avoid confusion the term should be discarded altogether, and that of iris alone retained to designate this important part of the organ.

The surface of the iris is flat or plane, although it appears convex when seen through the cornea, or when in dissecting the eye it falls on the convex surface of the crystalline lens. It is remarkable that the aperture or pupil is not exactly in the centre of the disc, but a little towards the inside. The anterior surface presents a very peculiar and remarkable appearance, evidently not depending on or arising from vascular ramifications or nervous distribution. This appearance is described with precision and accuracy both by Zinn and Haller, although unnoticed or only briefly alluded to in many of the slovenly compilations which have appeared since they wrote. It is, however, described by Meckel, who saw what he describes, and read what he quotes. Haller's words are as follow:—"In anteriori lamina iridis eminet natura flocculenta, varie in flammulas quasdam introrsum euntes disposita, quibus aliqua est similitudo rotundorum arcuum, ad centrum pupillæ convexorum. Quivis flocculus est serpentinarum striarum introrsum convergentium, et intermistarum macularum fuscarum congeries: conjuncti vero flocculenti fasciculi arcum quasi serratum, eminentem, ad aliquam a pupilla distantiam efficiunt, qui convexus eminet, quasi antrorsum, supra reliquum planum pupillæ elatus. Fabricæ pulchritudinem nulla icon expressit." (Elementa Physiologiæ, tom. v. p. 369.) Zinn's description is equally accurate and precise. In the 12th volume of the Medico-Chirurgical Transactions I have noticed this structure in the following words: "If the iris be attentively examined in the living subject, or under water after the cornea has been removed, a number of irregularly shaped masses may be seen projecting from the middle space between the circumference and the pupil. From the convexities of these masses, a number of elevated lines, equally irregular in size and number, proceed toward the pupil, and attach themselves at the distance of about a twentieth part of an inch from its margin, and from this point of attachment a number of much smaller *striæ* converge to the edge of the central opening. It is quite impossible for words to give an adequate idea of this appearance. If I ventured to compare it with any other with which I am acquainted, I should say that it resembled strongly the *carneæ columnæ* and *cordæ tendineæ* of the heart, both in form, arrangement, and irregularity of conformation. This structure is more strongly marked in the hazel than in the blue iris; and in many cases the fleshy projections coalesce, by which they appear less distinct; but the loops or cords which arise from them always exist, and often project so much from the plane of the iris as to admit of having a small probe or bristle passed beneath them. That this appearance of the iris does not depend on any particular disposition of its vessels, is, I think, obvious, from the thickness of these cords or striæ being so much greater than the vessels of the iris, from their being arranged in a manner altogether different from vascular inosculation, and finally, because the iris when successfully injected and expanded does not present that interlacement of branches surrounding the pupil which has so often been described from observation of its uninjected state." The anterior surface of the iris is of a light blue colour in persons of fair skin and light hair, of a blue grey in others, sometimes of a mixture of tints called a hazel iris; and in negroes and others, where the skin is stained by the usual colouring matter, the iris is of a deep brown, and is commonly described as a black eye, being pervaded by the black pigment throughout its texture, as well as coated with it on its posterior surface. In animals altogether destitute of the usual colouring matter on the surface, called albinos, the iris has no other colour than that of the blood which circulates in its vessels. The annexed engraving is a copy of a most accurately executed representation of the face of the iris, shewing the *carneæ columnæ* and *cordæ tendineæ* much magnified.

Fig. 107.

The posterior surface of the iris is as remarkable as the anterior, but altogether different in its nature. I have given the following description of it in the paper to which I allude in the Medico-Chirurgical Transactions. "In order to obtain a correct view of the posterior surface of the iris, a transverse vertical section of the eye should be made at the distance of about an eighth of an inch behind the cornea, and the lens, and portion of vitreous humour attached to it, removed: the iris now appears covered by a thick layer of black pigment, marked by a number of converging lines; these lines on close inspection are found to be channels or hollows, as if resulting from a puckering or folding of the membrane. The pigment is secured from being detached, and diffused in the aqueous humour, by a fine transparent membrane, which is closely attached to the margin of the pupil, from whence it is continued over the back of the iris, and anterior extremities of the ciliary processes, to the circumference of the lens, over the front of the capsule of which it is also probably extended, if it be, as may be supposed, the membrane of the aqueous humour. This delicate membrane may be turned down by the point of a needle; as it is connected to the iris by loose cellular structure only, in the interstices of which the black pigment is deposited. It is at first black, but by gentle agitation in water the colouring matter is removed, and the membrane remains transparent. When the membrane and pigment have been removed, the back of the iris appears free from colour, and marked by a number of delicate elevated folds, converging from the ciliary processes to within a short distance of the pupil; they are permanent and essential, and seem of the same nature as the ciliary processes. The pupil is immediately surrounded by a well-defined distinct circle, about the twentieth part of an inch in diameter, of a denser structure than the rest of the iris: this is what has been long described as the orbicular muscle, or constrictor of the pupil. If the iris be treated, as I before mentioned, by maceration and extension, this appearance still preserves its integrity, and retains its original character." Haller and Zinn describe these converging radiating folds, but the former denies the existence of the circular arrangement round the margin of the pupil, of the presence of which I do not entertain the slightest doubt, but which is sometimes so slightly marked, that I am not surprized to find its existence doubted if the part has not been examined in a variety of examples. This circle, or orbicular muscle, is sometimes equally visible on the anterior surface, but is generally obscured by the converging cords above described. The folds or elevations on the back of the iris, converging toward the pupil, have been considered the muscular agents for dilating the pupil, but if examined in the eyes of the larger quadrupeds, it is obvious that they are destined to give this part of the organ the requisite degree of opacity, and to afford an appropriate place for the deposit of the black pigment, in this respect closely resembling the ciliary processes, and the pecten in the eye of birds, so much so, that I think they might be appropriately called the ciliary processes of the iris.

The iris is most plentifully supplied with bloodvessels and nerves. The two long ciliary arteries which penetrate the sclerotic posteriorly advance horizontally, about the middle of the eyeball, between that membrane and the choriod, to the iris, where each divides into two branches, which proceed round the circumference and inosculate with each other, thus forming an arterial circle, from which numberless branches converge to the pupil. Much importance has been attached by anatomists to the manner in which these radiating vessels are disposed, in consequence of the representation of Ruysch, who exhibited them as forming a series of inosculations at a short distance from the pupil, since called the lesser circle of the iris. I do not deny that the vessels of the iris inosculate as in other parts of the body, but I do not believe that they present this very remarkable appearance, and I suspect that Ruysch exaggerated what he had seen, or described from an iris in which the injection had been extravasated and entangled in the tendinous cords, which I have described as extending from the fleshy bodies to the margin of the pupil. The question is fortunately of no importance. It is sufficient to know that the organ is amply supplied with arterial blood.

The iris is plentifully furnished with nerves: they are derived from the third and fifth pairs, with communications from the sympathetic, and consequently having connexions with the sixth. They penetrate the sclerotic posteriorly, and advance towards the iris between the sclerotic and choroid, about fifteen or twenty in number: arrived at the ciliary ligament, they divide at acute angles, and may be traced through this structure until they are finally lost in the iris, as seen in the annexed figure.

Fig. 108.

From the foregoing description, it appears that the iris is eminently distinguished for the perfection of its organization; and endowed as it is with the power of enlarging or diminishing the aperture in its centre, there can be little doubt that it is a beautiful application of muscular structure and function to the perfection of this most elaborately constructed organ. The authority of Haller operates to the present day to throw a doubt upon the muscularity of the iris; but Haller, strange as it may appear, was not correctly informed in many particulars respecting this structure. He denies the existence of the orbicular muscle; he doubts the irritability of the organ, and he even considers it destitute of sensibility, and assumes that the pupil is dilated after death. Any anatomist may, however, demonstrate the orbicular muscle; any surgeon breaking up a cataract, may elicit the irritability, and see the pupil contract, as the fragments of the lens or the side of the needle touch its margin. The pain produced by pinching or cutting the iris in operations for cataract and artificial pupil is no longer matter of doubt, and the assumption that the pupil dilates when death takes place is disproved by daily observation. The pupil contracts to exclude light when too abundant, and dilates to admit it when deficient in quantity; the heart contracts to expel the blood, and dilates to receive it; the diaphragm contracts to fill the lungs, and relaxes to assist in emptying them. I can see no material difference between the phenomena exhibited by the actions of the iris, and those displayed by the muscular system generally. I believe that when the pupil contracts to intercept light, that contraction is accomplished by the orbicular muscle, which operates as any other sphincter; and that when the pupil is dilated to admit light, the dilatation is accomplished by the contraction of the structure, which I have said resembles the *carneæ columnæ* and *cordæ tendineæ* in the heart.

During fœtal life the aperture in the centre is closed by a membrane, hence technically called *membrana pupillaris*. The discovery of this membrane was first announced by Wachendorf, but was subsequently claimed by Albinus, and still later by Dr. Hunter for a person of the name of Sandys. It is usually described as existing from the earliest period of fœtal life to the seventh month, when it disappears. In the paper communicated by me to the Medico-Chirurgical Society, I have endeavoured to shew that this description is not correct, but that this membrane continues to the ninth month. The account there given is as follows: "If the eye be examined about the fifth month, the *membrana pupillaris* is found in great perfection, extended across a very large pupil; the vessels presenting that singular looped arrangement, (with a small irregular transparent portion in the centre,) well depicted by Wrisberg, Blumenbach, Albinus, Sömmerring, Cloquet, and others. About the sixth month it is equally perfect; the pupil is however smaller, the iris being more developed. Subsequently to this date the vessels begin to diminish in size and number, and a larger transparent portion occupies the centre. At the approach of the eighth month, a few vessels cross the pupil, or ramify through the membrane at a short distance from the margin, without at all presenting the looped appearance of the previous period, but admitting a free communication between the vessels of the opposite side of the iris. The pupil is now still more diminished in size, and the iris has assumed its characteristic coloured appearance; notwithstanding the absence of vessels, the membrane still preserves its integrity, though perfectly transparent. The period now approaches when it is to disappear; this occurrence takes place, according to my observations, a short time previous or subsequent to birth. In every instance where I have made the examination, I have found the *membrana pupillaris* existing in a greater or less degree of perfection in the new-born infant; frequently perfect without the smallest breach, sometimes presenting ragged apertures in several places, and, in other instances, nothing existing but a remnant hanging across the pupil like a cobweb. I have even succeeded in injecting a single vessel in the *membrana pupillaris* of the ninth month. Where I have examined it in subjects who have lived for a week or fortnight after birth, as proved by the umbilicus being healed, I have uniformly found a few shreds still remaining. It is obvious from the preceding observations, that the membrane does not disappear by a rent taking place in the centre, and retraction of the vessels to the iris, as supposed by Blumenbach, but that it at first loses its vascularity, then becomes exceedingly thin and delicate, and is finally absorbed. The demonstration of what I have advanced respecting this delicate part is attended with much difficulty, and requires great patience. The display of the *membrana pupillaris* of the seventh month is comparatively easy; but at the ninth month, or subsequently, it can only be accomplished by particular management. The eye, together with the appendages, should be carefully removed from the head; it should then be freed from all extraneous parts by the scissors, under water, and a careful section made at a short distance behind the cornea; taking care to include the vitreous humour in the division, in order that the lens may remain in its proper situation. The portion to be examined should now be removed into a shallow vessel of water, to the bottom of which a piece of wax has been secured. The operator should be provided with fine dissecting forceps and needles in light handles; with one needle he should pin the sclerotic down to the wax, and with the other raise the lens, and portion of vitreous humour attached to it, from the ciliary processes, and separate the ciliary ligament from the sclerotic. He may now expect to discover the membrana pupillaris, but its perfect transparency renders it completely invisible; he may, however, ascertain the existence, by taking a minute particle of the retina and dropping it into the centre of the pupil, where it remains suspended if this membrane exist. The preparation should now be taken up in a watch-glass, and placed in a weak mixture of spirit and water, and a little powdered alum raised on the point of a needle dropped upon it. After a day or two it may be examined; and if the membrane be present, it has become sufficiently opaque to be visible, and may now be suspended in a bottle of very dilute spirit." In the annexed engravings, *A* represents the membrana pupillaris of about the fifth month, presenting the peculiar looped arrangement of the vessels. *B* represents the membrane about the eighth month, not presenting the looped arrangement. *C* represents the membrane with a red vessel in its structure at the ninth month. *D* shews a few shreds of the membrane remaining a week or more after birth.

Fig. 109.

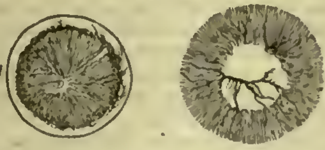
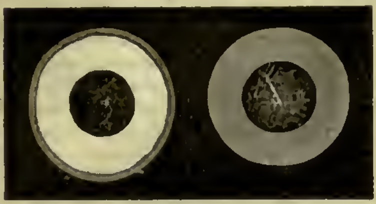


Fig. 110.



The pupil is closed by this membrane during fœtal life in order to preserve its dimensions, and secure a correct growth of the iris while the organ is in darkness. If the membrane disappeared about the seventh month, the pupil should become dilated and remain so during the two succeeding months, unless the muscular power be undeveloped, which is not probable, as it may be seen to operate shortly after birth.

Of the retina. — This is the third spherically disposed membrane entering into the structure of the eye, and may be considered the most essential of all, being that which is endowed with the peculiar description of sensibility which renders the individual conscious of the presence of light. It is as exactly fitted to the inside of the choroid as that membrane is to the sclerotic, but does not extend to the anterior margin of the choroid as that structure extends to the anterior margin of the sclerotic. The retina is destined to be penetrated by the rays of light, which, reflected from surrounding objects, are collected to form images on the bottom of the eye, consequently its extension as far forward as the choroid or sclerotic is unnecessary, and nature makes nothing superfluous. It is discontinued at the posterior extremities of the ciliary processes of the choroid, at the distance of about an eighth of an inch from the anterior margin of that membrane.

The retina is evidently the optic nerve expanded in the bottom of the eye in the form of a segment of a sphere. That nerve differs, in some respects, in construction from the other nerves of the body. In its course from the hole in the bone through which it enters the orbit until it enters the eye, it is of a cylindrical form, and proceeds in a waving line to its destination. The medullary fibres are involved in a tough strong material, not separable into cords or bundles as in other nerves, but constituting a cylinder of collected tubes, from the divided extremity of which the medullary matter may be squeezed in as soft and pulpy a form as it exists in the brain. It is not easy to determine by anatomical investigation, whether the medullary material is disposed in tubes or in a cellular structure, but as that material is universally disposed in a fibrous form, both in brain and nerve, it is more than probable that it is so arranged here. These cerebral fibres involved thus in a cylindrical bundle of tubes, technically called *neurilema* by modern anatomists, is covered externally by a fine transparent membrane, adhering to it so closely that it requires some care to separate it; and this is again covered by a tube of strong fibrous membrane, the sheath of the optic nerve continued from the *dura mater* to the sclerotic, to which membrane it adheres so firmly, that it cannot be separated except by the knife. Formerly the sclerotic was considered to be a continuation of the dura mater, and much importance, in a pathological point of view, was attached to the circumstance, but although both structures are of the fibrous class, the sclerotic is very different in texture, and the adhesion between them is not more remarkable than any other of the numerous adhesions which occur between fibrous membranes.

Where the optic nerve enters the eye, it is contracted in diameter, as if a string had been tied round it, and then passes through a hole in the sclerotic, to which it adheres. When seen from the inside, after removing the retina and choroid, it appears in the form of a circular spot, perforated with small holes, from which the medullary material may be expressed. This is the *lamina cribrosa* of Albinus, considered to be a part of the sclerotic, but which is really nothing more than the terminating extremity of the nerve.

The optic nerve does not enter the eye in the centre of the globe, but about an eighth of an inch to the side of it, assuming the centre to correspond to the extremity of a line passing from the middle of the cornea, through the centre of the eyeball to its back. The nerve is generally described and represented as projecting in the form of a round prominence, as it enters the eye; but this is not, I believe, the state of the part during life, but is produced by the contraction of the *neurilema* pressing out the medullary matter in this form. As the nerve enters the eye, it immediately expands into and constitutes the retina, the medullary fibres separating and spreading out on the spherical vitreous humour. The expansion of the nerve in separate fibres cannot be distinctly seen in the human eye, but may be recognized with some care in the eye of the ox, and without difficulty in that of the hare and rabbit, where it divides into two bundles, as has been well described by Zinn in the Göttingen Commentaries.

The retina does not consist of medullary or cerebral fibrous matter alone. As the brain has its *pia mater* and arachnoid membrane, and the nerve its *neurilema*, this nervous structure has its appropriate provision for its support and the distribution of its vessels. This is the vascular layer, first accurately described by Albinus. It is a delicate transparent membrane, of such strength, that when detached, it may be moved about in water, and freely examined without breaking. It adheres so firmly to the hyaloid membrane of the vitreous humour in the fresh eye, that it cannot be separated entire, and the medullary fibres adhere so closely to its external surface, that they cannot be detached at all in the form of a distinct membrane. To demonstrate the vascular layer, the sclerotic should be carefully removed, leaving a portion of the optic nerve freed from its sheath; the choroid should then also be removed under water, by tearing it asunder with a pair of forceps in each hand. The vitreous humour, covered by the retina only, should then be allowed to remain about two days in the water, at the end of which time the medullary layer softens and separates into flakes, which may be scraped from the vascular layer beneath by passing the edge of a knife gently over it, after which the vascular layer may be detached by careful management, and suspended in a bottle from the optic nerve.

The retina is supplied with blood from the ophthalmic artery, a small branch of which penetrates the optic nerve at a short distance from the back of the eye, and proceeds through its centre until it arrives at the retina. The hole in the centre of the nerve, through which it passes, was formerly called the *porus opticus.* Arrived at the retina, the vessel, under the name of the central artery of the retina, divides into two branches, which surround the *foramen* of Sömmerring, and sending ramifications in every direction, terminate by encircling the anterior margin. Besides the branches which carry red blood, the central artery probably furnishes a transparent branch to the centre of the vitreous humour, as such a branch running on to the back of the crystalline lens, may be injected in the eye of the fœtus, and a transparent production from the central artery into the vitreous humour may be observed in the eyes of oxen and other large animals. The arteries of the retina supply the vitreous humour with blood, as no other source exists, except from the ciliary processes of the choroid, which, being buried in the hyaloid membrane, most probably furnish vessels to the anterior part, and in dissecting the vascular layer above described, in which the vessels ramify, it is found to adhere to the hyaloid membrane by points along the course of the vessels, which points, it is reasonable to believe, are small branches.

As the medullary or cerebral fibres of the retina are sustained on the inside by the vascular layer above described, they are also protected on the outside by another membrane, which separates them from the inner surface of the choroid. This is the membrane which I described in a communication in the Philosophical Transactions in 1819, and as I cannot give a more intelligible account of it than that there contained, I venture to introduce it here.

"Anatomists describe the retina as consisting of two portions, the medullary expansion of the nerve, and a membranous or vascular layer. The former externally, next to the choroid coat, and the latter internally, next to the vitreous humour. All, however, except Albinus and some of his disciples, agree, that the nervous layer cannot be separated so as to present the appearance of a distinct membrane, though it may be scraped off, leaving the vascular layer perfect. That the medullary expansion of the optic nerve is supported by a vascular layer, does not, I think, admit of doubt; but it does not appear that Albinus was right in supposing that the nervous layer can be separated in form of a distinct membrane, though shreds of a considerable size may be detached, especially if hardened by acid or spirit.

"Exclusive of these two layers, I find that the retina is covered on its external surface by a delicate transparent membrane, united to it by cellular substance and vessels. This structure, not hitherto noticed by anatomists, I first observed in the spring of the last year, and have since so frequently demonstrated, as to leave no doubt on my mind of its existence as a distinct and perfect membrane, apparently of the same nature as that which lines serous cavities. I cannot describe it better, than by detailing the method to be adopted for examining and displaying it. Having procured a human eye, within forty-eight hours after death, a thread should be passed through the layers of the cornea, by which the eye may be secured under water, by attaching it to a piece of wax, previously fastened to the bottom of the vessel, the posterior half of the sclerotic having been first removed. With a pair of dissecting forceps in each hand, the choroid coat should be gently torn open and turned down. If the exposed surface be now carefully examined, an experienced eye may perceive, that this is not the appearance usually presented by the retina; instead of the blue-white reticulated surface of that membrane, a uniform villous structure, more or less tinged by the black pigment, presents itself. If the extremity of the ivory handle of a dissecting knife be pushed against this surface, a breach is made in it, and a membrane of great delicacy may be separated and turned down in folds over the choroid coat, presenting the most beautiful specimen of a delicate tissue which the human body affords. If a small opening be made in the membrane, and the blunt end of a probe introduced beneath, it may be separated throughout, without being turned down, remaining loose over the retina; in which state if a small particle of paper or globule of air be introduced under it, it is raised so as to be seen against the light, and is thus displayed to great advantage; or it is sometimes so strong as to support small globules of quicksilver dropped between it and the retina, which renders its membranous nature still more evident. If a few drops of acid be added to the water after the membrane has been separated, it becomes opaque and much firmer, and may thus be preserved for several days, even without being immersed in spirit.

"That it is not the nervous layer which I detach, is proved by the most superficial examination; first, because it is impossible to separate that part of the retina, so as to present the appearance I mention; and, secondly, because I leave the retina uninjured, and presenting the appearance described by anatomists, especially the yellow spot of Söemmerring, which is never seen to advantage until this membrane be removed: and hence it is that conformation, as well as the fibrous structure of the retina in some animals, become better marked from remaining some time in water, by which the membrane I speak of is detached.

"The extent and connections of this membrane are sufficiently explained by saying, that it covers the retina from the optic nerve to the ciliary processes. To enter into farther investigation on this subject would lead to a discussion respecting the structure of the optic nerve, and the termination of the retina anteriorly, to which it is my intention to return at a future period.

"The appearance of this part I find to vary in the different classes of animals and in man, according to age and other circumstances. In the fœtus of nine months it is exceedingly delicate, and with difficulty displayed. In youth it is transparent, and scarcely tinged by the black pigment. In the adult it is firmer, and more deeply stained by the pigment, which sometimes adheres to it so closely as to colour it almost as deeply as the choroid coat itself; and to those who have seen it in this state, it must appear extraordinary that it should not have been before observed. In one subject, aged fifty, it possessed so great a degree of strength as to allow me to pass a probe under it, and thus convey the vitreous humour covered by it and the retina from one side of the basin to the other; and in a younger subject I have seen it partially separated from the retina by an effused fluid. In the sheep, ox, horse, or any other individual of the class mammalia which I have had an opportunity of examining, it presents the same character as in man; but is not so much tinged by the black pigment, adheres more firmly to the retina, is more uniform in its structure, and presents a more elegant appearance when turned down over the black choroid coat. In the bird it presents a rich yellow brown tint, and when raised, the blue retina presents itself beneath; in animals of this class, however, it is difficult to separate it to any extent, though I can detach it in small portions. In fishes, the structure of this membrane is peculiar and curious. It has been already described as the medullary layer of the retina by Haller and Cuvier, but I think incorrectly, as it does not present any of the characters of nervous structure, and the retina is found perfect beneath it. If the sclerotic coat be removed behind, with the choroid coat and gland so called, the black pigment is found resting upon, and attached to, a soft friable thick fleecy structure, which can only be detached in small portions, as it breaks when turned down in large quantity. Or if the cornea and iris be removed anteriorly, and the vitreous humour and lens withdrawn, the retina may be pulled from the membrane, which remains attached to the choroid coat, its inner surface not tinged by the black pigment, but presenting a clear white, not unaptly compared by Haller to snow.

"Besides being connected to the retina, I find that the membrane is also attached to the choroid coat, apparently by fine cellular substance and vessels; but its connection with the retina being stronger, it generally remains attached to that membrane, though small portions are sometimes pulled off with the choroid coat. From this fact I think it follows, that the accounts hitherto given of the anatomy of these parts are incorrect. The best anatomists describe the external surface of the retina as being merely in contact with the choroid coat, as the internal with the vitreous humour, but both totally unconnected by cellular membrane, or vessels, and even having a fluid secreted between them: some indeed speak loosely and generally of vessels passing from the choroid to the retina, but obviously not from actual observation, as I believe no one has ever seen vessels passing from the one membrane to the other. My observations lead me to conclude, that wherever the different parts of the eye are in contact, they are connected to each other by cellular substance, and, consequently, by vessels; for I consider the failure of injections no proof of the want of vascularity in transparent and delicate parts, though some anatomists lay it down as a criterion. Undoubtedly the connection between these parts is exceedingly delicate, and, hence, is destroyed by the common method of examining this organ; but I think it is proved in the following way. I have before me the eye of a sheep killed this day, the cornea secured to a piece of wax fastened under water, and the posterior half of the sclerotic coat carefully removed. I thrust the point of the blade of a pair of sharp scissors through the choroid coat into the vitreous humour, to the depth of about an eighth of an inch, and divide all, so as to insulate a square portion of each membrane, leaving the edges free, and consequently no connection except by surface; yet the choroid does not recede from the membrane I describe, the membrane from the retina, nor the retina from the vitreous humour. I take the end of the portion of choroid in the forceps, turn it half down, and pass a pin through the edge, the weight of which is insufficient to pull it from its connection. I separate the membrane in like manner, but the retina I can scarcely detach from the vitreous humour, so strong is the connection. The same fact may be ascertained by making a transverse vertical section of the eye, removing the vitreous humour from the posterior segment, and taking the retina in the forceps, pulling it gently from the choroid, when it will appear beyond a doubt that there is a connection between them.

"Let us contrast this account of the matter with the common one. The retina, a membrane of such delicacy, is described as being extended between the vitreous humour and choroid, from the optic nerve to the ciliary processes, being merely laid between them, without any connection, and the medullary fibres in contact with a coloured mucus retained in its situation by its consistence alone. This account is totally at variance with the general laws of the animal economy; in no instance have we parts, so dissimilar in nature, in actual contact: wherever contact without connection exists, each surface is covered by a membrane, from which a fluid is secreted; and wherever parts are united, it is by the medium of cellular membrane, of which serous membrane may be considered as a modification. If the retina be merely in contact with the vitreous humour and choroid, we argue from analogy, that a cavity lined by serous membrane exists both on its internal and external surface: but this is not the fact. In the eye a distinction of parts was necessary, but to accomplish this a serous membrane was not required; it is only demanded where great precision in the motion of parts was indispensable, as in the head, thorax, and abdomen; a single membrane, with the interposition of cellular substance, answers the purpose here. By this explanation we surmount another difficulty, the unphilosophical idea of the colouring matter being laid on the choroid, and retained in its situation by its viscidity, is discarded; as it follows, if this account be correct, that it is secreted into the interstices of fine cellular membrane here, as it is upon the ciliary processes, back of the iris, and pecten, under the conjunctiva, round the cornea, and in the edge of the membrana nictitans and sheath of the optic nerve in many animals. Dissections are recorded where fluids have been found collected between the choroid and retina, by which the structure of the latter membrane was destroyed; the explanation here given is as sufficient to account for the existence of this fluid, as that which attributes it to the increased secretion of a serous membrane."

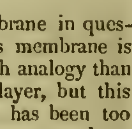
The membrane is represented as it exists in the eye of the sheep, in the annexed figure, from my paper in the Medico-Chirurgical Transactions.

Fig. 111.

Mr. Dalrymple, in his valuable work on the anatomy of the eye, takes a different view of the arrangement of this part of the retina: he says:—" From observations made on the human eye, in connection with other experiments on the eyes of animal, I am induced to consider it as *a double reflected serous membrane.* I was first led to take up this opinion in the year 1827, by the accidental observation of a very delicate membrane, which lined and was adherent to the entire choroid. Having minutely injected the eye of a sheep, I made a vertical transverse section through the sclerotic, choroid, and retina, which last membrane, with Jacob's tunic, properly so called, and the vitreous body I removed. I then placed the remaining portion of the eye in dilute spirits of wine, intending to preserve it for the exhibition of the tapetum, which in this instance was remarkably beautiful. A few minutes after its immersion the tapetum lost to a considerable extent its brilliant hue, and I removed it from the glass to wash from its surface some deposit, which I thought might have obscured its polish. In doing this, however, I detached a delicate membrane, minutely filled with injection, and this membrane it was which on being placed in the spirit, became slightly opaque and produced the effect alluded to; for the *tapetum* thus denuded instantly recovered, and still retains its brilliancy."

The inference that the membrane in question is a double reflected serous membrane is certainly more in conformity with analogy than the assumption that it is a single layer, but this uniformity in nature's operations has been too much insisted upon. I have above stated my reasons for considering it a single layer, and not a double serous membrane; and I should be inclined to think that the layer which Mr. Dalrymple found adhering to the choroid was the membrane itself, which had not come away with the retina and vitreous humour, as I have found sometimes to happen, did not Mr. Dalrymple further state that he has " in his possession a preparation, which does most distinctly shew the double portions of this membrane; one lining the choroid, the other reflected over the pulpy structure of the retina." Mr. Jones, in the work formerly alluded to, gives the annexed representation of the membrane as it appears when highly magnified. *Fig.* 113 is a representation of the membrane by Mr. Bauer, magnified fifty diameters, from the Philosophical Transactions for 1822.

Fig. 112.



In the centre of the retina, and consequently in the axis of vision, about an eighth of an inch from the entrance of the optic nerve, a very remarkable condition of structure exists. This is a small point destitute of cerebral or medullary fibres, appearing like a hole in the membrane, and hence called the *foramen* of Sömmerring, from the distinguished anatomist who discovered it. This point is surrounded by a yellow margin, and the retina is here also puckered into a peculiar form of fold. Sömmerring, in the Commentationes Societatis

Fig. 113.

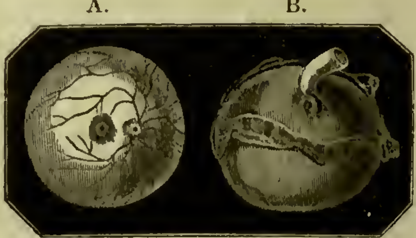
Regiæ Gottingenses, gives the following account of the discovery. " On the 27th of January, 1791, while I examined the eyes of a very fine and healthy young man, a few hours previously drowned in the Rhine, being perfectly fresh, transparent, and full, and supported in an appropriate fluid, with the intention of exhibiting a perfect specimen of the retina to my pupils in the anatomical theatre, I so clearly detected in the posterior part of the retina, which was expanded without a single fold, on account of the perfect state of the eye, a round yellow spot, that I was convinced it was a natural appearance, and not a colour produced by any method of preparation. In examining this spot more accurately, I perceived in its centre a little hole occupying the situation of the true centre of the retina. With the same care I examined the other eye and found it exactly similar. I then communicated the discovery to my pupils in the public demonstrations." " In this precise spot, or in the very centre of the retina, is found an actual deficiency of the medullary layer, or a real hole perfectly round, with a defined margin a fourth of a line in diameter." " The transparent vitreous humour and black pigment are so clearly seen through this hole, that there can be no doubt that it is a real aperture, which being situated in the centre of the retina may be appropriately termed the *foramen centrale*. Surrounding this *foramen* centrale the remarkable yellow colour resembling that of *gum guttæ* is so disposed that it appears much deeper toward the margin, and totally disappears at a distance of a line. This colour varies much according to the age of the individual, being very faint in infants, much deeper at puberty, on account of the thickness and whiteness of the retina at that period, appearing of a deep yellow brownish or crocus colour. In more advanced age the colour is less intense, principally on account of the diminished whiteness of the retina, which also appears extenuated at that period. Even the choroid, where it corresponds to this foramen, sometimes appears a little deeper-coloured."

In the paper above alluded to, published in the Medico-Chirurgical Transactions, I have given the result of some careful inquiries into the structure of this part, from which the following observations are extracted. " Sömmerring describes it as a hole in the retina with a yellow margin, mentioning as accidental a fold which occupies the situation of this hole and tends to conceal it, and thus accounting for its remaining so long unnoticed. This appearance is so constant and remarkable, that its existence may be very rationally considered essential to correct vision, and it therefore becomes an interesting object of speculation. The circumstances which it seems important to ascertain, are, whether it is actually a hole in the retina with a yellow margin; whether, in addition to this hole, the retina is folded or puckered in at this part; or whether the appearance of a hole arises from a deficiency of the medullary layer of the retina without any orifice in its vascular layer. Both Sömmerring himself and many others seem to consider that the fold is accidental and the consequences of changes occurring after death. It is here necessary to call to mind what those changes are with respect to the retina. If the eye had become flaccid previous to dissection, the retina on being exposed presents an irregular surface, arising from a number of folds diverging from the optic nerve as from a centre, and evidently produced by the loss of support from the partial evaporation of the fluid of the vitreous humour. These folds, however, never observe any regular form, or preserve precise situations, and may be obliterated by changing the position of the eye in the water. They disappear altogether after the part has remained some time in water, in consequence of the vitreous humour becoming again distended from imbibing the fluid in which it is immersed. It however requires no very great care or experience to distinguish between those accidental folds and the peculiar one in question. If the examination be made from without, removing the sclerotic and choroid behind, the retina appears to be forced or drawn at this point into the vitreous humour to the depth of about a twelfth of an inch, the entire fold being something more than an eighth in length. At first there is little or no appearance of a hole, but after the eye has remained for some time in the water, the fold begins to give way, and a small slit makes its appearance, which gradually widens, and assumes the appearance of a round hole. This hole is large in proportion to the degree to which the fold has yielded; and when the fold totally disappears, as it sometimes does, the transparent point gives the appearance which Sömmerring represents, of a hole with a yellow margin. If, instead of making the examination in this way from the outside, we view this part through the vitreous humour, the appearance of the hole is more remarkable; but still that part of the retina is evidently projected forward beyond the level of the rest of that membrane. In the eye of a young man, which I had an opportunity of examining under peculiarly favourable circumstances, within five hours after death, I noticed the following appearances. The cornea and iris having been cut away, and the lens removed from its situation, I placed the part in water, beneath one of the globular glasses, and held it so as to allow the strong light of a mid-day sun to fall directly upon it; when the retina to the outside of the optic nerve presented unequivocally the appearance of being drawn or folded into the form of a cross or star, with a dark speck in the centre, surrounded by a pale yellow areola. I further satisfied myself of the prominence of the fold by holding a needle opposite to it, while the light shone full upon it, a shadow being thus cast upon the retina which deviated from the straight line when passed over the situation of the fold. To ascertain whether there is actually a hole in the retina, or merely a deficiency of nervous matter at this point, I allowed the eye to remain for some days in water, until the connexions of the parts began to give way. I then introduced a small probe between the retina and vitreous humour, the part still remaining in water, and bringing the blunt point of the instrument opposite the transparent spot, attempted to pass it through, but found I could not do so without force sufficient to tear the membrane. I also removed the nervous matter by maceration and agitation in water, and on floating the vascular layer, found that I could no longer ascertain where the spot had originally existed, there being no hole in the situation previously occupied by the transparent speck."

It is remarkable that the *foramen* of Sömmerring has not been found in the eyes of any of the *mammalia* except those of the *quadrumana*, in some of whom it has been detected by Home, Cuvier, and others, but the extent to which it may be traced in this tribe has not been satisfactorily ascertained. Dr. Knox, in a paper in the Memoirs of the Wernerian Natural History Society, announces the discovery of its existence in certain lizards. In the *lacerta superciliosa* he says, " the retina is very thick, and somewhat firm and opaque. Where the optic nerve enters the interior of the eye-ball, there is a distinct *marsupium* or black circular body, proceeding forwards apparently through the centre of the vitreous humour. Anteriorly, somewhat superiorly and towards the mesial line or plane, we perceive, on looking over the surface of the retina which regards the vitreous humour, a comparatively large transparent, nearly circular spot, through which may be distinguished the dark-coloured choroid. Close to this is generally placed a fold or reduplication of the retina, which is in general remarkably distinct. This fold or folds, (for there are more than one) either proceed from the transparent point towards the insertion of the optic nerve, or close to it. Sometimes the fold seems, as it were, to lie over the transparent point, and partly to conceal it from view; or the point is formed in the edge of the fold itself, as in apes, but in general the fold runs directly from the insertion of the optic nerve upwards and inwards, pressing very close to the edge of the *foramen centrale*." The foramen was also seen in the *lacerta striata*, *lacerta calotes*, and others, while it was not to be detected in the gecko, crocodile, and some others. It was also subsequently discovered in the chameleon. The annexed figures represent the foramen of Sömmerring in the human eye. A, shews the retina expanded over the vitreous humour: on the right is the place from which the optic nerve was cut away, and from which the vessels branch out: on the left is the *foramen* of Sömmerring, represented by a black dot surrounded by a dark shade. B, shews the retina with a portion of the optic nerve. The external membrane is turned down as in the preceding representation of the same structure in the sheep's eye, and the *foramen* of Sömmerring, instead of a distinct hole, presents the appearance of a fold or depression with elevated sides. The wood-engraving does not admit of the delicacy of finish necessary to express perfectly this condition of the part.

Fig. 114.

A. B.



There is no part of the anatomy of the eye respecting which there has been so much diversity of opinion as the anterior termination of the retina. It has already been stated that it extends to the posterior extremities of the ciliary processes, where it is discontinued, presenting an undulating edge corresponding to the indented margin of this part of the *carpus ciliare*. Some assert that it extends to the margin of the lens, others that it is the vascular layer only which extends so far, and others that the vascular layer extends over the lens. No one however at present, who describes from observation, denies the termination of the nervous layer at the posterior margin of the ciliary body, although many insist upon the extension of the vascular layer to the circumference of the lens. The subject has received more attention than it deserves, as it involves no consideration of importance, either physiological or anatomical; but I am convinced from a very careful scrutiny that no such layer extends between the ciliary processes of the choroid and those of the hyaloid membrane; these two parts being mutually inserted into each other, as will presently be explained. In the paper above quoted in the Medico-Chirurgical Transactions I have explained what appears to me to be the arrangement of this part in the following words: "On removing the choroid, ciliary processes, and iris, we see the retina terminating with a defined dentated margin, about a quarter of an inch from the circumference of the lens: between this line of termination and the lens, the vitreous humour retains upon its surface part of the black pigment which covered the ciliary processes. If the eye be examined shortly after death, removing the black pigment from this part of the vitreous humour with a camel-hair pencil, there is an appearance of, at least, the vascular layer being continued to the lens; this part not being so transparent as the rest of the hyaloid membrane, or so opaque as the retina. From such an examination I was led to conclude that the vascular layer was continued to the margin of the lens, this part not being so transparent as the rest of the hyaloid membrane, or so opaque as the retina. From such an examination I was led to conclude that the vascular layer was continued to the margin of the lens, but I adopted a contrary opinion after I had witnessed the change which took place when the part had remained twenty-four hours in water: the retina then separating with a slight force, and frequently detached by the disturbance given in making the examination. If, after removing the choroid without disturbing the retina, the part be allowed to remain in water for some days, the medullary part of the retina begins to give way, and may be altogether detached by agitation in water, leaving the vascular layer firmly attached at the line of termination just described. With all the care I could bestow, I have, however, never succeeded in separating this layer from the vitreous humour further. If the maceration be continued for a few days longer, the vascular layer of the retina gives way, the larger vessels alone remaining attached at the original line of termination of the retina, and appearing to enter the hyaloid membrane at this part; the appearance which at first so much resembled the vascular layer proceeding towards the lens remaining unchanged, being in fact part of the vitreous humour itself. The circumstance which has most strengthened the notion of the retina being continued forward to the lens is, that often on raising the choroid and ciliary processes from the vitreous humour, we find those processes covered in several places by a fine semi-transparent membrane insinuated between the folds; this is supposed to be the vascular layer of the retina, but is really the corresponding part of the hyaloid membrane which is torn up, being firmly united to this part of the choroid."

After this article had been prepared for press, I received an admirable monograph upon the retina by B. C. R. Langenbeck, son of the celebrated professor of that name in the University of Göttingen, in which the nature, structure, and relations of this most important and interesting part of the organ are subjected to a critical and elaborate inquiry. He advocates the membranous nature of the black pigment on the inner surface of the choroid, and gives an engraving of its organization as ascertained by the microscope, resembling that given from the essay of Mr. Jones in the preceding pages. He devotes several pages to the description of the membrane which I found covering the medullary layer of the retina, and adds the testimony of a skilful anatomist in support of my description, sufficient to counterbalance the convenient scepticism of certain writers better skilled in making plausible books than difficult dissections. The fibrous structure of the medullary layer of the retina is established, and a plate given of the peculiar nodulated condition of these fibres. The work concludes with an account of the morbid changes of structure observed in the retina, a subject which, notwithstanding its manfest importance, has not hitherto attracted the attention which it deserves. I am indebted to Dr. Graves for the following abstract of some recent investigations of Treviranus on the same subject. "From microscopical examinations Treviranus demonstrates that the cerebral mass, both medullary and cortical, consists of hollow cylinders containing a soft matter. These cylinders, extremely minute in the cortical substance, are somewhat larger in the medullary, and still larger in the nerves. In the retina he finds, that after the optic nerve has penetrated the sclerotic and choroid, its cylinders or nervous tubes spread themselves out on every side either singly or collected into bundles, each cylinder or collection of tubes bending inwards through the vascular layer, and terminating in the form of a papilla on the vitreous humour."

Of the vitreous humour.—It has already been stated that the globe of the eye is divided into two chambers by the iris, the posterior of which is distended by a spherical transparent mass called the vitreous humour, which does not completely fill this chamber between the back of the iris and the hollow sphere of the retina, but is discontinued or compressed at a short distance from the back of the iris, having a narrow space between it and that membrane, called the posterior chamber of the aqueous humour. This transparent mass is composed of water containing certain saline and animal ingredients, deposited in exquisitely delicate and perfectly transparent cellular membrane; hence it is capable of sustaining its own weight and preserving its form when placed in water, and in air presents the appearance of a gelatinous mass, scarcely deserving the name of solid. The cellular structure, in which the watery fluid is lodged, has been called the hyaloid membrane, and the whole mass denominated the vitreous humour. The fluid of the vitreous humour, according to Berzelius, is composed of water, containing about one and a half per cent. of animal and saline ingredients; it has a saline taste, and acquires a slight opaline tint by being boiled. It consists of water 98.40, chloruret of soda with a little extractive matter 1.42, a substance soluble in water 0.02, and albumen 0.16. Its specific gravity is 1.059. When the hyaloid membrane is examined in its natural state, its cellular organization can scarcely be ascertained on account of its transparency; but if it be suspended on the point of a pin until the fluid is allowed to drop out, it may be inflated with a fine blowpipe and dried, or if the whole be placed in strong spirit or weak acid, the membrane becomes opaque, and its organization obvious. It has been supposed that the cells in which the fluid is lodged present a determinate form, and attempts have been made to prove this by freezing the eye and examining the frozen fragments; but any one who has seen the hyaloid membrane rendered opaque by acid must allow that the cells are too minute to admit of such investigation, and that the frozen masses, supposed to be the contents of cells, are merely fragments of the hyaloid membrane with their contained fluid. Although the hyaloid membrane is perfectly transparent, and the red particles of the blood do not circulate in its vessels, there can be little doubt that its growth and nutrition are effected by the circulation of a transparent fluid in vessels continuous with those conveying red blood. It is an established fact that transparent textures which in a natural state do not exhibit a trace of coloured fluid, when excited or inflamed, become filled with red vessels, as may be seen in the conjunctiva. It is therefore reasonable to admit that the hyaloid membrane does not present a deviation from this general law. The fluid of the vitreous humour, it is to be presumed from analogy, is secreted by the vessels of the hyaloid membrane, and if no red vessels can be detected, the secretion must be accomplished by transparent ones. It has already been stated that the vascular layer of the retina adheres to the surface of the vitreous humour, and that the points of adhesion are stronger along the course of the vessels than in the intermediate spaces; it is therefore most probable that the more superficial part of the sphere is supplied with transparent blood from the arteries of the retina, while a branch directly from the central artery, as it penetrates the *porus opticus*, enters behind, and extends to the back of the lens: such a branch can be injected in the fœtus, and is found to ramify on the back of the capsule of the lens; and in the eyes of large quadrupeds a transparent production, probably vascular, has been observed proceeding from the entrance of the optic nerve into the mass of the vitreous humour. It is also probable that the ciliary processes of the choroid, which are buried in the hyaloid membrane anteriorly, supply blood to that part of the sphere. That the vitreous humour undergoes changes analogous to those which take place in textures supplied with red blood, is proved by its hyaloid membrane being found opaque and thickened in eyes which have been destroyed by internal inflammation. A total disorganization of the vitreous humour is a frequent occurrence, the hyaloid membrane losing its cohesion to such a degree that the fluid escapes from the eye as freely as the aqueous humour when the cornea is divided in the operation of extraction; and after the lens and its capsule have been removed by operations with the needle, opacity of the hyaloid membrane is occasionally, although rarely, observed. Allusion has frequently been made in books to an appearance in the eye denominated *glaucoma*, attributed, rather vaguely, to opacity of the vitreous humour; it appears, however, to be nothing more than the usual opacity of the lens which occurs in advanced life, seen through a dilated pupil. As an additional proof of the vascularity of the vitreous humour may be adduced the fact, that in the eyes of sheep, injured by blows in driving to the shambles, the vitreous humour is deeply tinged with red blood.

The spherical mass of vitreous humour, it has already been stated, is exactly fitted into and adheres to the inner surface of the retina. From the anterior termination of the retina to the posterior chamber of the aqueous humour, it is in contact with, and adhering to, the ciliary processes of the choroid. Where it is truncated or compressed on its anterior part to form the posterior chamber of the aqueous humour, it has the crystalline lens fitted into a depression in its centre, while a narrow circle of it appears between the circumference of the lens and the anterior extremities of the ciliary processes of the choroid, forming part of the boundaries of this chamber of aqueous humour.

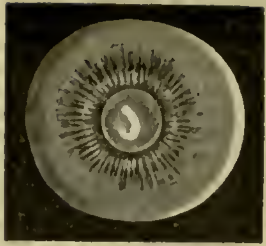
If the eye be allowed to remain for a day or two in water in order to destroy by maceration the delicate connexions between the hyaloid membrane and the choroid, and then the vitreous humour with the lens attached carefully separated, the point of a fine blowpipe may be introduced under the surface of the hyaloid membrane at the circumference of the lens, and a series of cells encircling the lens inflated. This is the canal of Petit, or canal *godronné*. It is thus described by the discoverer in the Histoire de l'Academie des Sciences for 1726. "I have discovered a small canal surrounding the crystalline, which I call the circular canal godronné; it can be seen only by inflating it, and when filled with air it forms itself into folds similar to the ornaments on silver plate, called for this reason *Vaiselle godronné*. It is formed by the doubling of the hyaloid membrane, which is contracted into cells at equal distances by little canals which traverse it, and which do not admit of the same degree of extension as the membrane, which is very feeble; it thus becomes *godronné*. If the crystalline be removed from its capsule without injuring the membrane which forms this canal, these *godronné* folds are not formed by inflation or only in a very slight degree, but the canal becomes larger. It is in man commonly a line and a quarter, a line and a half or two lines in breadth, and not larger in the ox." Annexed is a representation of this canal of Petit on a large scale.

Fig. 115.

As the nature of the connection between the choroid and the hyaloid membrane, the formation of the posterior chamber of the aqueous humour, and the structure of this canal of Petit, have been the subject of controversy, I venture to introduce here an extract on this subject from the paper published by me in the Medico-Chirurgical Transactions.

"If the sclerotic, choroid, iris, and retina be removed one or two days after death, leaving the vitreous humour with the lens embedded on its anterior part, we observe a number of *striæ* on the vitreous humour, converging towards the circumference of the lens, corresponding in number, size, and form to the ciliary processes, giving the same appearance collectively that the circle of ciliary processes or *corpus ciliare* does on the choroid, and narrowed towards the nasal side as the *corpus ciliare* is. This appearance has been noticed by most authors, but some describe it as arising merely from the marks left by the ciliary processes, while others consider these *striæ* of the same nature as those productions of the choroid, and call them the ciliary processes of the vitreous humour; it is the *corona ciliaris* of Camper and Zinn. If we remove the black pigment with a camel-hair pencil, we leave those productions on the vitreous humour more distinctly marked than when covered by the colouring matter, and presenting all the characters above stated, commencing behind with a well-defined margin, and terminating anteriorly by attachment to the capsule of the lens, the furrows between them capable of receiving the ciliary processes of the choroid, and the folds calculated to be lodged in the corresponding furrows of these processes. The annexed figure is a representation of the vitreous humour of the human eye thus treated.

Fig. 116.



"If the cornea and iris be removed from a human eye within a few hours after death, a dark circle surrounding the lens, between it and the anterior extremities of the ciliary processes, may be observed: this is the part of the *corona ciliaris* of the vitreous humour to which the ciliary processes of the choroid do not extend, which appears dark on account of its perfect transparency; the converging *striæ* are evident, even on this part where the ciliary processes are not insinuated, interrupting the view if we attempt to look into the bottom of the eye by the side of the lens. It is, in my opinion, therefore certain, that part of the vitreous humour enters into the formation of the posterior chamber of the aqueous humour. The demonstration of this fact is, however, attended with difficulty, because the flaccidity arising from even slight evaporation of the fluids of the eye permits the ends of the ciliary processes which present themselves in the posterior chamber of the aqueous humour to fall towards the circumference of the lens, and appear attached there. For myself I can say that having made the dissection in the way just pointed out, the eye of course in water, and beneath one of those globular vessels which I formerly described, I could see to the bottom of the eye through the space in front of the vitreous humour, between the ciliary processes and the margin of the lens; this space is, however, perhaps larger in some individuals than in others. Each fold of the *corona ciliaris* of the vitreous humour seems to consist of two layers of hyaloid membrane, capable of being separated one from the other by inflation, and admitting of communication with each other round the lens. It appears to me that the canal of Petit or canal *godronné* is formed in consequence of these folds receiving the injected air one from the other; it is, however, generally described as being formed by the membrane of the vitreous humour splitting at the circumference of the lens, one layer going before and the other behind that body, the canal existing between these two layers and the capsule of the lens. That the capsule of the lens has no share in the formation of the canal of Petit, I conclude from filling this canal with air, and allowing the part to remain for some days in water, and then with great care removing the lens included in its capsule; this I do not find, however, causes the air to escape from the cells, but leaves them presenting nearly the original appearance; and after the air has escaped, I can pass a small probe all round in this canal, raising by this means the folds from the hyaloid membrane. It is difficult, however, to preserve the air in these folds for any length of time under water, because the tendency of the air to ascend causes the rupture of the membrane, by which it is allowed to escape. After the lens, included in its proper capsule, has been detached from its situation on the vitreous humour, the space it occupied presents the appearance of a circular depression, surrounded by those productions of the hyaloid membrane of which I have just spoken; the vitreous humour remaining in every respect perfect, notwithstanding this abstraction of the lens."

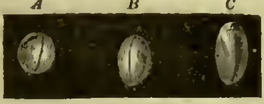
M. Ribes, in the Mémoires de la Société Médicale d'Emulation for 1816, describes the ciliary processes of the vitreous humour as follows. "At the anterior part of the vitreous humour, and at a short distance from the circumference of the crystalline, may be seen a ciliary body almost altogether similar to that of the choroid, and which has been named by anatomists *corona ciliaris*, but no writer has hitherto pointed out its structure, or the important office it appears to perform. Each of these processes has a margin adherent to the vitreous humour, and encroaches a little on the circumference of the lens. It appears to me impossible to ascertain whether the surfaces are reticulated, but they are villous. The free margin is obviously fringed, and presents nearly the variety of appearance observed in the fringes of ciliary processes (of the choroid) of different animals examined by me, except that the summits are black; the interval which separates each process of the vitreous humour is a species of depressed transparent gutter. The black colour of the free margins and the transparency of the space which separates each ciliary process adorns the anterior part of the vitreous humour with a circle remarkable for its agreeable effect, and which has been compared to the disc of a radiated flower." Dr. Knox, in a communication made to the Royal Society of Edinburgh, at the same time that mine was made to the Medico-Chirurgical Society, describes the ciliary processes of the choroid as follows: "In whatever way, the membrane or assemblage of membranes proceeds forwards to be inserted into the circumference of the capsule of the lens, forming in its passage numerous longitudinal folds, and small projecting fimbriated bodies, by which, in a natural state, the transparent humours are connected with the superjacent ciliary body (of the choroid); when examined with a good glass, these folds are remarkably distinct, and the whole bears the closest resemblance in its distribution to the true ciliary body and processes. I have, therefore, ventured to call them the internal or transparent ciliary body, or the ciliary body of the hyaloid membrane, in contradistinction to that of the choroid." It must not be forgotten that these ciliary processes of the hyaloid membrane were described by Monro in his Treatise on the Eye, and are strongly marked in a coarsely executed plate. He considered that the retina was continued to the lens, and describes its course under the ciliary processes of the choroid; thus "on examining the retina with still greater accuracy, it appears that it has exactly the same number of folds or doublings that the choroid coat has; for it enters double between the ciliary processes, nearly in the same way that the pia mater enters into the coats of the brain. The furrows and doublings of the retina, which, if we are to use the favourite term *ciliary*, may be called its *ciliary processes*, make an impression on the anterior part of the vitreous humour." The structure alluded to was also observed by Hovius nearly an hundred years before.

From the preceding observations respecting the ciliary processes of the vitreous humour, it may justly be inferred that the ciliary processes of the choroid, and these ciliary processes of the vitreous humour, are of the same nature, differing only in those of the choroid receiving red blood, while those of the vitreous humour receive a transparent fluid by their bloodvessels. The adaptation of these two circles of folds to each other appears to be a most beautiful example of mechanical construction occurring in soft parts: it is a species of dovetailing of the one structure into the other, by which an intimate union is secured between one part of considerable strength and another of extreme delicacy. A connexion equally perfect is established between the external surface of the choroid at its margin, and the corresponding margin of the sclerotic, by means of the ciliary ligament; in fact, without these two provisions of ciliary ligament and ciliary processes, and their application between the sclerotic, choroid, and vitreous humour, the chambers of the eye must be imperfectly constructed, and the optical mechanism of the organ defective. It is the mechanical bond between these dissimilar parts which perfects the chamber of aqueous humour, and prevents that fluid from escaping, either between the sclerotic and choroid, or between the choroid and vitreous humour.

Of the crystalline lens.—It has been already stated, that there is a double convex lens within the sphere of the eye, at a short distance behind the external lens or cornea. This is the crystalline lens or crystalline humour, which gives additional convergence to the rays of light transmitted through the pupil. It is placed in a depression, formed for its reception on the anterior, compressed, or truncated portion of the vitreous humour, where that body approaches the back of the iris, and constitutes part of the boundaries of the posterior chamber of the aqueous humour. In this depression it adheres firmly to the hyaloid membrane, and from the vessels of that structure derives its nutriment.

This double convex lens does not present the same curvature on both surfaces, the anterior being less curved than the posterior, in the ratio of about 4 to 3. Attempts have been made to determine with accuracy the nature of these curvatures, first by Petit, and subsequently by Wintringham, Chossat, and others. The results of the numerous experiments of Petit lead to the conclusion, that the anterior curvature is that of a portion of a sphere from six to seven lines and a half in diameter, the posterior that of a sphere of from five to six lines and a quarter. From the same source it appears that the diameter is from four lines to four lines and a half, the axis or thickness about two lines, and the weight three or four grains. I am, however, inclined to agree with the observation of Porterfield, that, "as it is scarce possible to measure the crystalline and the other parts of the eye with that exactness that may be depended on, all nice calculations founded on such measures must be fallacious and uncertain, and, therefore, should, for the most part, be looked on rather as illustrations than strict demonstrations of the points in question." The method by which Petit arrived at these results must render them of doubtful value, the curvatures having been determined by the application of brass plates cut to the requisite form. The results of Chossat's experiments, conducted with great care, and with the assistance of the megascope, are thus stated by Mr. Lloyd in his Treatise on Optics: "This author has found that the cornea of the eye of the ox is an ellipsoid of revolution round the greater axis, this axis being inclined inwards about 10°. The ratio of the major axis to the distance between the foci in the generating ellipse he found to be 1.3; and this agreeing very nearly with 1.337, the index of refraction of the aqueous humour, it follows that parallel rays will be refracted to a focus, by the surface of this humour, with mathemathical accuracy. The same author found likewise that the two surfaces of the crystalline lens are *ellipsoids* of revolution round the *lesser* axis; and it is somewhat remarkable that the axes of these surfaces do not coincide in direction either with each other, or with the axis of the cornea, these axes being both inclined *outwards*, and containing with each other, in the horizontal section in which they lie, an angle of about 5°." It must not be forgotten that these observations apply to the crystalline of the ox, not to that of man, and also that, as Chossat himself admits, the evaporation of the fluid part of the lens, or the absorption or imbibition of the water in which it is immersed, may materially alter the curvature. I cannot myself believe it possible to separate a fresh lens in its capsule perfectly from the hyaloid membrane without injuring its structure, and endangering an alteration in its form. Haller states that Kepler considered the anterior convexity to approach to a spheroid, and the posterior to a hyperbolic cone. Wintringham states the results of his inquiries as to this matter as follows:—"In order to take the dimensions of the eye of an ox, I placed it on a horizontal board and applied three moveable silks, which were kept extended by small plummets, so as to be exact tangents to the arch of the cornea, as well at each canthus, as at the vertex; then applying a very exactly divided scale, I found that the chord of the cornea was equal to 1.05 of an inch, the versed sine of this chord to be 0.29, and consequently the radius of the cornea was equal to 0.620215 of an inch. I then carefully took off the cornea, and replaced the eye as before, and found, by applying one of the threads as a tangent to the vertex of the crystalline, that the distance between this and the vertex of the cornea was 0.355 of an inch. Afterwards I took the crystalline out without injuring its figure, or displacing the capsula, and then applying the threads to each surface of this humour, as was done before to the arch of the cornea, I found that the chord of the crystalline was 0.74 of an inch, and its versed sine, with respect to the anterior surface, to be 0.189 of an inch, and consequently the radius of this surface was 0.45665 of the same. In like manner the versed sine to the same chord, with respect to the posterior surface of the crystalline, I found to be equal to 0.38845 of an inch. Lastly, I found the axis of the crystalline and that of the whole eye from the cornea to the retina to be 0.574, 2.21 respectively." Whatever doubts may be entertained respecting the accuracy of the measurements of the lens, there can be none that the form is different at different periods of life, in the human subject. It also appears to differ in different individuals at the same period of life, and probably the curvature is not the same in both eyes. In other animals the difference in form is most remarkable. In the human fœtus, even up to the ninth month, it is almost spherical. Petit states that be found the anterior curvature in a fœtus of seven months, a portion of a sphere of three lines diameter, and the posterior of two and a half, and the same in a new-born infant. In an infant eight days old, the anterior convexity was a portion of a sphere of four lines, and the posterior of three. All anatomists concur in considering the lens to approach more to a sphere at this period. In childhood the curvatures still continue much greater than in advanced life; from ten to twenty probably decrease, and from that period to forty, forty-five, or fifty, remain stationary, when they become much less; being, according to the tables of Petit, portions of spheres from seven to even twelve lines in diameter, and on the posterior of six or eight. Every day's observation proves that the lens becomes flattened, and its curvatures diminished as persons advance in life. It is seen in dissection, when extracted by operation, and even during life; the distance between its anterior surface and the back of the iris being so great in some old persons, that the shadow of the pupil may be seen upon it, while at an earlier period it actually touches that part of the membrane. This diminution of the curvatures of the lens commences about the age of forty-five. Petit found the anterior convexity varying from a sphere of about seven to twelve lines diameter, and the posterior from five to eight in persons from fifty to sixty-five years of age. The alteration in power of adaptation, and the indistinctness of vision of near objects which takes place at this period, is probably to be attributed to this cause, although a diminution of the muscular power of the iris, and consequent inactivity of the pupil, may contribute to the defect. It is also to be recollected that the density of the lens is much increased at this period, and that the young person whose lens presents greater curvatures does not require concave glasses, as the old person requires convex ones. The state of the eye, after the removal of the lens by operation for cataract, proves that it is a part of the organ essentially necessary for correct vision. When the eye is in other respects perfect, without any shred of opaque capsule, any irregularity or adhesion of the pupil, or any alteration in the curvature of the cornea, as in young persons who have had the lens properly broken up with a fine needle through the cornea, vision is so good for distant objects, that such persons are able to pursue their common occupations, and walk with safety through crowded streets, but they require the use of a convex lens, of from three and a half to five inches focus, for reading or vision of near; old persons, however, generally require convex glasses on all occasions after the removal of the lens. That the curvatures of the lens are frequently different in different individuals may be inferred from the frequency of short sight, or defective power of adaptation, not attributable to any peculiarity of the cornea. Petit states that he found lenses of which the two convexities were equal, and others of which the anterior was greater than the posterior, and more than once, one more convex on its anterior surface in one eye, while that in the other eye was in a natural state. He also occasionally found the lens as convex in the advanced period of life as in youth. I have repeatedly observed the perfection of vision and power of adaptation much greater in one eye than the other in the same individual, without any defect of the cornea, pupil, or retina; and occasionally have found young persons requiring the common convex glasses used by persons advanced in life, and old persons becoming near-sighted, and requiring concaves. The annexed letters shew the difference of curvature at the different periods of life, as represented by Sömmerring. *A* is the lens of the fœtus; *B*, that of a child of six years of age; and *C*, that of an adult.

Fig. 117.



The colour of the lens is also different at different periods of life. In the fœtus it is often of a reddish colour; at birth and in infancy it appears slightly opaque or opaline; in youth it is perfectly transparent; and in the more advanced periods of life acquires a yellowish or amber tint. These varieties in colour are not visible, unless the lens be removed from the eye, until the colour becomes so deep in old age as to diminish the transparency, when it appears opaque or milky, or resembling the semitransparent horn used for lanterns. The hard lenticular cataract of advanced life appears to be nothing more than the extreme of this change of colour, at least when extracted and placed on white paper it presents no other disorganization; but the lens of old persons, when seen in a good light and with a dilated pupil, always appears more or less opaque, although vision remains perfect. The depth of colour is sometimes so great, without any milkiness or opacity, that the pupil appears quite transparent although vision is lost. This is perhaps the state of lens vaguely alluded to by authors under the name of black cataract.

The consistence of the lens varies as much as its colour. In infancy it is soft and pulpy, in youth firmer, but still so soft that it may be crushed between the finger and thumb, and in old age becomes tough and firm. Hence it is that in the earlier periods of life cataracts may be broken up completely into a pulp, and absorbed with certainty, while in old persons they adhere to the needle, unless very delicately touched, and are very liable to be detached from the capsule and thrown upon the iris, causing the destruction of the organ. On this account, therefore, the operation of extraction must generally be resorted to in old persons labouring under this form of cataract, while the complete division of it with the needle and exposure of the fragments to the contact of the aqueous humour secures its removal by absorption in young persons. It must not, however, be forgotten that the softer lenticular cataract occasionally occurs in advanced life.

The crystalline lens is a little heavier than water. Porterfield, from the experiments of Bryan Robinson, infers that the specific gravity of the human lens is to that of the other humours as eleven to ten, the latter being nearly the same as water; and Wintringham, from his experiments, concludes that the density of the crystalline is to that of the vitreous humour in the ratio of nine to ten; the specific gravity of the latter being to water as 10024 to 10000. The density of the lens is not the same throughout, the surface being nearly fluid, while the centre scarcely yields to the pressure of the finger and thumb, especially in advanced life. Wintringham found the specific gravity of the centre of the lens of the ox to exceed that of the entire lens in the proportion of twenty-seven to twenty-six. The refractive power is consequently greater than that of the other humours. On this head Mr. Lloyd, in his Optics, says, " In their refractive power, the aqueous and vitreous humours differ very little from that of water. The refractive index of the aqueous humour is 1.337, and that of the vitreous humour 1.339; that of water being 1.336. The refractive power of the crystalline is greater, its mean refracting index being 1.384. The density of the crystalline, however, is not uniform, but increases gradually from the outside to the centre. This increase of density serves to correct the aberration by increasing the convergence of the central rays more than that of the extreme parts of the pencil." Dr. Brewster, in his Treatise on Optics, says, " I have found the following to be the refractive powers of the different humours of the eye, the ray of light being incident upon them from the eye: aqueous humour 1.336; crystalline, surface 1.3767, centre 1.3990, mean 1.3839; vitreous humour 1.3394. But as the rays refracted by the aqueous humour pass into the crystalline, and those from the crystalline into the vitreous humour, the indices of refraction of the separating surface of these humours will be, from the aqueous humour to the outer coat of the crystalline 1.0466, from the aqueous humour to the crystalline, using the mean index, 1.0353, from the vitreous to the outer coat of the crystalline 1.0445, from the vitreous to the crystalline, using the mean index, 1.0332." Dr. Young says, "On the whole it is probable that the refractive power of the centre of the human crystalline, in its living state, is to that of water nearly as 18 to 7; that the water imbibed after death reduces it to the ratio of 21 to 20; but that on account of the unequable density, its effect in the eye is equivalent to a refraction of 14 to 13 for its whole size."

Respecting the chemical composition of the lens, Berzelius observes, that "the liquid in its cells is more concentrated than any other in the body. It is completely diaphanous and colourless, holding in solution a particular animal matter belonging evidently to the class of albuminous substances, but differing from fibrine in not coagulating spontaneously, and from albumen, inasmuch as the concentrated solution, instead of becoming a coherent mass on the application of heat, becomes granulated exactly as the colouring matter of the blood when coagulated, from which it only differs in the absence of colour. All those chemical properties are the same as those of the colouring matter of the blood. The following are the principles of which the lens is composed: peculiar coagulable albuminous matter 35.9, alcoholic extract with salts 2.4, watery extract with traces of salts 1.3, membrane forming the cells 2.4, water 58.0.

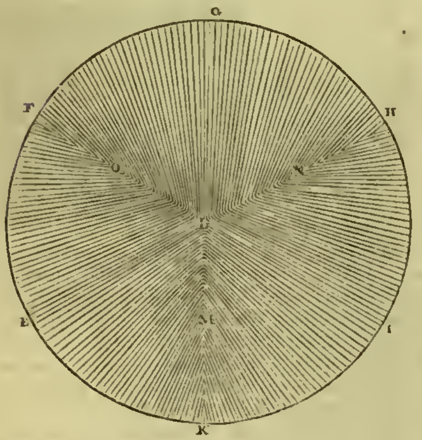
From the preceding observations it might reasonably be supposed that the lens is composed of a homogeneous material, such as albumen or gelatine, more consolidated in the centre than at the circumference; but this is not the case; on the contrary, it exhibits as much of elaborate organization as any other structure in the animal economy. It consists of an outer case or capsule, so totally different from the solid body contained within it, that they must be separately investigated and described. The body of the lens, it has been already stated, consists of certain saline and animal ingredients combined with more than their weight of water, and when perfectly transparent presents the appearance of a tenacious unorganized mass; but when rendered opaque by disease, loss of vitality, heat, or immersion in certain fluids, its intimate structure becomes visible. If the lens with the capsule attached to the hyaloid membrane be removed from the eye and placed in water, the following day it is found slightly opaque or opaline, and split into several portions by fissures extending from the centre to the circumference, as seen in *fig.* 118. This appearance is rendered still more obvious by immersion in spirit, or the addition of a few drops of acid to the water. If a lens thus circumstanced be allowed to remain some days in water, it continues to expand and unfold itself, and if delicately touched and opened by the point of a needle, and carefully transferred to spirit, and as it hardens is still more unravelled by dissection, it ultimately presents a remarkable fibrous or tufted appearance, as represented in the figure below, drawn by me some years ago from a preparation of the lens of a fish thus treated (the *Lophius piscatorius*). The three annexed figures represent the structure of the lens above alluded to: A is the human crystalline in its natural state; B, the same split up into its component plates; and C, unravelled in the fish.

Fig. 118.

A B C

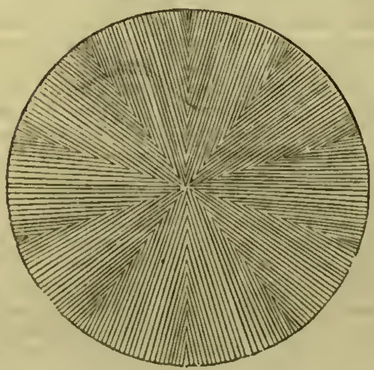
This very remarkable structure of the body of the lens appears to have been first accurately described by Leeuwenhoek, subsequently by Dr. Young, and still more recently by Sir David Brewster. Leeuwenhoek says, "It may be compared to a small globe or sphere, made up of thin pieces of paper laid one on another, and supposing each paper to be composed of particles or lines placed somewhat in the position of the meridian lines on a globe, extending from one pole to the other." Again he says, "With regard to the beforementioned scales or coats, I found them so exceedingly thin, that, measuring them by my eye, I must say that there were more than two thousand of them lying one upon another." "And, lastly, I saw that each of these coats or scales was formed of filaments or threads placed in regular order, side by side, each coat being the thickness of one such filament." The peculiar arrangement of these fibres he describes as follows: "Hence we may collect how excessively thin these filaments are; and we shall be struck with admiration in viewing the wonderful manner they take their course, not in a regular circle round the ball of the crystalline humour, as I first thought, but by three different circuits proceeding from the point L, which point I will call their axis or centre. They do not on the other side of the sphere approach each other in a centre like this at L, but return in a short or sudden turn or bend, where they are the shortest, so that the filaments of which each coat is composed have not in reality any termination or end. To explain this more particularly, the shortest filaments, M K, H N, and O F, which fill the space on the other side of the sphere, constitute a kind of axis or centre, similar to this at L, so that the filaments M K, having gone their extent, and filled up the space on the other side, in like manner as is here shewn by the lines E L I, return back and become the shortest filaments H N. These filaments H N, passing on the other side of the sphere, again form another axis or centre, and return in the direction O F, and the filaments O F, again on the other side of the sphere, collect round a third centre, and thence return in the direction K M; so that the filaments which are on this side of the sphere collect round a third centre, and thence return in the direction K M; so that the filaments which are on this side the shortest, on the other side are the longest, and those which there are the shortest are here the longest." Annexed is Leeuwenhoek's representation (*fig.* 119).

Fig. 119.



Dr. Young differs from Leeuwenhoek as to the arrangement of the fibres and other particulars, and in his last paper corrects the description given by himself in a former one; he says, "The number of radiations (of the fibres) is of little consequence, but I find that in the human crystalline there are ten on each side, not three, as I once from a hasty observation concluded." "In quadrupeds the fibres at their angular meeting are certainly not continued as Leeuwenhoek imagined." Beneath is Dr. Young's last view of the arrangement of the fibres, which Dr. Brewster has shown to be incorrect, but the introduction of which is justified by the source from which it is derived.

Fig. 120.

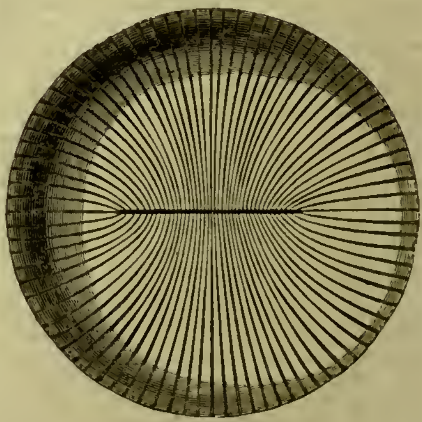


Sir David Brewster says that the direction of the fibres is different in different animals; the simplest arrangement being that of birds, and the cod, haddock, and several other fishes. In it the fibres, like the meridians of a globe, converge to two opposite points of a spheroidal or lenticular solid, as in the annexed figure.

Fig. 121.

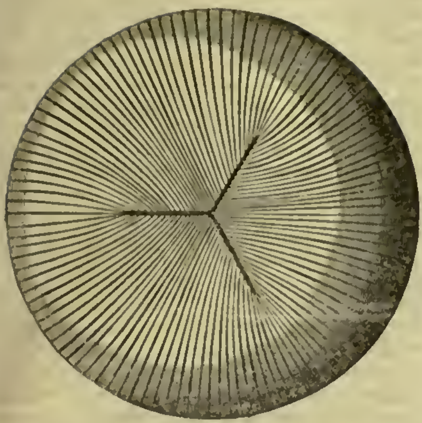
The second or next simplest structure he detected in the salmon, shark, trout, and other fishes; as well as in the hare, rabbit, and porpoise among the mammalia; and in the alligator, gecko, and others among reptiles. Such lenses have *two septa* at each pole, as in the annexed figure.

Fig. 122.



The third or more complex structure exists in mammalia in general, "in which *three septa* diverge from each pole of the lens, at angles of 120°, the septa of the posterior surface bisecting the angles formed by the septa of the anterior surface, as in the annexed figure (*fig.* 123).

Fig. 123.



The mode in which these fibres are laterally united to each other is equally curious. Sir David Brewster says that he ascertained this in looking at a bright light through a thin lamina of the lens of a cod, when he observed two faint and broad prismatic images, situated in a line exactly perpendicular to that which joined the common coloured images. Their angular distance from the central image was nearly five times greater than that of the first ordinary prismatic images, and no doubt whatsoever could be entertained that they were owing to a number of minute lines perpendicular to the direction of the fibres, and whose distance did not exceed the $\frac{12}{800}$dth of an inch. Upon applying a good microscope to a well-prepared lamina, the two fibres were found united by a series of teeth exactly like those of rack work, the projecting teeth of one fibre entering into the hollows between the teeth of the adjacent one, as in *fig.* 124.

Fig. 124.

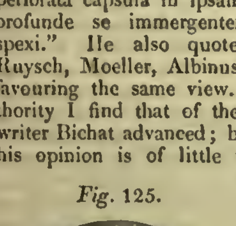
I have said that the lens consists of an outer case or capsule totally different from the solid body contained within it. This capsule is strong, elastic, and perfectly transparent. In the paper to which I have alluded in the Medico-Chirurgical Transactions, I gave the following detailed description of its nature and properties:—

"The real nature of the capsule of the lens has not, I think, been sufficiently attended to; its thickness, strength, and elasticity, have certainly been noticed, but have not attracted that attention which a fact so interesting, both in a physiological and pathological point of view, deserves. That its structure is cartilaginous, I should conclude, *first*, from its elasticity, which causes it to assume a peculiar appearance when the lens has been removed, not falling loose into folds as other membranes, but coiled in different directions; or if the lens be removed by opening the capsule behind, and withdrawing it through the vitreous humour, allowing the water in which the part is immersed to replace the lens, the capsule preserves in a great degree its original form, especially in the eye of the fish; *secondly*, from the density and firmness of its texture, which may be ascertained by attempting to wound it by a cataract needle, by cutting it upon a solid body, or compressing it between the teeth; *thirdly*, from its permanent transparency, which it does not lose except on the application of very strong acid or boiling water, and then only in a slight degree; maceration in water for some months, or immersion in spirit of strength sufficient to preserve anatomical preparations, having little or no effect upon it. If the lens be removed from the eye of a fish dressed for the table, the capsule may be raised by the point of a pin, and be still found almost perfectly transparent. This combination of density and transparency gives the capsule a peculiar sparkling appearance in water, in consequence of the reflection of light from its surface, resembling a portion of thin glass which had assumed an irregular form while soft; this sparkling I consider very characteristic of this structure. The properties just enumerated appear to me to distinguish it from every other texture but cartilage; still, however, it may be said that cartilage is not transparent, but even the cartilage of the joints is semi-transparent, and, if divided into very thin portions, is sufficiently pellucid to permit the perception of dark objects placed behind it, and we obtain it almost perfectly transparent where it gives form to the globe of the eye, as in the sclerotic of birds and fishes. If the soft consistence, almost approaching to fluidity, of the external part of the lens, be considered, the necessity of a capsule capable itself of preserving a determinate form is obvious. If the lens were enclosed in a capsule such as that which envelopes the vitreous humour, its surface could not be expected to present the necessary regular and permanent curvature; nor could we expect that if the form of the lens were changed, it could be restored without this provision of an elastic capsule."

The capsule is liable to become opaque and constitute cataract, as the body of the lens is. These capsular cataracts are easily distinguished from the lenticular. They never present the stellated appearance frequently observed when the texture of the opaque lens opens in the capsule as it does when macerated in water, nor the uniform horny or the milky blue appearance of common lenticular cataract. The opacity in capsular cataract exists in the shape of irregular dots or patches, of an opaque paper-white appearance, and when touched with the needle are found hard and elastic, like indurated cartilage, the spaces between the specks of opacity frequently remaining perfectly transparent.

It appears to be generally assumed by writers on anatomy that a watery fluid is interposed between the body of the lens and its capsule, from an incidental observation of Morgagni when discussing the difference in density between the surface and centre of the lens; hence it has been called the *aqua Morgagni*. The observation of this celebrated anatomist, in his *Adversaria Anatomico*, which has led to the universal adoption of this notion, is, however, merely that upon opening the capsule he had frequently found a fluid to escape. "Deinde eâdem tunicâ in vitulis etiam, bobusque sive recens, sive non ita recens occisis perforata, pluries animadverti, illico humorem quendam aqueum prodire: quod et in homine observare visus sum, atque adeo credidi, hujus humoris secretione prohibitâ, crystallinum siccum, et opacum fieri ferè ut in extracto exsiccatoque crystallino contingit." He does not, however, subsequently dwell upon or insist upon the point. I do not believe that any such fluid exists in a natural state, but that its accumulation is a consequence of loss of vitality; the water combined with the solid parts of the lens escaping to the surface and being detained by the capsule, as occurs in the pericardium and other parts of the body. In the eyes of sheep and oxen, when examined a few hours after death, not a trace of any such fluid can be detected, but after about twenty-four hours it is found in considerable quantity. In the human eye a fluid sometimes accumulates in the capsule, constituting a particular form of cataract, which presses against the iris, and almost touches the cornea; but such eyes are, I believe, always unsound. From this erroneous notion of an interposed fluid between the lens and its capsule has arisen the adoption of an unsustained and improbable conclusion, that the lens has no vital connexion with its capsule, and consequently must be produced and preserved by some process analogous to secretion. Respecting this matter I have observed, in the paper above alluded to, "The lens has been considered by some as having no connexion with its capsule, and consequently that its formation and growth is accomplished without the assistance of vessels; such a notion is so completely at variance with the known laws of the animal economy, that we are justified in rejecting it, unless supported by unquestionable proof. The only reasons which have been advanced in support of this conclusion are, the failure of attempts to inject its vessels, and the ease with which it may be separated from its capsule when that membrane is opened. These reasons are far from being satisfactory; it does not necessarily follow that parts do not contain vessels, because we cannot inject them; we frequently fail when there can be no doubt of their existence, especially where they do not carry red blood. I have not myself succeeded in injecting the vessels of the lens, but I have not repeated the trial so often as to make me despair of accomplishing it, more especially as Albinus, an anatomist whose accuracy is universally acknowledged, asserts, that after a successful injection of the capsule of the lens, he could see a vessel passing into the centre of the lens itself. Lobé, who was his pupil, bears testimony to this. The assertion that the lens is not connected with its capsule, I think I can show to be incorrect; it has been made from want of care in pursuing the investigation, and from a notion that a fluid exists throughout between the lens and its capsule. When the capsule is opened, its elasticity causes it to separate from the lens; especially if the eye be examined some days after death, or has been kept in water, as then the lens swells, and often even bursts the capsule and protrudes through the opening, by which the connexion is destroyed. I have however satisfied myself that the lens is connected with its capsule (and that connexion by no means slight) by the following method. I remove the cornea and iris from an eye, within a few hours after death, and place it in water, then with a pair of sharp-pointed scissors I divide the capsule all round at the circumference of the lens, taking care that the division is made behind the anterior convexity, so that the lens cannot be retained by any portion of the capsule supporting it in front. I next invert the eye, holding it by the optic nerve, when I find that the lens cannot be displaced by agitation, if the eye be sufficiently fresh. In the eye of a young man about six hours dead, I found that, on pushing a cataract needle into the lens, after the anterior part of the capsule had been removed, I could raise the eye from the bottom of the vessel, and even half way out of the water, by the connexion between the lens and its capsule. It afterwards required considerable force to separate them, by passing the needle beneath the lens, and raising it from its situation. I believe those who have been in the habit of performing the operation of extraction, have occasionally encountered considerable difficulty in detaching the lens from its situation after the capsule had been freely opened, this difficulty I consider fairly referable to the natural connexion just noticed." When the lens enclosed in its capsule is detached from the hyaloid membrane, the connexion between it and the capsule is destroyed by the handling, and, in consequence, it moves freely within that covering, affording to those who believe that there is no union between the two surfaces fallacious evidence in support of that opinion, which, if not sustained by better proof, should be abandoned. Dr. Young insists upon the existence of the natural connexion by vessels and even by nerves between the lens and its capsule; he says, "The capsule adheres to the ciliary substance, and the lens to the capsule, principally in two or three points; but I confess I have not been able to observe that these points are exactly opposite to the trunks of nerves; so that probably the adhesion is chiefly caused by those vessels which are sometimes seen passing to the capsule in injected eyes. We may, however, discover ramifications from some of these points upon and within the substance of the lens, generally following a direction near to that of the fibres, and sometimes proceeding from a point opposite to one of the radiating lines of the same surface. But the principal vessels of the lens appear to be derived from the central artery, by two or three branches at some little distance from the posterior vortex, which I conceive to be the cause of the frequent adhesion of a portion of a cataract to the capsule about this point; they follow nearly the course of the radiations and then of the fibres; but there is often a superficial subdivision of one of the radii at the spot where one of them enters." The great size of the vessels distributed on the back of the capsule in the fœtus strengthens the conclusion that the lens is furnished with vessels as the rest of the body. When the eye of a fœtus of seven or eight months is finely injected, a branch from the central artery of the retina is filled and may be traced through the centre of the vitreous humour to the back of the capsule, where it ramifies in a remarkably beautiful manner, assuming, according to Sömmerring, a stellated or radiating arrangement. Zinn declares that he found branches from this vessel penetrating the lens: "Optime autem placet observatio arteriolæ lentis, in oculo infantis, cujus vasa cera optime erant repleta, summa voluptate mihi visæ, quam prope marginem ad convexitatem posteriorem dilatam, duobus ramulis perforata capsula in ipsam substantiam lentis profunde se immergentem cortissime conspexi." He also quotes the authority of Ruysch, Moeller, Albinus, and Winslow, as favouring the same view. Against such authority I find that of the French systematic writer Bichat advanced; but on such a point his opinion is of little value. Annexed is Zinn's representation of the distribution of the branch of the central artery on the back of the capsule, from a preparation in Lieberkühn's museum. Similar figures have been given by Albinus, Sömmerring, and Sir Charles Bell.

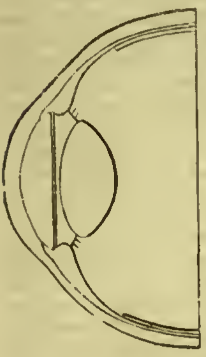
Fig. 125.



Of the aqueous humour.—In the preliminary observations at the commencement of this article, I stated that a cavity or space filled with water exists between the cornea and crystalline lens, in which space the iris is extended, with its aperture or pupil, to moderate the quantity of light, and interrupt the passage of the extreme rays. It is bounded anteriorly by the concave inner surface of the cornea, and posteriorly by the crystalline lens and other parts, and is necessarily divided into two spaces or chambers by the iris. That in front of the iris, called the anterior chamber, is bounded by the concave inner surface of the cornea anteriorly, and by the flat surface of the iris posteriorly, which, I have already stated, is a plane, not a convex surface, as represented in the plates of Zinn and others. The size of this space is necessarily small, and varies in different individuals according to the convexity of the cornea, which also frequently varies. It is always, however, sufficiently large to allow the surgeon to introduce a needle to break up a cataract without wounding the iris or cornea. The posterior chamber is bounded in front by the back of the iris, and behind by the crystalline lens; with that portion of the hyaloid membrane of the vitreous humour, which is between the anterior termination of the ciliary processes of the choroid and the circumference of the lens. The circumference of the posterior chamber is bounded by the anterior extremities of the ciliary processes of the choroid, as they extend from the vitreous humour to the back of the iris. It does not appear to be generally admitted or well understood that any part of the hyaloid membrane of the vitreous humour enters into the composition of the posterior chamber of the aqueous humour, notwithstanding the decisive opinion and accurate representation of the celebrated Sömmerring, in which I entirely concur, as I have stated above in describing the vitreous humour.

The size of the posterior chamber has been the subject of much discussion and controversy, and various attempts have been made by freezing the eye and other means to determine the matter. Petit, after a careful investigation, considered that the distance between the lens and iris was less than a quarter or half a line, in which Haller appears to concur. Winslow, in the Memoirs of the French Academy for 1721, insists that the iris is in contact with the lens. Lieutaud, in his *Essais Anatomiques*, is equally positive on this point, and even denies altogether the existence of a posterior chamber. The question is not an indifferent one, inasmuch as it involves important considerations as to operations for cataract and inflammations of the iris. Modern anatomists appear, generally, to consider the distance between the lens and iris to be greater than it really is. Although I cannot agree with Winslow and Lieutaud that the margin of the pupil is always in contact with the lens, I believe it frequently is so, especially in the earlier periods of life, when the curvatures of the lens are considerable. In iritis adhesions generally take place between the margin of the pupil and the capsule of the lens, a consequence not easily accounted for, if the parts be not in contact. In old age the lens becomes much flattened, and therefore retreats from the pupil, to such a degree that the shadow of the iris may often be seen in a crescentic form on a cataract; and in such persons, whether from this cause or from the inflammation not being of the adhesive character, blindness is more frequently attended with dilated pupil. In breaking up cataracts through the cornea, I have repeatedly satisfied myself of the contact or close vicinity of the two surfaces by placing the needle between them. The annexed outline section, from the work of Sömmerring, shews how small he considered the space between the iris and lens, and displays accurately how the posterior chamber is formed by the iris anteriorly, the lens posteriorly, and the ciliary processes at the circumference, with the small circular portion of the hyaloid membrane of the vitreous humour between the ciliary processes of the choroid and the circumference of the lens.

Fig. 126.

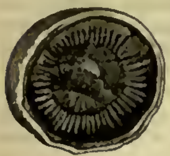


It appears to me unaccountable why surgeons, with these anatomical facts before them, still continue to introduce the needle into the posterior chamber, to break up cataracts, instead of passing it through the cornea into the anterior chamber, where ample space exists, and a full view is obtained of all the steps of the operation. In doing so the needle is thrust through opaque parts among delicate structures, into a narrow cavity, where, hidden by the iris, it can be used with little certainty of correct application. At the same time, instead of penetrating the simple structure of the cornea, which bears injury as well as any other structure of the body, the instrument pervades the fibrous sclerotic, a structure impatient of injury and prone to inflammation, punctures the ciliary ligament at the imminent risk of injuring one of the ciliary nerves or even wounding the long ciliary artery, and finally passes through one of the most vascular parts in the body, the *corpus ciliare*. The practice appears a signal instance of the influence of education, habit, and authority in setting improvement at defiance. The proofs afforded of the close vicinity of the margin of the pupil to the capsule of the lens, should remind the surgeon that one of the greatest dangers to be apprehended in iritis is the adhesion of these two parts, and that one of the first steps in the treatment should be to separate them by the application of belladonna, which, by its peculiar influence on the pupil, dilates that aperture, and, consequently, brings its margin more opposite the circumference of the lens and at a greater distance from the prominent central portion.

The aqueous humour, although constituting so essential a part of the optical mechanism of the eye, is but small in quantity; according to Petit not more than four or five grains. Its specific gravity and refractive power scarcely differ from that of water; and according to Berzelius, 100 parts contain 98.10 of water, 1.15 of chloruret of soda with a slight trace of alcoholic extract, 0.75 of extractive matter soluble in water only, and a mere trace of albumen. It is perfectly transparent, but is said to be milky in the fœtus.

The source from which this fluid is derived has been the subject of controversy in consequence of Nuck, a professor of anatomy at Leyden, having asserted that he had discovered certain ducts through which it was transmitted, and published a small treatise to that effect, which ducts were proved to be vesssels by a cotemporary writer, Chrouet, in which decision subsequent authors have concurred. In the present day this fluid is generally believed to be secreted by a membrane lining the cavity, as the fluid which lubricates the serous cavities is secreted by their lining membranes. Although this is in all probability the fact, the circumstances are not exactly the same in both cases. In the serous cavities, merely as much fluid as moistens the surface is poured out, while in the chamber of the aqueous humour sufficient to distend the cavity is secreted. In the serous cavities the membrane from which they derive their name can be demonstrated; in the chamber of aqueous humour this can scarcely be accomplished. I have resorted to various methods to enable me to demonstrate the existence of the membrane of the aqueous humour on the back of the elastic cornea, such as maceration, immersion in hot water, soaking in alcohol, and treating with acids, alkalis, and various salts, but without effect. In describing the structure of the cornea, I have shewn that the elastic cornea itself cannot for a moment be considered the membrane in question, on account of its strength, thickness, elasticity, and abrupt termination; and I do not think that the demonstration of a serous membrane expanded on such a structure as transparent cartilage is to be expected, inasmuch as the demonstration of the synovial membrane on the cartilages of incrustation in the joints is attended with much difficulty. The pathological fact which tends most to prove the existence of such a membrane here, is, that in iritis, especially that of a syphilitic character, the aqueous humour appears often very muddy, especially in the inferior half of the chamber; this, however, in the latter stages may be found to arise from a delicate speckled opacity on the back of the cornea, which remains permanently, and injures vision considerably. Analogy also favours the inference that the whole cavity of the chamber must be lined by serous membrane, inasmuch as all structures, of whatsoever nature they may be, in the serous or synovial cavities, are so covered or lined. This provision is so universal, that if such various structure, as the elastic cornea, iris, capsule of the lens, ciliary processes, and hyaloid membrane, which enter into the construction of the chamber of aqueous humour, be exposed to the contact of the fluid without any intervening membrane, it constitutes an unexpected anomaly in the animal œconomy. The consequences of inflammation greatly strengthen the conclusion that the cavity is lined by a membrane of the serous character. The slightest injuries or even small ulcers of the cornea are frequently accompanied by effusion of purulent matter into the anterior chamber, from the extension of the inflammation into that cavity, constituting the *hypopion* or *onyx* of the books; and the yellow masses which appear on the iris in syphilitic iritis, whether they are abscesses, or as they are called, globules of lymph, are effusions beneath a delicate membrane, as vessels may be seen with a magnifying glass, ramifying over them. In iritis the rapidity with which adhesions are formed between the margin of the pupil and the capsule, proves that these two structures are covered by a membrane of this nature. In addition to all these facts the still more conclusive one is to be adduced, namely, that the membrane can without difficulty be demonstrated on the back of the iris, as I have stated in speaking of that part of the organ, and as it is represented in *fig.* 127, where the fold of membrane stained with black pigment is seen turned down from that structure.

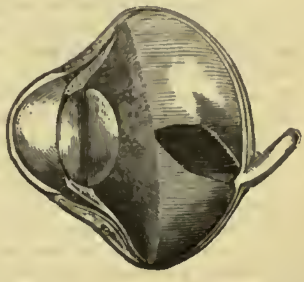
Fig 127.



In the preceding pages I have availed myself of whatever valuable and appropriate facts in comparative anatomy I found calculated to illustrate or explain the structure of the human eye. There are, however, two organs in other animals which do not exist even in the most imperfect or rudimental state in the human subject—the *pecten* or *marsupium nigrum* in birds, and the *choroid gland* or *choroid muscle* in fishes.

Of the pecten.—This organ is called *pecten* from its folded form bearing some resemblance to a comb, and *marsupium nigrum* from its resemblance in the eye of the ostrich to a black purse, according to the anatomists of the French Academy, who compiled the collection of memoirs on comparative anatomy. The organ is obviously a screen projected from the bottom of the eye forward toward the crystalline lens, and, consequently, received into a corresponding notch or wedge-shaped hollow in the vitreous humour; it appears to be of the same vascular structure as the choroid, and is deeply stained with the black pigment, which renders it perfectly opaque and impervious to light. The annexed figure, from the work of D. W. Sömmerring, represents it in the eye of the golden eagle.

Fig. 128.



It is composed of a delicate membrane, highly vascular, folded exactly like the plaits of a fan, and when removed with sharp scissors from the bottom of the eye, and its free margin cut along the edge so as to allow the folds to be pulled open, it may be spread out into a strip of continuous riband-shaped membrane, as seen in *fig.* 129, from a paper of Sir E. Home's in the Philosophical Transactions for 1822.

Fig. 129.

The first account I find of it is by Petit in the Mém. de l'Acad. Roy. 1735. He says it is a trapezium or trapezoid, five lines long at the base, and three lines and a half deep, composed of parallel fibres, and that a fine transparent filament runs from the anterior superior angle to the capsule of the crystalline lens, not easily seen on account of its transparency, and that sometimes the angle itself is attached to the capsule near its margin. Haller, in his work "Sur la formation du cœur dans le poulet," describes it as follows:—"It is a black membrane folded at very acute angles, as the paper of a fan, upon which transparent vessels are expanded; it generally resembles the ciliary processes. It originates from the sclerotic in the posterior part of the eye by a serrated line, pierces the choroid, retina, and vitreous humour to attach itself to the side of the capsule of the crystalline, very near the corona ciliaris. The posterior extremity is broad, and the anterior narrows till it becomes adherent to the capsule of the lens by an insertion a little narrower. This insertion appears to be effected by the intervention of the hyaloid membrane, to which this fan is attached. I have not had time to establish this connexion to my satisfaction, and I still entertain doubts respecting it. I have seen a red artery accompany this feather-like production and run to the crystalline. It would be very convenient for physiology that this folded membrane should prove muscular; we should then have the organ sought after, which would retract the crystalline to the bottom of the eye." In the Elementa Physiologiæ, t. v. p. 390, he says it originates from the entrance of the optic nerve, but that you may remove the retina and leave the pecten. He says again, " it advances forward to the posterior part of the capsule, to which it sometimes adheres by a thread, and sometimes the lens is merely drawn toward it." An artery and vein is supplied to each fold, and perhaps to the capsule of the lens. In the *Opera Minora* he says that there are two red vessels to each fold in the kite, and no cord runs to the lens; that in the heron a branch of artery runs to each fold, and it adheres so closely to the lens that it cannot be ascertained whether a red vessel runs from it to the lens or not; that in the duck it is contracted toward the lens, and adheres to it by a thread containing a red vessel. He also says that in the wild duck it arises from the margin of the linea alba, which terminates the entrance of the optic nerve, contains numerous vessels, and adheres to the lens; and in the pie it is large and adheres to the lens, so as to pull it. D. W. Sömmerring says, that in the pecten of the golden eagle, of which *fig.* 128 is a representation, there are fourteen folds like ciliary processes, and that it adheres by a transparent filament to the capsule of the lens; that in the great horned owl it is short and thick, with eight folds, and adhering to the lens by an hyaloid filament, although at a great distance from it; and that in the macaw it is longer than broad, has seven folds, and adheres to the lens. In the ostrich he says it is shaped like a *patella* at its base, which is white, oval, and thick; eight lines long and five broad, distinctly separate from the choroid, above which it rises, the retina being interposed. From the longer diameter of this patella (or base) a white plane or lamina projects even up to the lens, and sends out on each side seven small plaits, the lower ones partly double, the upper ones simple, black, and delicate. This conical body, something like a black purse, tapers toward the lens, and by its apex is attached to the capsule by a short semi-pellucid ligament. The white substance of the base and partition of the pecten should not be confounded with the medullary part of the optic nerve, which, emerging on all sides from beneath the base, expands into a great, ample, and tender retina, terminating behind the ciliary processes with a defined margin. Cuvier, in his Lectures on Comparative Anatomy, says, " It appears of the same nature as the choroid, although it has no connexion with it; it is likewise very delicate, very vascular, and imbued with black pigment. Its vessels are derived from a particular branch of the ophthalmic artery, different from two which belong to the choroid; they descend on the folds of the black membrane and form ramifications there of great beauty when injected. This membrane penetrates directly into the vitreous humour, as if a wedge had been driven into it; it is in a vertical plane directed obliquely forward. The angle nearest the cornea in those species in which it is very broad, and all its anterior margin in those in which it is narrow, comes nearly to the inferior boundary of the capsule of the crystalline. In some species it approaches so near that it is difficult to say whether or not it is attached to it; such is the case in the swan, the heron, the turkey, &c. according to Petit; but there are other birds in which it remains at some distance, and in which it does not appear to attach itself except to some of the numerous plates which divide the vitreous humour into cells. In the swan, heron, and turkey, this membrane is broader in the direction parallel to the produced extremity of the optic nerve than in the contrary direction. In the ostrich, cassowary, and owl the reverse is observed. It is folded like a sleeve in a direction perpendicular to the caudal termination of the optic nerve. The folds are rounded in most species; in the ostrich and cassowary they are compressed and sharp, and so high perpendicular to the plane of the membrane that at first sight it resembles a black purse. The folds vary in number, there being sixteen in the swan, ten or twelve in the duck and vulture, fifteen in the ostrich, and seven in the grand duke or great horned owl.

The purpose for which the pecten exists in the eyes of birds does not appear to be fully ascertained. Petit says, " when a bird views an object with both eyes, the rays enter obliquely in consequence of the situation of the cornea and crystalline lens, and proceed to the bottom of the eye; but as they enter in lines parallel to the membrane, they do not encounter it. The rays which enter the eye in lines perpendicular to the plane of the cornea encounter this membrane, and are absorbed by it as well as those which come from the posterior side; the subject is, however, a difficult one." Haller supposed that it was merely destined to afford a medium through which vessels might pass to carry blood to the crystalline. Cuvier says, " It is difficult to assign the real use of this membrane. Its position should cause part of the rays which come from objects at the side of the bird to fall upon it. Petit believed that it was destined to absorb these rays and prevent their disturbing distinct vision of objects placed in front. Others thought, and the opinion has been lately reiterated by Home, that it possesses muscular power, and that its use is to approach the lens to the retina when the bird wishes to see distant objects. Nevertheless, muscular fibre cannot be detected in it, and the experiments intended to prove its muscularity after death are not absolutely conclusive; moreover, as it is attached to the side of the crystalline, it could move it only obliquely." The experiments and inferences contained in Sir E. Home's paper in the Philosophical Transactions for 1796, do not appear to me worthy of any attention. A pecten in an imperfect or rudimentary state appears to exist in fishes and reptiles, and has been noticed by Haller, W. Sömmerring, and Dr. Knox. In the article Aves of this work Mr. Owen has also described the pecten, and to that article I refer the reader for additional information.

Of the choroid gland or choroid muscle.—The eyes of fishes present several remarkable peculiarities, to be accounted for perhaps from their occasional residence in the obscurity of the deep, and at other times near the surface, exposed to the full blaze of sunshine; they must also be frequently exposed to great pressure at considerable depths. The sclerotic is not merely a fibrous membrane, but is strengthened by a cartilaginous cup, and sometimes even by one composed of bone; the cornea is generally flat or presenting little of lenticular character; the crystalline lens is spherical, and so dense that its central part is a hard solid; and the choroid presents the remarkable peculiarity which I have now to describe.

On cutting through the cartilaginous sclerotic, a fluid is found generally interposed between this and the choroid; at least it is so in the *genus gadus*, (cod, haddock, &c.) The external part of the choroid is formed by a most beautiful membrane of a brilliant silver aspect, scarcely to be distinguished from that metal when rough and recently cleaned. On tearing this membrane away, the vascular choroid is exposed, and a red horse-shoe-shaped prominent mass, encircling the entrance of the optic nerve, appears. This is the choroid gland or choroid muscle. The veins of the choroid, apparently commencing from the iris, ascend in tortuous inosculating branches, of enormous size compared with the dimensions of the part, and appear to terminate by entering this horse-shoe-shaped organ, but this is not their distribution, as it is not hollow. The area enclosed by the organ round the optic nerve does not exhibit the same extreme vascularity. On pulling away a delicate film which covers the organ, it appears composed of *laminæ* or plates divisible into fibres, which run transversely from within outwards, confined into a compact body by the delicate film just spoken of, and a concave depression in the structure beneath. The annexed plate, made from an accurate drawing of a careful dissection, represents the general form and vascularity remarkably well.

Fig. 130.

Haller, speaking of the choroid in fishes, says, "this organ is a fleshy pulp, composed of short columns densely consolidated, resembling red gelatine." Cuvier says, "its colour is commonly a vivid red, its substance is soft and more glandular than muscular; at least fibres cannot be distinguished on it, although the bloodvessels form more deeply coloured parallel lines on its surface. Its form is commonly that of a small cylinder bent like a ring round the nerve, which ring is not, however, complete; a segment of greater or less length is always deficient. Sometimes, as in the *Perca labrax*, it is composed of two pieces, one on each side of the optic nerve. In other cases it is not in a circle but an irregular curve, as in the Salmon, Tetradon mola, and Cod; but in the carps and most other fishes it approaches to to a circle. Those who suppose that the eye changes its figure according to the distance of objects, think that this muscle is destined to produce this effect by contracting the choroid; but it appears to me that the numerous vessels passing out of it should rather lead to its being considered a gland destined to secrete some of the humours of the eye. These vessels are white, fine, very tortuous, and appear to traverse the tunica Ruyschiana; they are well seen in the *Tetradon mola* and *Perca labrax*. In the Cod they are very large, anastomose together, and are covered by a white and opaque mucus. This gland does not exist in the cartilaginous fishes, as the Rays and Sharks, in which it approaches more to the character of the eye in the Mammalia, as has already been observed in speaking of the tapetum and ciliary processes." D. W. Sömmering says, "Around the insertion of the nerve is seen a peculiar red, thick, soft body of a horse-shoe shape, respecting which it is doubted whether it be muscular, glandular, or merely vascular. It is undoubtedly extremely vascular, and contains many large, branching, inosculating vessels, forming a proper membrane gradually becoming thin, and terminating at the iris. This vascular membrane constitutes the second or middle layer of the choroid." This description applies to the eye of the Cod. Sir E. Home, in a Croonian lecture published in the Philosophical Transactions for 1796, says that Mr. Hunter considered the organ in question to be muscular, and proceeds to state that "this muscle has a tendinous centre round the optic nerve, at which part it is attached to the sclerotic coat; the muscular fibres are short, and go off from the central tendon in all directions: the shape of the muscle is nearly that of a horse-shoe; anteriorly it is attached to the choroid coat, and by means of that to the sclerotic. Its action tends evidently to bring the retina forwards; and in general the optic nerve in fishes makes a bend where it enters the eye, to admit of this motion without the nerve being stretched. In those fishes that have the sclerotic coat completely covered with bone, the whole adjustment to great distances must be produced by the action of the choroid muscle; but in the others, which are by far the greater number, this effect will be much assisted by the action of the straight muscles pulling the eye-ball against the socket, and compressing the posterior part, which, as it is the only membranous part in many fishes, would appear to be formed so for that purpose." Although it must be admitted that these conclusions of Sir E. Home are derived from insufficient data, and are probably incorrect in many particulars, yet it is not very improbable that the part in question may be muscular, and, if so, may be instrumental in adapting the eye to distance by pushing up the retina toward the lens. The organization of the part is certainly not merely vascular, as stated by Cuvier, and undoubtedly bears a stronger resemblance to muscular than any other structure; it also retains the peculiar colour of red muscle after all the rest of the eye has been blanched by continued maceration in water. I think, however, Sir E. Home goes too far when he describes a central tendon without reservation.

For further information on the subject of this article, see Vision, and Vision, Organ of.

Bibliography.—In pursuit of information respecting the anatomy of the eye, the student need scarcely go farther back than Zinn's work, or the article on the same subject in Haller's Elementa Physiologiæ. The older anatomical writers were, generally speaking, uninformed on the subject. Ruysch's works contain some observations worthy of attention at the time he wrote, but now scarcely worth recording; especially as he was a vain man, and wrote for present fame and character rather than truth. In Albinus's *Annotationes Academicæ* a few facts are recorded, upon the accuracy of which the student may place reliance, as he was an anatomist. Morgagni also added to the existing information of the period at which he wrote, but has left little more than notes or cursory remarks. Petit's papers in the Mémoires de l'Academie Royale des Sciences contain much original and valuable matter. In this earlier period the contributions of Nuck, Hovius, Briggs, and Leeuwenhoek should not be overlooked. Cotemporary with or immediately following Haller and Zinn, Porterfield, Le Cat, Lieutaud, the second Monro, Blumenbach, Sommerring, and many others made valuable additions to our information on this subject. The annexed list contains the titles of those works which I have consulted; some of the more modern German monographs I have been obliged to quote or consult from those who copied from them, having endeavoured in vain to procure them: such are those of Döllenger, Chelius, Huschke, Jacobson, Kieser, Weber, and some others.

Nuck, Lialographia et ductuum aquosorum anatome nova, Lugd. Bat. 1695. *Warner Chrouet*, De tribus humoribus oculi, 1691. *Hovius*, De circulari humorum motu in oculis, Ludg. Bat. 1716. *Briggs*, Ophthalmographia, Lugd. Bat. 1686. *Leuwenhoek*, Arcana naturæ detecta, Delphis, 1695; or in the Philosophical Transactions, or in the translation of his select works by Hoole, Lond. 1816. *Ruyschii* Thesaurus, Amstel. 1729. *Albinus*, Annotationes academicæ. *Morgagni*, Adversaria anatomica, Ludg. Bat. 1723, and Epistolæ, Venetiis, 1750. *Haller*, Elementa physiologiæ corporis humani, tom. v. Lausanne, 1763; also in Opera minora, and Formation du cœur dans le poulet. *Zinn*, Descriptio anatomica oculi humani, Gotting. 1780, and also in Commentarii Societatis Regiæ Scientiarum Gottingenses, t. iv. 1754. *Petit*, in Mémoires de l'Academie Royale des Sciences, 1723, 25, 26, &c. *Winslow*, Mém. de l'Acad. 1721. *Moeller*, Observationes circa retinam, in Halleri Disputationes anatomicæ select. t. vii. *Camper*, De quibusdam oculi partibus, in Halleri Disp. anat. *Lobé*, De oculo humano, in same. *Wintringham*, On animal structure, London, 1740. *Le Cat*, Traité des Sens, Rouen, 1740. *Bertrandi*, Dissertatio de oculo, in Opero anatomische e cerusiche. *Porterfield*, On the eye, Edinburgh, 1759. *Lieutaud*, Essais anatomiques, Paris, 1766. *Duddell*, Treatise on the diseases of the horny coat in the eye, Lond. 1729. *Descemet*, An sola lens crystallina cataractæ sedes, Paris, 1758. *Demours*, Lettre à M. Petit, Paris, 1767. *Brendel*, De fabrica oculi in fœtibus abortivis, Got. 1752. *Blumenbach*, De oculis leucœthiopum et iridis motu, Gott. 1786. *Wachendorf*, Commercium litterarium, 1744. *Fontana*, Traité sur le venin de la vipère, Florence, 1781. *Walther, J. G.* Epistola anat. ad Wilhelm Hunter, Berolin, 1758. *Sömmering*, Abbildungen des menschlichen Auges, or Icones oculi humani; or translated into French by Demours. *Sömmering*, also in Commentarii Soc. Reg. Gotting. *Monro*, On the brain, the eye, and the ear, Edin. 1797. *Camparetti*, Observationes dioptricæ et anatomicæ de coloribus, visu et oculo, Patavii, 1798. *Sattig*, Lentis crystallinæ structura fibrosa, Halæ, 1794. *Mauchart*, De cornea, in Haller's Disputationes chirurgicæ, or in Reuss Dissertationes Tubingenses. *Dr. Young*, in the Philosophical Tansactions, 1793 et seq. *Home*, in several papers in the Philosophical Transactions, see Index. *Reil*, De structura nervorum, Halæ, 1796. *Rosenthal*, De oculi quibusdam partibus, 1801. *Angely*, De oculo organisque lachrymalibus, Erlang. 1803; or, again, Schreger vergleichenden Anatomie des Auges, Leipzig, 1810. *Baerens*, Systematis lentis crystallina monographia, Tubingæ, 1819, and in *Radius* Scriptores ophthalmologici minores. *Clemens*, Tunicæ corneæ et humoris aquei monographia, Gott. 1816, and in *Radius*, S. O. M. *Sachs*, Historia duorum leucœthiopum, Solisbaci, 1812. *Maunoir*, Sur l'organisation de l'iris, Paris, 1812. *Ribes*, in Mémoires de la Societé Méd. d'Emulation, an 8ième, Paris, 1817. *Chelius*, Ueber die durchsichtige Hornhaut des auges, Carlsruhe, 1818. *Voit*, Oculi humani anatomia et pathologia, Norimbergæ, 1810. *Hegar*, De oculi partibus quibusdam, Gott. 1818. *Cuvier*, Leçons d'anat. comp. *Bell's* Anatomy. *Meckel's* Handbuch d. menschl. anatomie, or the French translation. *Sömmering, D. W.* De oculorum hominis animaliumque sectione horizontale, Gott. 1818. *Knox*, Comparative anatomy of the eye, Trans. Royal Society of Edinburgh, 1823. *Cloquet, J.* Sur la membrane pupillaire, Paris, 1818. *Jacobson*, Supplementa ad ophthalmiatriam, Havniæ, 1821. *Döllenger*, Illustratio ichnographica oculi, Werceburg, 1817. *Weber*, De motu iridis, Lipsiæ, 1828. *Jacob*, in Philosophical Transactions, 1819. *Martegiani*, Novæ observationes de oculo human., Napoli, 1812. *Sawrey*, An account of a newly-discovered membrane in the human eye, Lond. 1807. *Husche*, Commentatio de pectinis in oculo avium potestate, Jenæ, 1827. *Schneider*, Das ende der nervenhaut in menslichen auges, Munchen, 1827. *Kieser*, De anamorphosi oculi, Gott. 1804. *Jacob*, in Medico-Chirurgical Transactions, vol. xii. Lond. 1823. *F. A. ab Ammon*, De genesi et usu maculæ lutræ, Vinariæ, 1830. *Dieterich, F. C.* Uber die verwundengen des linsensystems, Tubing. 1824. *Döllenger*, Uber das Strahlenblaitchen im menschlichen auges in Acta Ph. Med. Acad. Cæsar-Leop. Car. nat. cur. t. ix. *Horrebow, M.* Tractatus de oculo humano, Havniæ, 1792. *Jacob Inuns*, Dissertatio inaug. de oculo, Lugd. Bat. 1820. *Lieblien, V.* Bemerkungen über das system der krystalliense bei Säugthieren und. vogeln. Wurzburg, 1821. *Müller, F.* Anatomische und physiologische darstellung des menschlichen auges, Wien. 1819. *J. Müller*, Zur vergliechenden physiologie des gesichtssines des menschen und der Thiere, Leipsig, 1826. *G. R. Treviranus*, Beitrage zur anatomie und physiologie der Sinnesweikezeuge des

Menschen und der Thiere, 1 Heft. Bremen, 1828. *Wardrop's* Morbid anatomy of the eye. *Dalrymple's* Anatomy of the eye, Lond. 1834. *Mackenzie*, On diseases of the eye. Lond. 1834. *Lloyd*, On light and vision, Lond. 1831. *Biot*, Précis elementaire de physique, Paris, 1824. *Langenbeck, B. C. R.* De retina, Gott. 1836. *Berzelius*, Traité de chimie, Paris, 1833. *Ammon*, Zeitschrift für die ophthalmologie. *Radius*, Scriptores ophthalmologici minores. *Reils*, Archiv. für die physiologie. *Meckel's* Archiv. *F. Arnold*, Untersuchungen über das auge des menschen, Heidelberg, 1832. *Giraldé*, Sur l'organization de l'œil, Paris, 1836. For the latest observations on the retina, see *Ehrenberg*, Beobachtung über Structur des Seelenorgans, Berlin, 1836.

For the comparative anatomy of the eye, which is still imperfect, I refer the student to the paper of Zinn in the Gottingen Commentaries, as above quoted; Bidloo, De oculis et visu; the article on the eye in Haller's Elementa Physiologiæ; Camparetti's observations; Home's papers in the Philosophical Transactions; Knox's Comparative anatomy of the eye; Cuvier's Comparative anatomy; J. Muller, Vergleichende Physiologie des Gesichtsiones; and, above all, to D. W. Sömmering's book. For perfect systematic treatises on the anatomy of the eye, the student is referred to Zinn's well-known and highly valuable work, Arnold's work just quoted, and, in English, Mr. Dalrymple's treatise.

(Arthur Jacob.)

FACE (in anatomy) (Gr. προσωπον; Lat. *facies, vultus, os;* Fr. *face;* Germ. *Antlitz, Gesicht;* Ital. *faccia).*—In vertebrated animals this term is applied to denote the anterior part of the head, with which most of the organs of the senses are connected; while the cranium is destined to contain and protect the encephalic organs, the face is the seat of the organs of sight, smell, and taste, and in some animals of a special organ of touch. The relative sizes of cranium and face depend, therefore, in a great measure on the relative development of those important organs which belong to each. For the characters of the face in the different classes of animals, we refer to the articles devoted to the anatomy of them, and to the article OSSEOUS SYSTEM.

FACE (in human anatomy). The face is situated before and below the cranium, which bounds it above; on the sides, it is limited by the zygomatic arches, behind by the ears and the depression which corresponds to the upper region of the pharynx, and below by the base of the lower jaw and the chin. The disposition of the face is symmetrical; its anterior surface is trapezoidal, the largest side being above; and its vertical section is triangular. It presents an assemblage of organs which serve different purposes, and which by their configuration and proportions constitute what are called the *features;* individually the face presents many varieties, not only in the form and degree of development of its several parts, as the nose, mouth, &c., but also in the condition of its bones, muscles, skin, and adipose tissue. The varieties of form presented by the face afford some of the most distinctive characters of the different races of mankind. It differs also according to the age and sex of the individual; in the infant, the peculiarities depend principally upon the disposition of the bones, and in particular on the absence of the teeth; but the soft parts have also their distinctions at this age, for while the fat is abundant, the muscles are but little developed, and hence the slightly marked features and the plump cheeks of infancy.

In old age, again, the aspect of the face is the reverse of this, for not only do its thinness and the predominance of the muscles throw out the features, but the skin is covered with folds and wrinkles, from its own relaxation and the absence of fat, aided perhaps by the action of the muscles. The loss of the teeth, moreover, allows the lower jaw (when the mouth is closed) to be thrown in front of the upper, and thus the length of the face is diminished, and a peculiar expression is imparted to the countenance.

In women, (from the delicacy of the features and the abundance of the cellular tissue,) the face preserves the roundness of form, and something of the characteristics of childhood.

BONES OF THE FACE.—The bones of the face comprise all those of the skull which do not contribute to form the cavity for the brain; they inclose, either by themselves or in conjunction with the adjacent bones of the cranium, 1. the organs of three senses, viz. sight, smelling, and taste; 2. the organs of mastication and the orifices of the respiratory and digestive canals; 3. they give attachment to most of the muscles of expression.

The face is divided into the *upper* or the fixed, and the *lower* or the moveable *jaw*, both of which are provided with teeth. The *lower jaw* is a single and symmetrical bone; the *upper jaw*, though formed of thirteen bones, consists principally of two, viz. the *ossa maxillaria superiora*, to which the others may be considered as additions, being attached to them immoveably, and forming altogether one large, irregular, and symmetrical piece, which constitutes the upper jaw.

Of the fourteen bones which contribute to the face, two only are single or median; the others are double, and form six pairs, viz. 2 *ossa maxillæ superioris;* 2 *ossa palati;* 2 *ossa nasi;* 2 *ossa malæ;* 2 *ossa lachrymalia;* 2 *ossa turbinata inferiora.* The two single bones are, the *vomer* and the *os maxillæ inferioris.*

The superior maxillary bones, (ossa maxillaria superiora; Germ. *die Obern Kinnbackenbeine oder Oberkiefer.)* These bones, situated in the middle and front of the face, are of a very irregular figure; they are united below along the median line, and form together, the greater part of the upper jaw. Each has *four surfaces*, viz. 1. *a facial* or *anterior;* 2. *a posterior* or *zygomatic;* 3. *an internal* or *naso-palatine;* 4. *a superior* or *orbitar.* The *borders* are three; 1. *an anterior* or *naso-maxillary;* 2. *a posterior* or *pterygoid;* 3. *an inferior* or *alveolar.*

The facial surface presents from before backwards, 1. *the fossa myrtiformis*, a depression situated above the incisor teeth, which gives attachment to the depressor labii superioris: 2. *the canine ridge*, which corresponds to the socket of the canine tooth, and which separates the myrtiform from, 3. *the canine* (or the infra-orbitar) *fossa*, which gives attachment to the levator anguli oris, and at the upper part of which is seen the Infra-orbitar foramen, giving exit to the vessels and nerves of the same name; 4. *the malar ridge*, a semicircular crest which descends vertically from the malar process to the alveolar border of the bone, and divides its facial from its *zygomatic surface*, which is prominent behind, where it forms the *maxillary tuberosity*, most conspicuous before the exit of the last molar tooth, which in the child is lodged within it. On this surface are several small holes, *(posterior dental foramina,)* which are the orifices of canals for the posterior and superior dental vessels and nerves.

From the upper and front part of the anterior surface of the bone a long vertical process (*the nasal process*) ascends between the nasal and lachrymal bones to be united with the frontal; its external surface is rough, presenting small irregular holes, which transmit vessels to the cancellous interior of the bone and to the nose, and giving attachment to the levator labii superioris alæque nasi muscle. The internal surface of this process is marked with some minute grooves and holes for vessels, and, tracing it from below upwards, by a transverse ridge or *crest* (*the inferior turbinated ridge*) for the lower spongy bone; above this by a depression corresponding to the middle meatus; next by a *crest (the superior turbinated ridge)* for the upper spongy bone of the ethmoid; and above this by a surface which receives and completes some of the anterior ethmoid cells. The nasal process has *three borders:* 1. an *anterior*, thin and inclined from above downwards and forwards; above, it is cut obliquely from the internal towards the external surface of the bone, and below in the contrary direction, so that this edge of the nasal process and the corresponding border of the nasal bone with which it is united, mutually overlap each other. 2. A *posterior border*, or surface, thick and divided into two margins by a deep vertical groove (the *lachrymo-nasal canal)* which contributes to lodge the lachrymal sac above, and the nasal duct below. The direction of the lachrymo-nasal canal is curved from above downwards and outwards; so that its convexity looks forwards and inwards, and its concavity in the contrary direction. The inner margin of this groove is thin, and is united above to the anterior border of the os unguis, and below to the inferior spongy bone. The outer margin is bounded and gives attachment to the tendon and to some of the fibres of the orbicularis palpebrarum; it commonly terminates below in a little tubercle (the *lachrymal tubercle)*. 3. The *upper border* of the nasal process, which is short, thick, and irregular, is articulated with the internal angular process of the frontal bone.

The *orbitar surface* of the bone is the smallest; it is quadrilateral, smooth, and slightly concave, with an inclination from above downwards and from within outwards; it forms the greater part of the floor of the orbit. Along the middle of its posterior half runs, in a direction forwards and outwards, the *infra-orbitar groove*, which anteriorly becomes a complete canal (*the infra-orbitar canal)*, and finally divides into an internal or larger canal, which terminates at the infra-orbitar hole in the canine fossa, and into an external or small conduit, which runs in the anterior wall of the antrum, and conveys the superior anterior dental nerves to the incisor and canine teeth; this outer subdivision of the canal presents several varieties in different individuals. The orbitar surface (or plate) has *four borders:* 1. *The posterior*, which, free and notched in the middle by the commencement of the infra-orbitar canal, forms with the orbitar plate of the sphenoid and palate bones *the inferior orbitar* or the spheno-maxillary fissure. 2. *The internal*, which articulates from behind forwards successively with the palate, the ethmoid, and the lachrymal bones. 3. *The anterior*, short and smooth, separates the orbitar from the facial surfaces of the bone; at its inner extremity is the nasal process already described. 4. *The external* is united to the malar bone; on the outer side of this border is a rough triangular projecting surface (the *malar process)* which receives the os malæ, and which forms an angle of union between the anterior, posterior, and superior surfaces of the upper maxillary bone.

The internal or *naso-palatine surface* is divided along the anterior three-fourths into two unequal parts by an horizontal plate of bone (*the palatine process):* above this is the nasal portion forming the upper three-fourths of this surface, and below it, is the palatine part which forms the remaining fourth. The palatine process forms the anterior three-fourths of the floor of the nose, and roof of the mouth; it presents a smooth *upper surface*, concave transversely, and nearly flat in the opposite direction: it is broad behind and narrow in front, where there is placed the orifice of the *anterior palatine canal*, which takes a direction downwards, forwards, and inwards, unites with the corresponding canal in the opposite bone at the median plane, and forms a common canal (*the canalis incisivus)*, which opens below by a hole (*the foramen incisivum)* on the roof of the mouth, immediately behind the middle incisor teeth. The anterior palatine canals and the incisive canal, which are often included together under a common name, form a tube resembling the letter Y, being bifid above and single below. The *inferior surface* of the palatine process is rough and concave, and forms the anterior and larger part of the roof of the mouth; its *internal border* is long and rough, thick in front, narrow behind, and united with the corresponding border of the opposite bone forms the *maxillary suture:* this border is surmounted by a half-furrow which, with that of its fellow bone, forms a groove for the reception of a part of the vomer. The *posterior border* is short and cut obliquely at the expense of the upper surface; it supports the anterior margin of the horizontal part of the palate-bone. The palatine division of the internal surface of the upper maxillary bone is narrow, and forms part of the arched roof of the mouth; along its junction with the palatine process is a broad shallow groove for lodging the posterior palatine nerves and vessels. The nasal portion of the internal surface is placed above the palatine process, and is lined on its anterior three-fourths by the pituitary membrane. Tracing this surface from before backwards we observe, 1. the *lower aperture* of the naso-lachrymal canal, situate just behind the inferior turbinated crest of the nasal process; 2. posterior to this, the *orifice of the maxillary sinus*, or *antrum* of Highmore, which in the separated bone is a large opening, but is contracted in the united face by the lachrymal, the ethmoid, the palate, and the inferior turbinated bones, which are attached around its margin. Above this aperture are seen some cells which unite with those of the ethmoid, and its lower edge presents a *fissure* in which is received the maxillary process of the palate-bone. Below the inferior turbinated crest, the naso-lachrymal canal and the orifice of the antrum, the bone is concave and smooth, and forms a part of the inferior meatus of the nose; behind this smooth surface and the orifice of the antrum, the bone is rough for the attachment of the vertical plate of the os palati, and it presents a *groove*, which, descending obliquely forwards to the palatine division of this surface, forms a part of the posterior palatine canal.

The maxillary sinus (sinus maxillaris, antrum Highmori; Germ. *die Oberkieferhöhle)* occupies in the adult the whole body of the bone: its form is triangular, with the base directed internally towards the orifice which has been already described, and the apex outwards towards the malar process. Its superior wall is formed by the orbitar plate; the posterior corresponds to the maxillary tuberosity; and the anterior to the canine fossa. All these walls present ridges or crests, which lodge canals for the passage of nerves. The posterior and anterior walls contain the *superior*, *anterior*, and *posterior* dental canals, which lodge nerves of the same name. The upper wall contains the infra-orbitar groove and canal, which gives passage to the upper maxillary nerve.

Borders.—1. The *anterior* or *naso-maxillary border* is united above along the nasal process to the nasal bone. Below this it is thin and presents a deep semicircular notch, which forms the lateral and inferior portions of the anterior aperture of the nose. At the lower extremity of this notch the bone projects, and forms with its fellow of the opposite side the anterior nasal spine. The remainder of this border proceeds downwards and a little forwards to terminate on the alveolar border of the bone between the two middle incisor teeth.

2. The *posterior* or *pterygo-palatine* border, thick, rounded, and vertical, is united below to the palate bone, and above it forms, with the palate bone, the anterior border of the pterygo-maxillary fissure.

3. The *inferior* or *alveolar* border is thick and broad, especially behind, and forms about the fourth of an oval. It is perforated with conical cavities *(alveoli)* for the reception of the roots of eight teeth. These cavities are separated by thin transverse laminæ. Tracing them backwards from the anterior extremity of the border, the orifices of the two first are nearly circular, and receive the incisors; they are the largest, and are placed below the nasal notch. The third, in form transversely oval, receives the canine tooth, is of great depth, and ascends in front of the canine fossa. The fourth and fifth, also transversely oval, but not so deep, receive the lesser molar teeth; they generally present ridges in their septa which correspond to grooves in the fangs of the teeth which are implanted into them.

The orifices of the three last cavities are quadrilateral, and receive the molar teeth. The sixth and seventh are subdivided into three lesser cavities, of which the two external are smaller than the inner one. Sometimes one of the molar teeth has four fangs, and then we find its socket subdivided into a corresponding number of cavities. The eighth alveolus, which receives the last molar tooth or dens sapientiæ, is not so distinctly divided into subordinate cavities, but presents ridges like the lesser molar. The outline of the alveolar border is waving, convex where it corresponds to the alveoli, and depressed opposite their septa. The whole of this border is covered by the gums, and presents innumerable pores for the nutritious vessels. The surfaces of the alveoli are also similarly marked.

Connexions.—The upper maxillary articulates with two bones of the cranium, viz. the ethmoid and frontal, and sometimes with the sphenoid by its pterygoid processes, or by an union of the orbitar plates of both bones at the outer extremity of the spheno-maxillary fissure. In this case the malar bone does not enter into the formation of this fissure. The upper maxillary articulates with its fellow and with all the bones of the face. The median and lateral cartilages of the nose are attached to it. It receives the upper teeth, and gives attachment to eight muscles, viz. the orbicularis palpebrarum, the inferior oblique of the eye, the levator labii superioris alæque nasi, the levator labii proprius, the depressor alæ nasi, the compressor narium, the levator anguli oris, and the buccinator; often also to some of the fibres of the temporal and the external pterygoid muscles. It lodges the naso-palatine ganglion, and gives passage to the infra-orbitar and to the anterior and posterior palatine and dental vessels and nerves. It forms the greater part of the sides of the nose, and of the floor of that cavity, and of the orbit, as well as of the roof of the mouth. It contains the maxillary sinus and the nasal duct.

Structure.—This bone is lighter than might be expected from its size, being occupied by the large antrum maxillare. It is cancellous only at the tuberosity, along the alveolar border, and at the malar and palatine processes.

Developement.—The ossification of this bone commences as early as the thirtieth or thirty-fifth day of fœtal life, near its alveolar border, and it is complete at birth. It presents at this period, and often much later, two remarkable fissures. 1. The incisive fissure, which may be traced from the alveolar border between the canine and lateral incisor tooth backwards and upwards, along the incisive canal towards the nasal process: it is seldom observable on the facial surface of the bone. The part of the bone circumscribed by this fissure appears to correspond to the intermaxillary bone of animals, and is probably developed as a separate piece: it supports the incisor teeth. 2. A fissure is often found extending from the infra-orbitar groove forwards to the orifice of the canal. The existence of these fissures has led some anatomists to suppose that the bone is developed by these ossific points.

At birth and in infancy the bone presents a much greater proportion from before backwards than vertically: its nasal process is long, its orbitar plate large, the antrum is already distinct, the tuberosity prominent, and there are some remarkable holes behind the incisor teeth, which are said to have an important connexion with the development of the second set of teeth.

In the adult the increase in the vertical dimensions corresponds with the developement of the antrum and alveolar border. In old age the alveoli are obliterated, the border contracts, and the jaw diminishes in height. In the small vertical diameter the senile and infantile upper jaw bear a resemblance to each other.

In the inferior mammalia, the maxillary bones are separated anteriorly in the middle line by a bone called *os intermaxillare* or *incisivum*, which contains the superior incisor teeth when they are present; sometimes this bone is distinctly divisible into two by suture. This bone is present, although the superior incisors be absent, as in Ruminants and Edentata, but in such cases is very small: on the other hand, when the incisor teeth are largely developed, it is of considerable size, as in the Rodentia. In the mature human fœtus no sign of this bone exists, but in examining the skulls of fœtuses about the third or fourth month of pregnancy, we observe it perfectly distinct from the maxillary bone. It sometimes happens that at more advanced periods, whether of intra or extra-uterine life, evidence of the separation of the intermaxillary bone exists, and as Meckel says, we often find a transverse narrow "*lacuna*" on the vault of the palate, extending from the external incisor tooth to the anterior palatine foramen. According to Weber, however, who examined the extensive collection of fœtal skeletons belonging to Professor Ilg in Prague, the intermaxillary bone was distinct only in those that had a double hare-lip. He considers, however, that the intermaxillary bone readily separates when the skull of a child of one or two years old is placed for some time in dilute muriatic acid.*

The palate bones, (ossa palatina; Germ. *die Saumenbeine,)* situated at the back part of the nose and roof of the mouth, locked between the maxillary bones and pterygoid processes of the sphenoid, consist of two thin plates, one short and horizontal, the *palatine;* the other long and vertical, *the nasal.* The palatine process, or plate, has two surfaces and four borders. The upper surface, or the nasal, is smooth and concave, and forms the posterior fourth of the floor of the nose. The lower surface, the palatine, rough, and slightly concave anteriorly, has on its posterior and outer part a transverse crest with a depression behind it for the attachment of the circumflexus palati muscle. In front and to the outer side of this is the inferior orifice of the posterior palatine canal, behind which are two or three small openings called *accessory palatine holes,* and in front of it is the commencement of the groove which lodges the posterior palatine vessels and nerves.

The *anterior border* is cut obliquely from below upwards and forwards, and rests on the posterior border of the palatine plate of the upper maxillary bone, forming with it the transverse palato-maxillary suture. The *posterior* border, thin and concave, gives attachment to the soft palate.

The *internal* border, rough and thick, is united to its fellow of the opposite side; above, it forms a grooved crest, which receives a part of the vomer, and is continuous with a similar crest formed on the internal border of the palatine plate of the upper maxillary bone. Behind, this border terminates in a sharp point, which, in conjunction with the corresponding projection of the opposite bone, forms the *posterior nasal spine,* to which the levator uvulæ muscle is attached. The *external* border is continuous with the vertical plate.

The *nasal process,* or plate, has two surfaces and four borders. The *internal* or *nasal* presents, tracing it from below upwards, 1. a smooth concave surface, which forms part of the inferior meatus: 2. a horizontal crest, the *inferior turbinated crest,* for the attachment of the inferior turbinated bone: 3. another concave surface forming part of the middle meatus: 4. another horizontal crest (the *superior turbinated crest),* shorter than the former, for the attachment of the middle turbinated bone of the ethmoid. This surface is covered with the pituitary membrane.

The *external* or *zygomato-maxillary* surface is rough in front, where it rests against the upper maxillary bone; behind this the lower two-thirds are marked by a groove, which, in conjunction with one on the upper maxillary bone, forms the posterior palatine canal. Above this, the bone is smooth, and forms the inner and deep part of the pterygo-maxillary fissure.

The *anterior* border, thin and projecting, forms a process (the *maxillary)* which is received into the fissure in the lower edge of the orifice of the maxillary sinus.

The *posterior* or *pterygoid* border is united to the anterior border of the pterygoid process of the sphenoid: below, it becomes broad and is continued along a process which stands

* See Weber in Froriep's Notizen, 1820, quoted in Hildebrandt's Anatomie, B. ii. S. 95.

downwards, outwards, and backwards, from the angle of union of the posterior borders of the vertical and horizontal plates of the bone. This process is the *pterygoid* or *pyramidal*, and presents three grooves behind, viz. one *internal* and one *external*, (of which the inner is the deeper,) for the reception of the anterior borders of the lower extremity of the pterygoid plates; and a *middle* triangular groove extending high up, and which forms a part of the pterygoid fossa. The outer surface of this process is rough, and is articulated with the upper maxillary bone: its apex is continuous with the external pterygoid plate.

The *inferior* border is united to the horizontal plate.

The *superior* border presents a deep semicircular notch (sometimes a hole), which with the sphenoid bone above forms the *spheno-palatine foramen*. This notch divides the upper border into two processes, 1. the posterior (the sphenoidal); 2. the anterior (the orbitar). The sphenoidal process is curved inwards and backwards, and has three surfaces, 1. an internal or nasal, forming part of the cavity of the nose; 2. an external, which forms below the spheno-palatine foramen the deep wall of the pterygo-maxillary fissure; 3. an upper, which is concave and rests against the body of the sphenoid bone, and contributes to the pterygo-palatine canal.

The orbitar process stands upwards and outwards on a narrow neck, and presents five surfaces. 1. The anterior (or maxillary) articulates with the upper maxillary bone. 2. The internal (or ethmoidal) forms a cell which unites with those of the ethmoid. 3. A posterior (or sphenoidal) presents a cell uniting with the sphenoid, and communicating with its sinuses. 4. The superior (or orbitar), which is smooth and contributes to form the floor of the orbit: its posterior border forms a part of the spheno-maxillary fissure, and separates the orbitar surface from, 5. the external or zygomatic, which looks into the pterygo-maxillary fissure.

Connexions.— Each palate bone articulates with five bones, viz. two of the cranium, the sphenoid and the ethmoid; and with three of the face, the upper maxillary, the inferior turbinated, and the vomer, besides its fellow bone of the opposite side. It is lined with the buccal and pituitary membrane. It contributes to form the cavities of the mouth, nose, and orbit; the pterygo-maxillary fissure, and the zygomatic and pterygoid fossæ. It gives attachment to the soft palate, and passage to the spheno-palatine, pterygo-palatine, and posterior palatine vessels and nerves; also to the two pterygoid muscles, the circumflexus palati, the levator uvulæ, the palato-glossus, and the palato-pharyngeus.

The *structure* is compact, except at its pterygoid process, where it is cancellous.

Developement.—It is complete at birth, except that the vertical plate is short to correspond with the short vertical diameter of the upper maxillary. About the third month ossification appears in a single point, at the junction of the two plates with the pyramidal process.

Malar bones (ossa malæ v. malaria v. zygomatica; Fr. os de la pommette; Germ. die Jochbeine oder Backenbeine).—These bones, corresponding in situation to the prominence of the cheeks, are somewhat of a quadrilateral figure. Each presents three surfaces; 1. *an external* or *facial; 2. an internal* or *temporo-zygomatic; 3. a superior* or *orbitar*. There are besides four borders and four angles.

The *facial surface* forms the eminence of the cheek, looks outwards and forwards, is smooth and slightly convex in front, and is marked by one or more small holes *(malar foramina)*, which give passage to vessels and nerves. It is covered above by the integuments and the orbicularis palpebrarum, and below and externally it gives attachment to the zygomatic muscles.

The *temporo-zygomatic surface* is smooth and concave below; and internally there is a rough surface which rests on the malar process of the upper maxillary: about the centre or towards the upper part of this surface is observed the internal orifice of a malar canal or a malar hole. The temporal muscle is attached to this surface.

The *orbitar surface* is smooth, concave, and is formed upon a plate of bone *(the orbitar process)*, which stands inwards, and contributes to the outer wall and floor of the orbit: its opposite surface above makes part of the temporal fossa. On the orbitar surface we observe the orifice of a malar canal. The orbitar process has an irregular summit, which receives the frontal bone; below, it is articulated with the outer border of the orbitar plate of the sphenoid; in the middle it corresponds to the extremity of the spheno-maxillary fissure; and inferiorly it is united to the outer border of the orbitar plate of the upper maxillary bone.

Of the four borders two are anterior and two posterior. The anterior superior, or the *orbitar*, is smooth, concave, and forms the outer and lower third of the base of the orbit. The anterior inferior, or the *maxillary*, rests upon the malar process of the upper maxilla from its extremity to the inferior orbitar foramen. The posterior superior, or *temporal* border, is waved like the letter S, and gives attachment to the temporal fascia. The posterior inferior, or *masseteric* border, is thick, and gives attachment to a muscle of the same name. The four angles are, 1. thick, rough, superior or frontal, which receives the external angular process of the frontal bone; 2. the interior or orbitar, which is pointed; and, 3. the inferior or malar, which is round, and forms the extremities of the maxillary border, and which rests on the malar process of that bone. The posterior or zygomatic is cut obliquely from above downwards and backwards, and supports the zygomatic process of the temporal bone.

Connexions.—The malar is connected with and locked between four bones, viz. the frontal, the sphenoid, the upper maxillary, and the temporal. It contributes to form the orbit, the temporal, and the zygomatic fossæ. It gives attachment to four muscles, viz. the temporal, the masseter, and the two zygomatic; and it gives passage to malar vessels and nerves.

The *structure* is compact, except near its upper and lower angles, where there is some cancellous tissue.

Developement.—Its ossification commences in one piece about the fiftieth day, and is completed at birth, when the bone appears thicker, and its orbitar plate larger in proportion than in the adult: its vertical diameter is, however, narrow, and the malar holes are large.

The nasal bones (ossa nasi; Germ. *die Nasenbeine)* form the upper part of the nose, and are placed between the nasal processes of the upper maxillary and below the frontal bones, inclining from above downwards and forwards. They have two surfaces, and their form is quadrilateral, the vertical exceeding the transverse diameter. They are stout and narrow above, and thin and broader below.

The *anterior* or *cutaneous* surface is smooth, covered by the integuments and pyramidalis muscle, concave from above downwards, convex transversely. An oblique hole for the passage of vessels is usually found above the centre of one or both nasal bones, and some smaller foramina are scattered over the surface.

The *posterior* or *pituitary* surface is concave, narrow, especially above, and lined by the olfactory membrane, presenting grooves for vessels and the internal orifice of the canal (or hole) mentioned above.

The borders are four: a *superior*, short, thick, dentated, inclined from above downwards and backwards, and resting on the nasal notch of the frontal bone between its two internal angular processes: the *inferior* border, longer than the preceding, thin, jagged, inclining from the median line downwards and outwards, and generally presenting about its centre a slight notch for the passage for a filament of the nasal nerve. This border forms the upper and front part of the anterior opening of the nasal fossæ, and gives attachment to the lateral cartilages of the nose. The *external* border is the longest, and is cut obliquely for its articulation with the nasal process of the upper maxillary bone. The *internal* border is shorter, thick and rough above, and thin below: it forms, on the inner aspect of the bone, in conjunction with the corresponding part of the bone of the opposite side, a ridge and groove for the reception of the nasal process or spine of the frontal bone, and for the upper and anterior border of the perpendicular plate of the ethmoid.

Connexions.—The nasal bones articulate with each other, with the frontal, ethmoid, and upper maxillary bones, and with the lateral cartilages of the nose: they form a part of the cavity of the nose.

Their *structure* is cancellous and thick above, thin and compact below.

Developement.—They are perfectly ossified at birth, when they are proportionally longer than in the adult, corresponding in this respect with the depth of the orbit and the smallness of the anterior aperture of the nose. The ossification of each nasal bone commences by a single point about the beginning of the third month.

The *lachrymal bones (ossa unguis* v. *lachrymalia;* Germ. *die Thränenbeine)* are quadrilateral in form, thin, semitransparent, and are situated on the anterior part of the inner wall of the orbit between the ethmoid, frontal, and upper maxillary bones; they derive one of their names from the resemblance which they bear to a finger-nail. Each bone presents two surfaces and four borders.

The *external or orbitar surface* is divided at its anterior third by a *vertical crest,* terminating below in a little curved process which forms the outer wall of the upper orifice of the nasal canal; in front of this crest the bone is perforated with numerous little holes, and its surface is concave and forms with that of the nasal process of the upper maxilla the canal for the lachrymal sac. The posterior part of this surface is smooth, nearly flat, and is continuous with that of the os planum of the ethmoid, which lies immediately behind it.

The *internal or ethmoidal surface* is rough, and is divided by a vertical groove, which corresponds to the crest on the orbitar aspect of the bone; the anterior division is convex and forms part of the middle meatus; the posterior division is in contact with the ethmoid and contributes to close its cells.

Of the *four borders,* the *superior* is the shortest and thickest; it is irregular and articulates with the inner border of the orbitar plate of the os frontis. The *inferior* is divided into two parts by the lower extremity of the crest already described on the anterior surface of the bone; in front of this the border descends along a thin process or angle of the bone, which is articulated with the inferior turbinated bone, and contributes to form the inner wall of the canal for the nasal duct; behind, this border is broad, and rests on the inner margin of the orbitar plate of the upper maxillary bone. The *anterior border* is slightly grooved for the reception of the inner margin of the posterior border of the nasal process belonging to the upper maxilla. The *posterior border* is thin and articulates with the anterior edge of the os planum. The os unguis has four angles, of which the anterior inferior is remarkable for its length.

Connexions.—This bone articulates with the frontal, the upper maxillary, the ethmoid, and the inferior turbinated; it contributes to form part of the orbit of the cavity of the nose and of the groove for the lachrymo-nasal duct. It gives attachment to the reflected portion of the tendon of the orbicularis palpebrarum, and to the tendon of the tensor tarsi muscles.

In *structure* it is thin and compact.

Development.—It is complete at birth, except at its posterior superior angle, where there is a deficiency between it and the frontal and ethmoid bones, and where a separate piece is sometimes formed. It is broader from back to front in proportion, at this period of life, than in the adult, and its lachrymal groove is larger. Its ossification commences by a single point between the third and sixth months.

A small lachrymal bone has been described as sometimes found at the lower part of the os unguis; and not unfrequently some separate pieces are found at its angles, formed either from the ethmoid or from the orbitar plate of the upper maxillary bone.

The *inferior turbinated bones, (ossa spongiosa v. turbinata infima;* Germ. *die untern Muschelbeine)* of an oval form, thin and spongy in their appearance, are placed horizontally along the lower part of the outer wall of the nasal cavities, separating the middle from the inferior meatus, and contributing to increase the surface of the nose. Each bone presents *two surfaces, two borders,* and *two extremities.* The *internal surface* is rough, convex, and looks towards the septum of the nose, which it sometimes touches on one side when that partition inclines more than usually to the right or left. The *external surface* is concave, exhibiting many small fossæ or pits; it looks towards the upper maxilla and forms a part of the inferior meatus. Both surfaces are very irregular or spongy and are pitted by vessels, but especially by veins, which ramify abundantly upon them. The *inferior border* is convex and thick, particularly at its centre, where it descends towards the floor of the nose. The *upper border* is thin and irregular, and presents from before backwards, 1. a thin edge, which is attached to the inferior turbinated crest on the nasal process of the upper maxilla; 2. a process *(the lachrymal)* which ascends towards the curved process of the os unguis, with which and with the adjacent part of the upper jaw-bone it unites to complete the canal for the nasal duct; 3. some irregular projections *(ethmoidal processes)* which ascend and unite with the ethmoid; 4. a thin, curled, dog's-ear-looking process (the *auricular* or *maxillary),* which, descending and overhanging the internal surface of the bone, is attached to the lower part of the opening of the antrum, which it contributes to circumscribe; 5. an edge which is articulated with the inferior turbinated crest of the palate-bone. The orifice of the antrum is situated just above the centre of this border, and opens consequently into the middle meatus.

The *extremities* or *angles* are formed by the union of the two borders; the *posterior* extremity is more pointed than the *anterior.*

Connexions.— Each inferior turbinated is united with four other bones, viz. the upper maxillary, the lachrymal, the ethmoid, and the palate. It is covered with the pituitary membrane; it contributes to enlarge the surface of the nasal cavity, and to form a part of the nasal canal and middle and lower meatus.

Its *structure* is compact.

Its *development* commences at the fifth month by a single point of ossification.

The *vomer* (Germ. *das Pflugscharbein)* is of a quadrilateral figure, and resembles a ploughshare; it is a single and symmetrical bone, situated in the median plane, and forming the posterior and inferior part of the septum nasi. It has *two lateral surfaces* and *four borders.* The surfaces, which are right and left, are smooth, flat, and lined by the pituitary membrane; sometimes, when the bone inclines much to either side of the nose, one of these surfaces is convex and the other concave; they present an oblique groove or grooves for the naso-palatine nerves and vessels.

The *superior border* (or surface) is broad, and may be termed the base of the bone; it presents a deep groove in the middle, which receives the rostrum of the sphenoid, and on each side of this are two plates or laminæ (sometimes called the alæ) which are received into fissures of the sphenoid on each side of the rostrum, and which contribute to form a longitudinal canal for the ethmoidal vessels.

The *anterior border* is oblique from above downwards and forwards; above it presents a deep groove, which is a continuation of that on the upper border, and which receives the perpendicular plate of the ethmoid: below, this border is nearly flat, where it is united to the middle cartilage of the nose.

The *inferior border* is the longest, and is received into the grooved crest formed by the united palatine plates of the superior maxillary and palate bones; in front this border extends as far as the anterior nasal spine.

The *posterior border,* thick above, thin below, is oblique, slightly curved, and forms the partition between the two posterior openings of the nose.

Connexions.—The vomer is connected with four bones, viz. the sphenoid and ethmoid above, the superior maxillary and palate below: it is covered with the pituitary membrane, and forms, with the perpendicular plate of the ethmoid and the middle cartilage, the septum of the nose.

Its *structure* is compact, and it is formed of two thin lateral plates, which are distinct above, but united inferiorly.

Its *development* occurs by a single ossific point about the third month, and at birth it is completely ossified.

The os maxillare inferius (Germ. *das untere Kinnbackenbein, oder der Unterkiefer).* This single bone, which alone forms the lower jaw, occupies the lower and lateral parts of the face; it is a flat, symmetrical bone, and bears some resemblance in shape to a horse-shoe. It consists of a middle or horizontal portion (the *body),* and of two lateral ascending branches (the *rami*), which are connected with the body nearly at right angles.

The *body* is curved, nearly horizontal, inclining from before backwards, and a little upwards, and presents *two surfaces* and *two borders.*

The *anterior surface* is convex, and has in the centre a vertical line *(crista mentalis externa),* which marks the union of the two halves of which the bone consists in the young subject: this line terminates below in a triangular eminence (the *mental process).* The vertical direction of the lower jaw at the symphysis, and its curved figure anteriorly, forming what is termed the chin, are both characteristic of the human race. From the angles of the mental process arises on each side the *external oblique line,* faintly marked in front, but becoming distinct as it ascends diagonally along this surface of the bone to terminate at the anterior border of the ramus of the jaw; it gives attachment to muscles and separates the external surface of the bone into two parts, viz. an anterior superior, which presents, external to the symphysis, 1. a depression (the *fossa mentalis*) for the attachment of a muscle; 2. to the outer side of this the *mental foramen*, which is directed obliquely upwards and outwards; it is the lower orifice of the *inferior dental canal*, which conveys nerves and vessels to the teeth of the lower jaw; 3. a number of ridges and grooves near the alveolar border of the jaw, which correspond to the sockets of the teeth and to the septa which divide them: this part of the bone is covered by the gums. The surface below and behind the oblique line is smooth, or only faintly marked with irregular lines for the attachment of the platysma myoides.

The *internal surface* of the body of the lower jaw is concave, and presents in the median line, at the symphysis, a vertical crest (*crista mentalis interna*), which is not so distinct as the corresponding ridge on the outer surface of the bone: at its lower extremity is a tubercle having four summits (*the genial processes, γένειον, chin, spina interna,*) which give attachment to two pairs of muscles, viz. the two superior genial processes to the genio-hyo-glossi, the two inferior to the genio-hyoidei: below and to the outer side of these processes, on the lower border of the bone, are two oval rough depressions, one on each side of the symphysis, for the attachment of the anterior bellies of the digastric muscles. From the genial processes proceeds obliquely upwards and backwards, to join the anterior border of the ramus of the jaw, the *internal oblique line*, or the *mylo-hyoid ridge*. It is distinctly marked and very prominent opposite the last molar tooth; like the external oblique line it divides the bone diagonally into two triangular portions, the anterior of which, situated above and in front of the ridge, is smooth, concave, and to the outer side of the genial processes presents a depression (*sublingual fossa*) for the reception of the sublingual gland: elsewhere this surface is lined by the gums, and forms the inner wall of the alveolar cavities; but it is destitute of the ridges and depressions which are seen on the outer surface of the bone. The triangular surface below the oblique line is marked by numerous small holes for the passage of nutritious vessels, and by a large depression (*the submaxillary fossa*) for the reception of the submaxillary gland. The two oblique maxillary lines which have been just described divide the body of the jaw into two portions, one superior or alveolar, the other inferior or basilar: in the fœtus the former predominates considerably; in the adult they are nearly equal, and in the edentulous jaw of old age the body almost entirely consists of the basilar portion.

The *upper or alveolar border* forms a lesser curve than that of the alveolar border of the superior maxilla: like it, however, it presents sockets for the reception of sixteen teeth, which vary also in form and depth in correspondence with the fangs of the teeth which they lodge. The orifices of the sockets, however, take a direction different from those of the upper jaw, for while the sockets of the upper incisors look downwards and forwards, those of the lower are directed upwards and backwards; and again the alveoli of the upper canine and molar teeth look downwards and outwards, whereas those of the lower are directed upwards and inwards: hence, from this different inclination of the teeth in the two jaws, and from the larger curve described by the alveolar border of the superior maxilla, we find that when the mouth is closed the upper front teeth cover the lower and at the sides overhang them a little. This arrangement is favourable to the division and mastication of the food.

The *lower border* or base is smooth and thick, and forms a larger curve than the upper, so that the surfaces of this jaw have an inclination from above downwards and forwards: it forms the oval border of the lower part of the face, and is the strongest portion of the bone.

The *rami* are flat, quadrilateral processes, which stand up from the body of the jaw at almost a right angle: in the child and old person this angle is much more obtuse. Each ramus presents two surfaces and four borders.

The *external* or *masseteric* surface has an inclination from above downwards and more or less outwards: it is rough, especially below, where it presents some irregular oblique ridges and depressions for the attachment of the masseter: in front of these marks, near the lower border of the bone, there is often a slight groove, which indicates the course of the facial vessels.

The *internal* or *pterygoid* surface is also rough below for the attachment of the internal pterygoid muscle. In its centre is the spreading superior orifice (*superior dental foramen*) of the *lower dental* canal, marked and partly hidden internally by a spine, which gives attachment to the internal lateral ligament of the temporo-maxillary articulation: from this hole, taking a direction downwards and forwards is a groove (the *mylo-hyoid groove*), which lodges the branch of the inferior dental artery and nerve.

The borders of the rami are, an *anterior* or buccal, grooved below, where it corresponds with the alveolar border of the bone; the margins of this groove, which are continuous with the oblique lines of the bone, unite above and form a sharp convex edge. The *posterior* or parotid border is round and thick above, and narrow below, and is embraced by the parotid gland: inferiorly and internally it gives attachment to the stylo-maxillary ligament. The *superior* or zygomatic border is sharp and concave, forming a notch (*the sigmoid notch*), which looks upwards. The *inferior* border is rounded, and is continuous with the lower border of the body.

The *angles* of the lower jaw are formed by the union of the body and rami; each is turned a little outwards, and in the adult forms nearly a right angle; in the infant and in the old person it is obtuse. This part of the bone is prominent and separates the insertion of the masseter and internal pterygoid muscles.

On the upper part of each ramus stand two processes, which are separated by the sigmoid notch; the anterior is the *coronoid*, which is of a triangular form, flattened laterally, and sharp in front and behind; its summit is somewhat rounded: this process gives attachment to the temporal muscles. The *condyloid* process is situated behind the sigmoid notch, and arises from the ramus by a narrow *neck*, which is directed upwards and a little inwards, swelling above into an oval head or condyle, that has an articular surface on its summit. This articular surface is transversely oval, convex, covered in the recent subject with cartilage, and inclines from within outwards and a little forwards. The condyle, from the direction of its neck, somewhat overhangs the internal surface of the ramus; it is articulated with the anterior division of the glenoid cavity of the temporal bone. The direction and form of its articular surfaces are calculated to facilitate the rotatory movements of the lower jaw during mastication. In front the neck of the condyle presents a depression for the attachment of the external pterygoid muscle.

Structure.—The lower jaw is formed of two complete plates, united by cancellous tissue, which is traversed by a long curved canal (the *inferior dental canal)*, which conveys the vessels and nerves that supply the teeth. This canal commences in a groove just above the superior dental foramen, which is situated on the internal surface of the ramus; it then enters the substance of the bone, taking the course of the internal oblique line below, and parallel to which it runs as far as the second bicuspid tooth, where it divides into two canals, one short and wide, which terminates on the external surface of the bone at the inferior dental foramen; and another smaller one, which continues onwards as far as the middle incisor tooth, where it ceases. From the upper side of this dental canal small tubes arise, which proceed to the alveoli; they convey vessels and nerves to the fangs of the teeth. The situation and size of the dental canal vary according to the age of the individual. At birth it runs near the lower border of the bone, and is of considerable magnitude; after the second dentition it becomes placed just below the mylo-hyoid ridge; in the edentulous jaw it runs along the alveolar border of the bone, its size is much diminished, and the mental foramen is found close upon the upper border of the bone.

Connexions and uses.—The lower jaw is articulated with the temporal bones, and receives the sixteen inferior teeth. It gives attachment to fourteen pairs of muscles, viz. the temporal, the masseter, the two pterygoids, the buccinator, the superior constrictor of the pharynx, the depressor anguli oris, the depressor labii inferioris, the levator menti, the platysma, the genio-hyo-glossus, the genio-hyoideus, the mylo-hyoideus, and the digastric. Four pairs of ligaments are attached to it, viz. the external and the internal lateral ligaments of the temporo-maxillary articulation, the pterygo-maxillary (or intermaxillary) ligament, and the stylo-maxillary ligament. It forms the lower part of the face and the cavity of the mouth; it protects the tongue, salivary gland, and pharynx; it differs from the upper jaw and from all the other bones of the head in its remarkable mobility; and it contributes essentially to mastication as well as to deglutition and articulation.

Development.—The lower jaw at birth consists of two lateral halves, which are united vertically in front along the median line by a piece of cartilage, forming what has been improperly called a symphysis. A few months after birth the removal of this cartilage commences, and the two halves of the bone become united below; but not unfrequently a fissure remains above for several months. At this period the alveolar border is, like that of the upper jaw, very thick, and contains some large irregular cavities which lodge the first set of teeth. Besides the superior dental foramen there is found in the fœtus another, which leads to a temporary canal that supplies the first set of teeth, and behind the alveoli of the incisors may be observed a row of holes which are said to be connected with the development of the second set of teeth. Some authors maintain that each side of the lower jaw is developed by four separate points of ossification; but this assertion wants confirmation. It is certain that this bone is among those which are the most early developed, and in the embryo of two months it is already of considerable size. Its alveolar border is at first a mere groove, of which the internal margin is defective, and which gradually becomes hollowed into separate sockets as the teeth are developed. The changes of form which the lower jaw undergoes from birth till old age depend chiefly upon the development and decay of the teeth. Some of these changes have been already noticed, and will be found to correspond with those which occur in the alveolar border of the upper maxilla; the varying form and direction of the rami and angles of the lower jaw we have noticed, and for the more detailed account of the development of this bone as connected with dentition, we refer to the article TEETH.

Of the face in general.—*Dimensions.*—The *vertical diameter* of the face is the greatest, and extends in front from the nasal eminences of the frontal bone to the lower border of the symphysis menti; this diameter decreases as we trace it backwards. The *transverse diameter* is next in length if measured at the level of the malar bone, where it is most considerable; below and above this it gradually diminishes. The *antero-posterior diameter* is greatest at the level of the cheek-bones, where it extends from the cuneiform process of the occipital bone to the anterior nasal spine of the upper maxilla; this diameter also diminishes both above and below, but more especially below, where it comprises merely the thickness of the mental portion of the lower jaw.

The bones which form the upper jaw are united with those of the cranium above by a very irregular surface; below they are on a level with the occipital foramen, and hence that part of the face which descends below the cranium is formed exclusively by the lower jaw.

The area of the face, as presented by a vertical longitudinal section of the skull, is of a triangular figure, and forms (the lower jaw excepted) in the European about one-fifth of the whole area of the skull; in the Negro the area of the face increases in proportion, and forms two-fifths of the whole.

The bones of the face form, when united, a pyramid with four irregular surfaces or regions, and presenting a base above, which is connected with the cranium, an apex below at the chin.

The *anterior surface* or facial region presents many varieties of form and proportion in different individuals, as well as others more important, which characterise the various races of mankind: (see the article Man.) This region is bounded above by the lower border of the frontal bone, extended between its two external angular processes: laterally it is limited by lines drawn from these processes to the anterior inferior angles of the malar bones: below this it follows the curve of the malar ridge of the upper maxilla, and it terminates at the outer extremity of the base of the lower jaw. This surface presents from above downwards along the median line, the fronto-nasal suture, which is continued laterally into the fronto-maxillary and fronto-ethmoidal sutures, all contributing to form the common transverse facial suture which unites the bones of the cranium and face. Below the fronto-nasal suture the nasal bones, united by the *nasal suture,* form the prominent arch of the nose in conjunction with the nasal processes of the upper maxillary bones, with which the ossa nasi articulate on each side by the naso-maxillary suture. Below the nasal bones is the anterior orifice of the nasal fossæ, of a pyriform shape, narrow above, broad inferiorly, where it terminates in the projecting anterior nasal spine: the margins of this orifice are sharp, and are formed by the nasal and upper maxillary bones. Below the nasal spine is the intermaxillary suture, which terminates on the alveolar border of the upper jaw between the middle incisor teeth: on each side of this suture is the myrtiform fossa. On the lower jaw is observed, in the median line, the mental ridge and process, and on each side of it a depression for muscles.

The facial region presents from above downwards, on each side, the aperture or base of the orbit, of a quadilateral form, and inclining from within outwards and a little backwards. The margin of this opening is formed above by the supra-ciliary ridge of the frontal bone, in which is observed the supra-orbitar notch or foramen. At the outer extremity of this ridge is the fronto-jugal suture, uniting the external angular process of the frontal bone with the frontal process of the malar: below this is the prominence of the cheek and the curved orbitar border of the malar bone, forming the outer and lower part of the margin of the orbit. Internal to this we find the short orbitar border of the upper maxillary bone, which presents at its nasal end the groove for the lachrymal sac. Below the inferior border of the orbit is the infra-orbitar foramen, to the outer side of which is the oblique jugo-maxillary suture, and below it the canine fossa, bounded externally by the malar ridge, in front by the canine ridge and the anterior orifice of the nose, and below by the alveolar border of the jaw and by the teeth. On the lower jaw we find the teeth, the alveolar ridges and depressions, the mental foramen, and the external oblique line.

The *posterior* or *guttural surface* consists of three parts, two of which, the upper and lower, are vertical; the middle is horizontal. The upper vertical portion presents along the median line the oblique posterior border of the vomer, which divides the posterior apertures of the nasal fossæ; above is the articulation formed by the base of the vomer and the sphenoid; below is the posterior nasal spine formed by the united palate bones. At the sides of the vomer are the oval posterior orifices of the nose, greatest in their vertical diameter, and bounded superiorly by the sphenoid and sphenoidal processes of the palate bones, inferiorly by the palatine plates of the same bones, internally by the vomer, and externally by the pterygoid processes. On the outside of these apertures are placed the pterygoid fossæ, formed by the pterygoid plates of the sphenoid and by the pyramidal process of the palate bone. External to these are the large zygomatic fossæ or spaces, which belong to the lateral regions of the face.

The *horizontal* portion of this surface is oval, concave, rough, and forms the roof of the mouth, consisting of the palatine plates of the palate and upper maxillary bones, on which is seen a crucial suture, formed by the longitudinal and transverse palatine sutures. At the posterior and outer angles of this horizontal portion are situated the posterior palatine canals and the grooves which proceed from them along the roof of the mouth; on the inferior surface of the palate bones are ridges and depressions for the attachment of muscles, while behind the middle incisor teeth is placed the anterior palatine foramen. At the sides and in front the palatine arch is bounded by the alveolar border and teeth of the upper jaw, behind which descend the pterygoid processes of the sphenoid and palate bones.

The inferior vertical division of this region is formed by the inner surface of the lower jaw and teeth; it presents in front, along the median line, the inner mental ridge, and the genial processes; external to these the internal oblique lines, the sublingual and submaxillary fossæ, the superior dental foramen, its groove and process; the condyles and angles of the jaw, its alveolar border and its base, which terminates it below, and near which, at the chin, are seen the depressions for the digastric muscles.

The *lateral or zygomatic surfaces* on each side are bounded above by the temporal border of the malar bone and by the zygomatic arch; in front by a line extended vertically from the external angular process of the frontal bone to the base of the lower jaw, and behind and below by the free border of the body and ramus of the inferior maxilla.

This region presents a superficial and a deep portion: the former comprises the lateral aspect of the malar bone, the zygomatic arch, and the external surface of the ramus of the jaw. On it we may remark, proceeding from above downwards, the temporal border of the malar bone and zygoma, forming the outer boundary of the temporal fossa; the external malar holes, the zygoma and its suture, which unites the malar and temporal bones; the inferior or masseteric border of the zygoma, the sigmoid notch of the lower jaw and the outer surface of its ramus, coronoid and condyloid processes and angle. The deeper division of this region presents the large zygomatic fossa, and is situated internal to the ramus of the jaw, which forms its outer boundary, and which must be removed to expose it completely: this done, the fossa is brought into view, bounded in front by the posterior surface of the upper jaw and part of the malar bone; superiorly by the inferior surface of the great wing of the sphenoid below its temporal ridge; at this part of the fossa are seen the spheno-temporal suture, the spinous process, and the spinous and oval foramina of the sphenoid bone. The narrow inner boundary is formed by the external pterygoid plate of the sphenoid; behind and below the fossa is open. At the bottom of the zygomatic fossa is situated the pterygo-maxillary fissure, forming the external orifice of the spheno-maxillary fossa, which is a cavity situated between the tuberosity of the upper jaw in front, and the pterygoid process and palate bone behind: in this fossa are five holes, viz. three which open into it from behind, the foramen rotundum, the vidian or pterygoid, and the pterygo-palatine; one opening internally at the upper part; the spheno-palatine; one below, the upper orifice of the posterior palatine canal. The zygomatic fossa presents also at its upper and anterior part, the spheno-maxillary fissure, which is directed from within outwards and forwards, and is formed internally by the orbitar processes of the palate and upper maxillary bones, externally by the orbitar plate of the sphenoid, and at its outer extremity, which is large, by the malar bone; it forms a communication between the orbit and the zygomatic fossa. Its inner end joins the sphenoidal and the pterygo-maxillary fissures, with the former of which it forms an acute, and with the latter, a right angle: thus these three fissures may be considered as branching from a common centre at the back of the orbit; they give passage to a number of vessels and nerves, and establish communications between the cavities of the face and cranium.

The *superior* or *cranial region* is very irregular, and is immoveably united to the cranium. It presents along the median line, from before backwards, the articulation of the nasal bone, with the nasal spine of the frontal, the union of this spine with the perpendicular plate of the ethmoid, the articulation of this plate with the vomer, the articulation of the vomer with the sphenoid.

Along the sides, from within outwards, are seen the arched roof of the nasal fossæ formed in front of the nasal bones, in the middle by the cribriform plate of the ethmoid, and behind by the body of the sphenoid. External to these parts are found the base of the pterygoid process, the articulation of the palate with the body of the sphenoid bone, the pterygo-palatine canal, the spheno-palatine foramen; next the spongy masses of the ethmoid united behind with the sphenoid, and anteriorly with the os frontis; and still more forwards are seen the articulations of this bone with the lachrymal, upper maxillary, and nasal. To the outer side of these articulations is the triangular roof of the orbit, limited externally by the sphenoid and malar bones and by the sphenoidal fissure. Next may be observed the orbitar plates of the sphenoid, forming the greater part of the outer wall of the orbit, and lastly the zygoma. The inner border of the orbitar plate of the frontal bone presents the fronto-lachrymal and the frontal-ethmoidal sutures; the outer border the spheno-frontal and fronto-jugal sutures.

The *internal structure* of the face appears to be very complex, presenting several cavities and divisions which give it at the same time strength and lightness. The arrangement of these parts may be understood by observing, 1. the *perpendicular septum* formed by the ethmoid and vomer, which divides the upper part of the face into two equal halves; 2. in each half *three horizontal divisions*, viz. an upper or frontal, which separates the cranium from the orbit; a middle or maxillary, placed between the orbit and the cavity of the nose, and an inferior or palatine situated between the nose and mouth; 3. *three outer divisions*, viz. an upper or spheno-jugal, forming the outer wall of the orbit, and separating that cavity from the temporal fossa; a middle, formed by the maxillary tuberosity which separates the cavity of the nose from the spheno-maxillary and zygomatic fossæ; an inferior, formed by the ramus of the jaw; 4. above and at the centre the ethmoid and lachrymal bones separate the orbits from each other and from the cavities of the nose.

The principal *cavities* of the face are the orbits, the nasal fossæ, and the mouth; and with these all the rest are more or less connected. These cavities will be described under the several articles, Orbit, Nose, Mouth.

Mechanism of the face.—The face forms a structure which combines both strength and lightness; the former quality is owing to the arched form of its exterior and to the strong pillars of supports (to be presently described) which connect its different parts to each other and to the cranium. The lightness of the face depends upon the thinness of some of its bones, and the large cavities which it comprises. The two upper maxillary bones form by their alveolar border and palatine arch a strong platform, from which ascend five osseous pillars; one median, formed by the vomer and the perpendicular plate of the ethmoid; two at the sides of the nose, formed by the nasal process of the superior maxilla; and at the lateral parts of the face two others, formed by the malar processes of the upper jaw and the malar bones. All these pillars connect the upper jaw with the bones of the cranium, and contribute by their form, strength, or extent of articulation to resist or diffuse the concussion of violent blows applied to the face. The strength of the lower jaw depends upon its arched form and upon its mobility, but, from its exposed situation, it is notwithstanding frequently broken.

Development of the face.—The development of the face consists not merely in its general increase, but in the relative proportion of its several parts at different periods of life. As the face contains the organs of sight, smell, and taste, together with those of mastication, we shall not expect to find it much developed in the fœtus and infant while these parts are scarcely called into action; accordingly, we observe the vertical diameter of the face (strictly so called) to be very short, which is owing to the slight elevation of the ethmoid, the lachrymal, the upper and the lower maxillary bones, consequent on the imperfect development of the nasal cavities, the maxillary sinuses, and the teeth; see *fig.* 131. The

Fig. 131.

orbits, indeed, are remarkably large, but this depends upon the great development of the cranium and the breadth of the orbitar plates of the frontal bones, for in their vertical diameters the orbits are not remarkable at this period of life.

The transverse diameter of the face in the fœtus is considerable across the orbits, but below these it is narrower in proportion than in the adult. The other chief peculiarities of the fœtal face are, the small size of the nasal cavities, the absence of the canine fossæ, depending partly on the small vertical diameter of the upper jaw, and partly upon the teeth being still lodged within it; the prominence and shortness of the alveolar borders of both jaws, the vertical direction of the symphysis menti, which even inclines from above downwards and a little backwards; the remarkable convexity of the maxillary tuberosities, owing to the teeth being lodged within them; and the great obliquity from above downwards and forwards of the posterior apertures of the nose, arising from the smallness of the maxillary sinuses; the small antero-posterior diameter of the palatine arch, which depends upon the same cause; and, finally, the oblique direction of the rami of the lower jaw: see *fig.* 377, vol. i. p. 742.

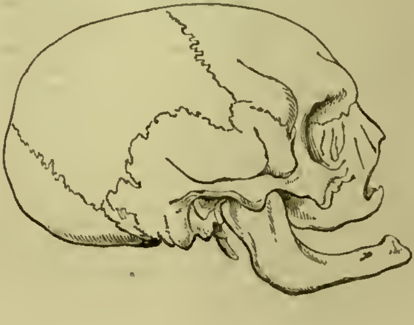
In the *adult*, as the ethmoid and turbinated bones together with the maxillary sinuses become developed, the nasal cavities enlarge, especially in their vertical diameter; above, they communicate with the frontal sinuses, which are now fully formed and projecting; the jaws have become deeper from the protru-

Fig. 132.

sion of the teeth, which cause a considerable addition to the vertical diameter of the face; below, the palatine arch has extended backwards with the development of the maxillary sinuses, and the posterior apertures of the nose have become in consequence nearly vertical: the rami of the lower jaw form also nearly a right angle with its body.

In old age the vertical diameter of the face decreases in consequence of the loss of the teeth and the contraction of the alveolar borders of the jaws, which touch each other when the mouth is closed; the rami of the jaw resume the oblique direction of childhood, (*fig.* 133;)

Fig. 133.



and the symphysis inclines from the shrunken alveolar border downwards and forwards to the base of the bone, and gives to the chin the projecting appearance which is so characteristic of this period of life.

The articulations of the face comprise those of the upper and that of the lower jaw.

The articulations of the bones of the upper jaw with each other and with those of the cranium are all of the kind called *suture*, but they present considerable variety in the extent, form, and adaptation of their articular surfaces. Those bones of the face which contribute to form its columns of support, and to which this part of the head owes its strength and resistance to violence, have their articular surfaces for the most part broad and rough, presenting eminences and depressions which are adapted to those of the contiguous bone; examples of this firm articulation are seen, 1. at the *anterior* part of the intermaxillary suture, where the two palatine plates unite and form the horizontal column or base of the upper jaw; 2. at the *nasal* columns, where the nasal bones and the nasal processes of the upper maxillæ unite with the frontal; 3. on the sides of the face, or where the bones form their lateral or malar columns, viz. at the jugo-maxillary and jugo-frontal articulations. The spheno-jugal articulation, seen within the orbit, and the zygomatic or temporo-jugal, though formed by the union of comparatively narrow surfaces or borders, derive strength from their irregularity, and, in the case of the zygomatic suture, from its indented form, which maintains its security from vertical blows, as the curved direction of the zygoma protects it from lateral injury.

Those sutures of the face which are, strictly speaking, harmonic, are such as are not exposed to any considerable pressure; they present, nevertheless, some varieties in their mode of juxta-position. In some the adaptation is *direct*, as in the pterygo-palatine. In others one border or surface is received by another *(schindylesis)*, as in the articulations of the vomer with the sphenoid above, and with the groove in the palatine plates of the upper maxillary and palate bone inferiorly. Sometimes the surfaces are simply applied against each other, as the nasal plate of the palate bone on the nasal surface of the upper maxillary. Lastly, the edges may alternately overlap each other, as those of the nasal and upper maxillary bones.

In all the sutures of the face, whatever may be the adaptation of the osseous surfaces, we find interposed a thin layer of cartilage uniting the contiguous surfaces of the bones. This is easily shown in some of the sutures by maceration, and only disappears in places as some of the bones become united with advancing age.

The great number of pieces of which the upper jaw consists, and the varying form and direction of the sutures, all contribute, with the figure of the bones themselves, to give strength to this part of the skull, and to break the force of blows by diffusing them over a widely extended surface.

The sutures of the face derive their names from the bones which contribute to form them; thus we have between the orbits the fronto-nasal, fronto-maxillary, and fronto-lachrymal sutures, all contributing to form part of the transverse suture. (See Cranium.) Lower down we find the nasal, the naso-maxillary, and the lachrymo-maxillary, which turns at right angles backwards along the inner wall of the orbit into the ethmoido-maxillary and palato-orbitar sutures. On the outer side of the orbit may be observed the fronto-jugal and spheno-jugal sutures; on the zygomatic arch the temporo-jugal suture; and below the prominence of the cheek, the jugo-maxillary suture, which is seen both on the anterior and posterior surface of the upper jaw. On the roof of the mouth are seen the longitudinal and the transverse palatine sutures, the former formed by the intermaxillary in front, and by the inter-palatine suture behind: the latter is often termed the transverse or horizontal palato-maxillary suture. There are some other sutures within the nose which it is unnecessary to enumerate.

The lower jaw articulates with the cranium by diarthrosis: this important joint will be particularly described in the article Temporo-maxillary articulation.

The bones of the face are invested with periosteum or a fibrous membrane, which is variously modified and arranged in the orbits, nose and mouth, &c.

ABNORMAL CONDITIONS OF THE BONES OF THE FACE.

In the true acephalous fœtus the bones of the face as well as those of the cranium are of course wanting, but the former are generally found in what are termed the false Acephalia (see Abnormal Conditions of the Cranium); it sometimes happens, notwithstanding, that the bones of the face are but imperfectly developed, presenting a variety of conformations which it is unnecessary to particularise. The bones of the face, in some cases alone, and in others in conjunction with those of the cranium, not unfrequently acquire a degree of development quite disproportionate with the rest of the skeleton. In Corvisart's Journal de Médecine the case of a Moor is cited, whose head and face were so enormous that he could not stir abroad without being followed by the populace. It is related that the nose of this man, who was half an idiot, was four inches long, and his mouth so large that he would bite a melon in the proportion that an ordinary person would eat an apple. I have now before me the skull of a native of Shields, who was remarkable during life for the length of his face; the entire head is large, but the bones of the face, and particularly the lower jaw, are enormously long. The abnormal development of the facial bones generally affects one jaw only, and more frequently the lower, as in the example just mentioned. Other cases, but they are much more rare, have been related in which the lower jaw was disproportionately small. When, from either of the circumstances which have been just mentioned, the development of the two jaws is unequal, the correspondence of their alveolar borders is lost, and mastication becomes in proportion imperfect: in mammiferous animals the unequal size of the lower jaw, by preventing suckling, is often a cause of death. The bones of the face are much more symmetrical than those of the cranium, and rarely present the disproportion in their lateral development which is observed in the latter.

Under the head of defect or arrest of development may be noticed, 1. the occasional absence of some of the bones, as for example, the lachrymal or the vomer; 2. the existence of fissures, or non-union of the upper maxillary bones, and, as a more rare case, the separation of the two halves of the lower jaw. Fissures of the upper jaw may exist in various degrees, and may occur with or without a corresponding cleft in the soft palate and lip; it may appear as a mere slit along the middle of the roof of the mouth, forming a narrow communication between that cavity and one side of the nose; or it may extend along the whole of the palatine arch, and be continuous behind with a similar division of the soft palate, without, at the same time, being accompanied with hare-lip. Sometimes the aperture is very wide, and the palatine plates of the upper maxillary and palate bones are almost entirely wanting; in this case the vomer and middle cartilage of the nose are also partially or entirely absent; and there is both hare-lip and cleft of the soft palate, so that the mouth, both sides of the nose, and the pharynx are laid into one great cavity. When the fissure exists at the anterior part of the palate only, it almost invariably occurs at the suture which has been described between the maxillary and intermaxillary bones, so that the cleft separates the canine from the lateral incisor tooth; when the fissure occurs on both sides of the face, the four incisor teeth are separated from the others and lodged in an alveolar border, which usually in this case projects more or less towards the lip, in which there is also commonly a single or double cleft or hare-lip. Sometimes the fissure occurs in the intermaxillary bone itself between the lateral and middle incisor teeth, and then we find a single incisor on one side and three on the opposite: it is very rarely that the cleft exists in the median line between the two intermaxillary bones.

Among the arrests of development which occur in the bones of the face may be enumerated a fissure which occasionally extends across the lower border of the orbit, and a suture which sometimes divides the os jugum into two pieces.

The *union* which not unfrequently takes place between the bones of the upper jaw by the obliteration of their sutures, is commonly the effect of age, and usually occurs between the bones of the nose, between the vomer and sphenoid, and between the inferior turbinated and upper maxillary bones. *Wounds* and fractures of the bones of the face readily unite. Those most subject to these injuries are such as are the most prominent, viz. those of the nose, cheek, and lower jaw; the last is the most frequently broken. The alveolar processes and the delicate bones in the orbit and nose are also liable to injury. The bones of the face are subject, like the rest, (though not so commonly as those of the cranium,) to hypertrophy and atrophy. Exostosis appears most frequently on the upper jaw, in the orbit, or along the alveolar border on the outer surface of the bones; on the lower jaw it is situated usually along the alveolar border, at the angle or on the body of the bone. Inflammation of the periosteum and bones of the face occurs spontaneously or as the result of injuries or disease, and presents the usual phenomena. Abscesses also take place either within the cancellous structure of the more solid bones, or in the cavities which they contain; when matter forms within the antrum, it may be evacuated by extracting the canine or the large molar tooth, which often projects into this cavity, and then piercing through the bottom of their sockets. When *necrosis* affects the bones of the face, its ravages are seldom repaired (as in the case of cylindrical bones) by the production of new osseous matter; some attempts at reparation after the separation of a sequestrum have been, however, observed in the lower jaw. *Caries*, either simple or connected with syphilitic or strumous disease, may attack nearly all the bones of the face, but it more particularly affects the alveolar borders of the jaws and the delicate bones about the nose and palate; it is often attended with partial necrosis. Caries of the face may occur as the result of malignant ulcerations, of lupus, or of the various forms of cancer which affect the soft parts. Both the upper and lower jaw are subject to *osteo-sarcoma*, commencing either on the surface or in the interior of the bones, and acquiring sometimes an enormous size, so as to encroach on the orbit, nose, and mouth, and materially to impede the motions of the lower jaw. For these growths and others more simple, of a *fibrous* or *fibro-cartilaginous* structure, large portions (sometimes amounting to nearly the whole) of the upper or lower jaw have been removed with success. *Cyst-like tumours*, containing a serous fluid, have been found in the lower jaw. The more intractable diseases of *medullary sarcoma* and *fungous growths* of various kinds also attack the bones of the face. A few cases of hydatids (the acephalo-cystus) have been met with in the upper jaw.

THE MUSCLES OF THE FACE

are arranged around the orifices of the eyelids, the nose, and the mouth, and may be divided into constrictors and dilators of these apertures. The nostrils, however, undergo but little variation in their dimensions, being maintained permanently open by the elastic cartilages which form them. The eyelids also contain elastic cartilages, which are moulded upon the front of the globe over which they glide in obedience to the muscles which dilate or contract the orifice between them. The mouth, which is the most mobile of the facial apertures, is also furnished with its contractor or sphincter muscle, and with many dilators which radiate from it at various angles.

All the muscles of the face are superficially situated, and most of them are subcutaneous.

In the *palpebral regions*, or about the eyelids on each side, are placed, 1. a constrictor, or the *orbicularis palpebrarum*, of which the *corrugator supercilii* is an associate; 2. the *levator palpebræ* and the *occipito-frontalis*, which are dilators, and antagonists of the two former muscles.

The *orbicularis palpebrarum*, (*naso-palpebral*, Chauss.) is a flat oval muscle, situated immediately underneath the skin, to which it adheres, and covering the base of the orbit and the superficial surface of the eyelids; in the middle it presents a transverse aperture, which is the orifice of the palpebræ, varying in size according to the individual, and giving apparently a greater or less magnitude to the globe itself, which, however, is of nearly uniform dimensions in different persons. The orbicularis, like the other sphincter muscles, consists of concentric fibres, but it is peculiar in having a fixed tendon on one side, from which a great part of the fibres arise; this *tendon of the orbicularis*, or ligamentum palpebræ, which is situated horizontally at the inner corner of the eye, is about two and a half lines in length, and half a line in breadth; it arises from the anterior border of the lachrymal groove in the nasal process of the upper maxillary bone, and passing horizontally outwards in front of the lachrymal sac, divides into a superior and an inferior slip, which are attached to the inner extremities of the corresponding eyelids. The tendon at first is flattened anteriorly and posteriorly, but afterwards becomes twisted so as to present horizontal surfaces. From its posterior part is detached a slip of fibres (the reflected tendon of the orbicularis), which proceeds backwards towards the os unguis, and forms the outer wall of the lachrymal canal.

The *orbicularis* arises, 1. from the borders and surfaces of this tendon and from its reflected slip; 2. from the internal angular process of the frontal bone and from the fronto-maxillary suture; 3. from the nasal process of the upper maxillary bone; and, 4. by short tendinous slips from the inner third of the lower border of the orbit. From these origins the upper and lower fibres of the muscle take a curved direction outwards, their concavity looking towards the aperture of the lids, and following the course of the upper and lower borders of the orbit, which they overlap. They unite at the outer side; not, however, by a tendinous raphé or septum, as some have described, but simply by the mingling of their fibres. Each half (the upper and lower) of the orbicularis consists really of two sets of fibres; one, which covers the margins of the orbits, and forms the circumference of the muscles, is strong, tense, and of the usual reddish colour; it arises from the direct tendon, and from the frontal or upper maxillary bone. These form the orbicularis properly so called. The other set, which is pale and thin, covers the lids and proceeds almost in a horizontal direction outwards from the palpebral bifurcation of the orbicular tendon: this forms the ciliary or palpebrales. These two sets of fibres, as we shall presently see, are distinguished as much by their functions as by their appearance.

Relations.—The *superficial surface* of that part of the muscle which covers the lids (the palpebrales) is connected to the skin by delicate loose cellular tissue entirely destitute of fat. The stronger fibres which form the outer part of the muscles are closely adherent to the integument by cellular tissue more densely woven, and presenting more or less fat. *The posterior surface* covers, above, the lower part of the frontalis and the corrugator supercilii, with whose fibres it is connected; internally the corresponding part of the fibro-cartilages of the lids, the lachrymal sac, and the inner border of the orbit externally, the outer border of the orbit and part of the temporal fascia inferiorly, the upper part of the malar bone, the origins of the levator labii superioris proprius, the part of the levator labii superioris alæque nasi, and the inferior border of the orbit. At its circumference this muscle corresponds, by its upper half, to the frontal, which it slightly overlaps, and internally to the border of the pyramidalis, with which it is connected; externally it is free. Below its border is free, covering the origin, and giving some fibres to the lesser zygomatic; and internally it is separated from the levator labii superioris alæque nasi by cellular tissue, in which runs the facial vein. The central fibres cover the palpebral fascia and the lids, which separate them from the conjunctiva.

Action.—The action of this muscle resembles that of other sphincters, the curved fibres in contraction approaching the centre; but as in the orbicularis palpebrarum these fibres are fixed at the inner side, it follows that the skin to which the muscle is attached by its anterior surface is drawn towards the nose, and when the muscle is in strong action, becomes corrugated, presenting folds which converge towards the inner angle of the eye; above, where the effect of the muscle on the skin is most marked in consequence of its closer connection with the integuments, the brow and the skin of the forehead are drawn down by it and its associate the corrugator; the lower fibres when in strong action, draw the cheeks upwards and inwards. Like the other sphincters, also, this is a mixed muscle. Those fibres which may be supposed to be voluntary, are the larger and outer ones, which correspond to the border of the orbit, and are of a red colour. The involuntary fibres are those thin ones which cover the lids, are of a pale colour, like the muscles of organic life, and arise from the palpebral subdivisions of the horizontal tendon. They contract involuntarily while we are awake, in the action of winking, and during sleep in maintaining the lids closed; they also act under the will in closing the lids, particularly the upper. It appears then that the orbicularis may be divided both anatomically and physiologically into two sets of fibres; an outer, or orbicularis proper, which is entirely a voluntary muscle, and an inner (the palpebralis) which is both voluntary and involuntary in its action. These fibres may act independently of each other, for in winking and during sleep the palpebralis contracts, while the orbicularis is quiescent; and the orbicularis may contract even strongly, as when we peer with the eyes under the influence of a strong light, while the fibres of the palpebrales are relaxed. It has been supposed, however, by some, that during sleep the lid is closed simply by the weight of the upper palpebra, and the relaxation of its proper elevator muscle, but this seems in contradiction to the fact that we meet with resistance in endeavouring to unclose the lids of a sleeping person.

Corrugator supercilii, which is the associate of the orbicularis palpebrarum, has been already described, together with the occipito-frontalis, which is the antagonist of those muscles. See CRANIUM, MUSCLES OF THE, vol. i. p. 747.

Levator palpebræ superioris (orbito-palpebral), though situated within the orbit, is nevertheless the direct antagonist of the palbebralis, and is therefore properly described with these muscles of the face. It is a thin triangular muscle, which arises by a narrow slender tendon at the back of the orbit from the inferior surface of the lesser wing of the sphenoid bone, above and in front of the optic foramen; from this origin the fibres proceed almost horizontally forwards under the roof of the orbit, and gradually spreading and becoming thinner as they advance, curve over the globe of the eye, and are inserted into the upper border and anterior surface of the upper lid.

Relations.—Its *upper surface* is in contact, behind, with the frontal branch of the ophthalmic nerve, which with some cellular tissue alone separates it from the periosteum of the roof of the orbit; anteriorly with cellular tissue and the palpebral fascia, which separate it from the orbicularis. The *lower surface* behind rests upon the superior rectus oculi, with which it is connected by cellular tissue, and anteriorly on the conjunctiva and upper lid.

Its *action* is to raise the upper lid, and to draw it backwards over the globe and under the supra-ciliary ridge. There is no separate muscle to effect the depression of the lower lid, that action being occasioned, as Sir C. Bell ingeniously suggested, by the protrusion of the eyeball.

Nasal region.—The muscles of this region, some of which are common to the upper lip, are, 1. *the pyramidalis;* 2. *the levator labii superioris alæque nasi;* 3. *the triangularis nasi;* 4. *the depressor alæ nasi.*

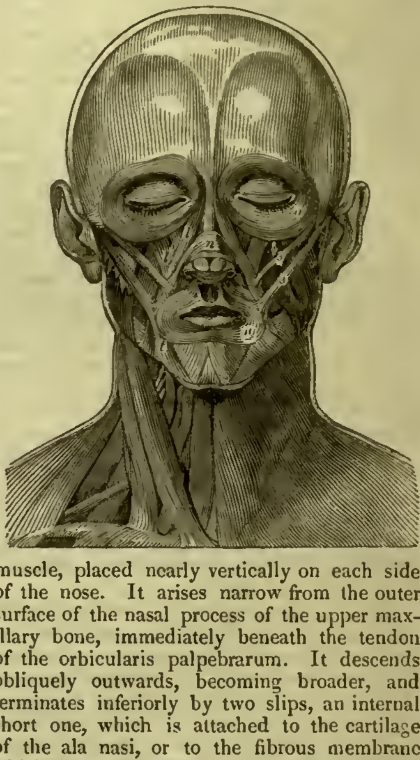
Pyramidalis is situated between the brows, and may be considered as a prolongation of the inner fibres of the frontalis: it is of a triangular form; its base above is continuous with the fibres of the frontalis; below it contracts and is inserted into the aponeurotic expansion of the triangularis nasi. It is separated from its fellow slip of the opposite side by a groove of cellular tissue.

Relations.—Its superficial surface adheres to the skin; its deep one rests on the nasal eminence of the frontal bone, the nasal bones, and part of the lateral cartilage of the nose.

Use.—If this muscle acts at all on the nose, it is by drawing up the skin when the occipito-frontalis is in action. Its more probable use is to give a fixed point to the frontalis, and to draw down the inner extremity of the brows and the skin between them.

Levator labii superioris alæque nasi.—(l', fig. 134.) This is a thin, long, triangular

Fig. 134.



muscle, placed nearly vertically on each side of the nose. It arises narrow from the outer surface of the nasal process of the upper maxillary bone, immediately beneath the tendon of the orbicularis palpebrarum. It descends obliquely outwards, becoming broader, and terminates inferiorly by two slips, an internal short one, which is attached to the cartilage of the ala nasi, or to the fibrous membrane which invests it; and an outer longer slip, which is attached to the skin of the upper lip near the nose, and mingles its fibres with the transversalis nasi, the levator labii superioris proprius, and the orbicularis oris.

Relations.—Covered by the skin, and overlapped a little above by the orbicularis palpebrarum, this muscle covers the nasal process of the upper maxillary bone, the triangularis nasi, and the depressor alæ nasi. Its inner border above corresponds to the pyramidalis.

Its *action* is to raise the ala of the nose and the adjacent part of the upper lip; in so doing it dilates also the nostril and becomes a muscle of inspiration. When strongly thrown into action, it corrugates the skin of the nose transversely.

Triangularis nasi (transversalis nasi, compressor naris, Albin.) *(n, fig.* 134), is a very thin triangular muscle, placed transversely on the middle of the side of the nose. To expose its origin, the levators of the upper lip must be turned aside, and the skin of the nose very carefully dissected off. Its origin is then seen as a narrow slip from the inner part of the canine fossa, below the ala nasi; from this point the fibres radiate inwards and upwards, and expand into a very thin aponeurosis, which crosses the ala nasi and the lateral cartilage of the nose to be confounded along the median line with that of the opposite muscle, and with the pyramidalis. Bourgery describes two other origins, one superficial, attached to the skin below and to the outside of the ala nasi, and a middle one crossing and connected with the fibres of the levator of the upper lip.

Relations.—It is covered at its origin by the levator labii superioris alæque nasi, and internally by the integuments to which it superficially adheres; it rests on part of the upper jaw, on the cartilages of the ala, and on the lateral cartilage.

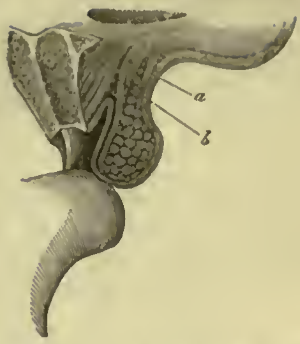
Its *action* is yet undetermined by anatomists, some considering it a compressor or constrictor of the nose, others as a dilator or elevator. Cruveilhier thinks that its action varies with the form of the ala, which, when convex, makes it a compressor, when concave a dilator. Perhaps, as M. Bourgery suggests, its action depends upon which extremity is fixed, and that, when its base is fixed, its superficial fibres dilate the nostrils and draw the lip upwards and inwards, and that, when the muscle acts towards its maxillary attachment, it compresses the nostril.

Depressor alæ nasi (musculus myrtiformis), (fig. 134.) To expose this muscle the upper lip should be reversed, and the mucous membrane divided on each side of the frænum labii. It is a short flat muscle, radiating upwards from the myrtiform fossa of the upper jaw, where it arises towards the ala of the nose, into the posterior part of which it is inserted below and internal to the dilator nasi. This muscle really consists of two sets of fibres, one which has been just described, the other which is in front of this and is attached above to the ala and septum of the nose, below to the inner surface of the orbicular fibres. The first set, or the naso-maxillary fibres, are depressors of the alæ and contractors of the nostrils; the second, or naso-labial fibres, are elevators of the upper lip.

Relations.—It is covered by the mucous membrane of the upper lip, by the orbicularis oris, and by the levator labii superioris alæque nasi; it covers the myrtiform fossa of the upper jaw: its inner border is separated from its fellow by the frænum.

A *dilator alæ nasi* is described by Bourgery as a little triangular muscle, consisting of fibres placed underneath the skin lying on the outside of the ala nasi, from the posterior part of whose cartilages the fibres arise by a narrow point, and then radiate upwards, outwards,

Fig. 135.



and downwards, to be mingled with the fibres of the elevators of the lip, the orbicularis, and the naso-labial, all being attached to the skin. This muscle, according to Bourgery, directly draws the ala outwards, and is consequently a dilator of the nostril.

The labial region presents in the centre, 1. a sphincter (the orbicularis oris), with which are associated two muscles on each side, *the depressor labii superioris* and *the levator labii inferioris:* all these are contractors or compressors of the lips: 2. a number of antagonist muscles or dilators, which comprise many muscles, which on each side radiate from the lips, or from their commissure at different angles. They are, above, the levator labii superioris proprius and the zygomaticus minor; below, the depressor labii inferioris at the commissure, the buccinator, the levator anguli oris, and the depressor anguli oris. By some anatomists the muscles of this region of the face are divided into, 1. the sphincter, and, 2. the elevators and depressors of the lips.

Orbicularis or *sphincter oris (labial,* Chauss. and Dum.) (*o o, fig.* 134) is a thick oval muscle, placed transversely around the aperture of the mouth, which varies in size in different persons, but bears no relation to the size of the buccal cavity. It extends above from the free border of the upper lip to the nostrils, and inferiorly from the free border of the lower lip to the depression above the chin. Its fibres, arranged in successive layers, consist of two semi-elliptical halves, one superior, the other inferior, which are on each side united externally to the commissure of the lips by decussating each other, and mingle also at their circumference with the dilators which are attached to it. These fibres are concentric, with their curve towards the lips; the most central run nearly in a horizontal direction along the borders of the lips, and take a direction forwards, which gives the prominence to the lips which is so remarkable in the Negro. The outer fibres are more curved, and receive between their layers the extensors of the lips, which are attached around them. This is the only muscle of the face which has no attachment to bone.

Relations.—The anterior surface is closely connected with the thick skin which covers it. The *posterior* surface and free border is covered with the mucous membrane of the mouth, from which it is only separated in places by the labial glands, by the coronary vessels, and by numerous nerves. Its outer border or circumference receives the antagonist muscles which are attached around it.

Actions.—The *orbicularis* enjoys a very varied and extensive motion, and possesses the remarkable power of either acting as a whole or in parts. Its simple use is to close the mouth, in correspondence with the elevation of the lower jaw, by bringing the red borders of the lips in contact, or by pressing them together firmly. But the upper or lower labial fibres can act separately, or the fibres at either commissure, or the fibres of one side may contract, while the others are quiescent, so that different parts of the lips may be moved by different portions of the muscle, which is made in this way to antagonize in turn the different muscles which are attached around.

The lips may be thrown forward by the contraction of the labial and commissural fibres forming in strong action a circular projection, as in the action of whistling, or, when more relaxed, in blowing. By the contraction of the inner labial fibres the lips may, on the contrary, be turned inwards so as to cover the teeth. The play of the mouth, however, which contributes in so eminent a degree to the expression of the face, depends not only on the orbicularis, but upon its association with the different muscles which are attached around it.

Naso-labialis is a small subcutaneous slip of fibres, only distinctly seen in strong muscular lips. It is situated on each side of the median depression of the upper lip, and arises from the lower septum of the nose at the back part of the nostril; it proceeds downwards and outwards, and is soon lost in the fibres of the orbicularis. It is an elevator of the middle part of the upper lip, and is considered by some as an attachment of the orbicularis.

Levator labii superioris (*l'*, *fig.* 134) is a thin, flat, quadrilateral muscle, situated about the middle of the face, and nearly on the same plane with the levator labii superioris alæque nasi. It arises from the malar and upper maxillary bones where they form three-fourths of the lower border of the orbit, by short tendinous slips; from this origin the fibres, converging a little, take a direction downwards and inwards, and are inserted partly superficially into the skin of the upper lip, and partly into the fibres of the orbicularis, between the insertion of the levator labii superioris alæque nasi and the lesser zygomatic, with which its fibres are partly covered and confounded.

Relations.—Its anterior surface is covered above by the orbicularis palpebrarum, below by the skin and by the muscles with which its fibres are mingled at its insertion. Its posterior surface covers the infra-orbitar vessels and nerves at their exit from the infra-orbitar foramen, which, with some fat and cellular tissue, separates it from the upper part of the levator anguli oris. It covers also part of the triangularis nasi.

Its *action* is to raise and draw a little outwards the upper lip.

Zygomaticus minor (3', *fig.* 134) is a narrow rounded muscle, often wanting. It arises from the external surface of the os malæ, and frequently also from the deep fibres of the orbicularis palpebrarum, by which its origin is covered; it proceeds downwards and inwards, and is attached to the skin and orbicularis palpebrarum above the commissure of the lips, where its fibres are also confounded with those of the levator labii superioris proprius.

Relations.—This muscle is covered in front by the orbicularis palpebrarum and skin; its posterior surface conceals a part of the levator anguli oris and of the labial vein.

Action.—It is an associate of the levator labii superioris, and contributes to raise the upper lip and draw it a little outwards.

Zygomaticus major (3, *fig.* 134), placed to the outer side and a little below the preceding muscle, is of a rounded form, and arises by short tendinous slips from a depression on the posterior part of the outer surface of the os malæ, near its lower border. Its fibres proceed downwards and inwards, nearly parallel with those of the lesser zygomatic, but much longer; and expanding a little below, they become confounded with the fibres of the orbicularis oris at their commissure, and with those of the levator labii superioris, levator anguli oris, and depressor anguli oris. Its superficial fibres are attached to the skin.

Relations.—This muscle is surrounded by fat, which separates it from the skin. By its deep surface it rests above on the os malæ and the masseter; below, it is separated by fat from the buccinator and the levator labii superioris: it crosses also the labial vein.

Its *action* carries the commissure of the lips upwards and outwards, and is intermediate between the action of the levator and the buccinator: it is the antagonist of the levator anguli oris in drawing the lip outwards; its associate in raising it. When both these muscles act, the commissure of the lips is directly raised.

Levator anguli oris (musculus caninus): (*c*, *fig.* 136).—To expose this, the levator labii superioris must be removed. It is a flat quadrilateral muscle, which arises from the middle of the canine fossa of the upper jaw, and becoming somewhat narrower takes a direction downwards and a little outwards and forwards, to terminate at the commissure of the lips, where its fibres mingle with those of the orbicularis, the buccinator, and the depressor anguli oris.

Relations.—Deeply placed above, its anterior surface is covered by the infra-orbitar vessels and nerves, and by fat, which separate it from the levator labii superioris and the lesser zygomatic. Below it is covered by the zygomaticus major and the integument. The posterior surface of this muscle rests on the upper maxillary bone on the mucous membrane of the mouth, and on the buccinator. Its *action* is to raise the commissure of the lips, and draw it a little inwards. Its action when associated with that of the zygomatics has been already explained.

Depressor anguli oris (triangularis oris) (t, fig. 134) is a thin, triangular, subcutaneous muscle, situated at the lower part of the face. It arises by a broad base from the lower border of the inferior maxilla, and from the surface of the bone between this border and the external oblique line, extending from the chin to within half an inch of the masseter. The fibres converge and ascend towards the commissure of the lips, the posterior fibres taking a direction upwards and forwards, the middle nearly vertical, and the anterior describing a curve upwards and backwards: they all terminate at the commissure of the lips, where they become united with those of the orbicularis and of the buccinator, and more superficially with the great zygomatic and levator anguli oris.

Relations.—Its superficial surface is covered by the skin and by the fibres of the platysma, with which it is mingled. Its deep surface rests upon part of the depressor labii inferioris and buccinator: above it is connected with all the muscles of the commissure and with the skin.

Action.—This muscle draws down the angle of the mouth, and in this respect is the antagonist of the great zygomatic and levator anguli oris.

Depressor labii inferioris (quodrutus menti), (d, fig. 136, 137) flat and of a square form, is placed internal to the preceding, which partly conceals it. It arises from the inner half of the external oblique line of the lower jaw, and also from the platysma, with whose fibres it is continuous. Its fibres, which are parallel, proceed upwards and inwards to be attached to the lip; the deep fibres mingle with those of the orbicularis; the superficial pass in front of that muscle, and are fixed in the skin of the lip. The inner fibres decussate above with those of the muscle on the opposite side; below, with those of the levator menti.

Fig. 136.

Relations.—At its origin this muscle is covered by the triangularis, and elsewhere by the skin, to which it adheres intimately above. Its deep surface covers part of the lower jaw, the mental vessels and nerves, part of the orbicularis oris and levator menti. Through the angular interval between the two depressors of the lower lip, the levatores menti pass to their insertion.

Its *action* is to draw downwards and outwards one side of the lower lip; if the muscles on both sides act, the lip is drawn downwards and extended transversely. The stronger actions of this muscle are usually accompanied by those of the platysma, with whose fibres, as we have seen, it is continuous.

Levator menti (houppe du menton) (e, fig. 136, 137) may be exposed by everting the lip and dividing the mucous membrane: it is a small round muscle, situated at the lower part of the face, and forming on each side a great part of the prominence of the chin. It arises in the incisive fossa below the incisor teeth of the lower jaw, external to the symphysis, and proceeds downwards and forwards: it passes under the lower border of the orbicularis oris, and emerging between the depressor labii inferioris, expands a little to be inserted into the skin of the chin. Its fibres below are mingled with fat; internally they are confounded with those of the fellow muscle, and externally with the fibres of the quadratus menti.

In its *action* this muscle raises and corrugates the chin, and by so doing raises also the lower lip and throws it forward.

Fig. 137.

Buccinator (b, fig. 136, 137). This muscle is situated on the side of the cheek, and to expose it completely it is necessary to divide the muscles attached to the angle of the mouth, and to remove the ramus of the jaw and the muscle attached to it. The buccinator is a broad flat muscle, and arises, 1. behind and in the middle from an aponeurotic line, the pterygo-maxillary ligament or inter-maxillary ligament, which is common to it and the superior constrictor of the pharynx, and which is extended between the lower extremity of the internal pterygoid plate of the sphenoid bone and the posterior extremity of the internal oblique line of the lower. Above, the buccinator arises, 2. from the outer surface of the upper alveolar process, between the first malar tooth and the tuberosity; 3. below from the outer side of the alveolar border opposite the three last malar teeth. From these three origins the fibres proceed forwards, the superior curving a little downwards, the inferior upwards, and the middle passing horizontally towards the angle of the mouth, where they mingle with the fibres of the orbicularis and the elevators and depressors of the commissure. The inferior and superior fibres become shorter as we trace them forwards, and some of them decussate at the angle of the mouth to unite with the opposite labial half of the orbicularis.

The fibres of the buccinator are wavy, overlapping each other, so that they admit of great distention, which is, however, limited by a buccal fascia, which is given off from the pterygo-maxillary ligament.

Relations.—The buccinator is deeply situated behind, where it is covered by the ramus of the jaw and the edge of the masseter, from which it is separated by a quantity of fat, which projects beyond the mass, fills up the hollow in front of the masseter, and is always found even in thin subjects. In the middle it corresponds to the buccal vessels and nerves and to the transverse facial artery, which runs nearly parallel to its fibres, and to the duct of the parotid gland, which, resting at first upon its fibres, pierces them opposite the second molar tooth of the upper jaw, and opens obliquely into the mouth. A buccal fascia covers the posterior half of the muscle. At the commissure the buccinator is covered by the muscles which are attached to the angle of the mouth, and is crossed at right angles by the external maxillary artery and vein. By its internal surface this muscle covers the mucous membrane of the mouth, from which it is only separated by a layer of buccal glands.

Action.—This muscle, being fixed behind, above, and below, acts principally in front on the commissure of the lips, which it draws horizontally backwards, elongating the aperture of the mouth transversely, and throwing the cheek into the vertical folds which are so remarkable in old age. In this respect it is the direct antagonist of the orbicularis oris: if both these muscles act together, the lips are extended and pressed against the teeth. When the cavity of the mouth is distended with air or liquids, this muscle is protruded at the cheeks, and its fibres become separated and curved. If now the muscle acts, the fibres become straightened, and the fluid is expelled from the mouth either abruptly or gradually according to the resistance of the orbicularis. This action of the orbicularis is exemplified either in spirting fluids from the mouth, or in playing on wind instruments. In mastication the buccinator presses the food from between the cheek and gums into the cavity of the mouth. It assists also in deglutition when the mouth is closed, by pressing the food backwards towards the pharynx.

Among the muscles of the face, it is necessary to allude to some parts of the platysma, which are not only seen in this region, but which contribute materially to the motion and expression of the face. The platysma (*p, p, p, fig.* 138) is a large, broad, membranous layer of fibres, which extend from the upper and anterior part of the chest, where they commence in the subcutaneous tissue, upwards over the anterior and lateral part of the neck, to the jaw and lower part of the face, where they are inserted above. The whole superficial surface of the muscle is subcutaneous, but less firmly attached to the integument just under the jaw than elsewhere. The under surface of its cervical portion is in relation with numerous important parts on the face: it covers from before backwards the lower part of the chin, the quadratus menti, the triangularis oris, the base of the lower jaw, the facial vessels, and part of the masseter. The arrangement of its facial portion is all that need be described here.

Fig. 138.

As the fibres of the muscle incline upwards towards the median line, they meet below the symphysis of the chin, and some ascend as high as the levator menti. Externally the fibres seem to split to enclose the depressor anguli oris, and to proceed upwards and forwards with that muscle and the quadratus menti to the lower lip and its angle. The middle fibres are attached to the base of the jaw, and posteriorly they mount over the angle, and are lost on the fascia of the masseter. A curious slip crosses these transversely, descending a little from the fascia covering the parotid gland towards the angle of the mouth. It is the risorius Santorini, which is, however, often wanting. The platysma draws down the whole of the lower part of the face, or, acting more slightly, depresses the lower lip and the commissure in conjunction with their proper depressors. The slip called risorius, on the contrary, raises the angle of the mouth.

The only fasciæ of the face are, 1. a palpebral fascia, which connects the convex edges of the tarsal cartilages to the border of the orbit; and, 2. a buccal fascia, which, extending forward from the intermaxillary ligament, covers the posterior half of the buccinator muscle: anterior to this it becomes lost in the surrounding cellular tissue.

General review of the muscles of the face.—With one exception, all the muscles of the face are attached at one part to bone, and at another either to the skin or to some other muscle: their fibres are also red and firm at their fixed attachment, pale and thinner at their moveable extremity. With the exception of the orbicularis oris, which is a symmetrical muscle, all the others are arranged in pairs, one on each side of the face. The mouth being the most moveable, has by far the greatest number grouped around it. It possesses, 1. a sphincter, the orbicularis oris, the important action of which on the lips in suction, respiration, whistling, blowing, and playing on wind instruments, in speech and in expression, has already been partly spoken of. The associate of this muscle is the levator menti. 2. The antagonist of this are, *a*, the naso-labialis, the transversalis nasi, the levator labii superioris, both proper and common to it and the nose, and which raise the upper lip; *b*, the depressor labii inferioris and platysma, which draw down the lower lip; *c*, the buccinator, which extends the aperture of the mouth transversely; *d*, the zygomatics, the risorius Santorini, and the levator anguli oris, which draw the commissure upwards; and, *e*, the depressor anguli oris and platysma, which draw it downwards.

About the eyes there are on each side, 1. a sphincter, the orbicularis palpebræ and palpebralis, with the associate, the corrugator supercilii; 2, the dilators, the occipato frontalis and levator palpebræ. About the nose there are, 1, a constrictor, the depressor alæ nasi; 2. the dilators, levator labii superioris alæque nasi and the dilator nasi; 3. the triangularis nasi, which probably both dilates and contracts the orifice of the nostrils according to the attachment, which is fixed.

The muscles of the face, including the pyramidalis, the levator palpebræ, the naso-labialis, and the dilator alæ nasi, are sixteen pairs in number; if we add the occipito-frontalis, the corrugator supercilii, and the platysma, nineteen pairs, and one symmetrical, the orbicularis oris. Of these, four pairs belong to the eye, three pairs to the nose, ten pairs and one single one to the mouth: two pairs are common to the mouth and the nose.

The use of the muscles of the face with respect to expression is a subject of so much interest, and involves so many collateral facts, that it will be better considered under the separate article PHYSIOGNOMY. It will be sufficient to observe here that the muscles which express lively feeling and the gay passions, such as the occipito-frontalis, the levator palpebrarum, the levators and dilators of the lips and their commissure, do for the most part either raise or draw the parts from the median line; and that those muscles which manifest the sadder feelings and the darker passions, as the corrugator supercilii, the pyramidalis, the levator menti, the depressors of the lower lip and its commissure, either depress the parts or draw them from the median line. The constant and habitual exercise of either of these sets of muscles leaves corresponding permanent folds in the skin, which are indicative of the habitual feelings and passions of the individual.

The integuments of the face.—The skin of the face is, with the exception of some parts, remarkable for its tenuity, for its abundant supply of vessels, nerves, and follicles; for the growth of hair, which covers some parts of it; and for its attachment to the subjacent muscles. The vascularity of the skin in some parts is even beautiful, tinting the cheek and lips, as in the act of blushing, assisting in the expression of the feelings and passions. The subcutaneous cellular tissue is, in general, very dense in this region, and is mingled with more or less fat, except on the eyelids, where it is loose, delicate, and quite destitute of adipose tissue. Generally speaking, the skin of the face is more adherent, and the subjacent cellular tissue is more dense and less fatty, along the median line than at the lateral parts; the nose and lips offer examples of this fact. At the sides the cellular tissue is looser below, near the base of the jaw, than higher up on the cheeks. Most of the muscles are more or less surrounded with fat, which, however, particularly abounds on the cheeks and between the masseter and buccinator muscles.

Vessels of the face.—The *arteries* are derived chiefly from the external carotid, viz. 1. the external maxillary or the facial artery, and its branches; 2. branches from the temporal, particularly the transverse facial artery; 3. branches from the internal maxillary, more particularly the infra-orbitar, the buccal, and the superior and inferior dental arteries; 4. some arteries which emerge from the orbit and are derived from the ophthalmic branch of the internal carotid. These vessels communicate very freely with each other, and form with their accompanying veins an intricate vascular network over the face. See CAROTID ARTERY.

The *veins* are principally branches of the *external jugular*, viz. 1. the *facial vein* with its branches, which correspond generally to the trunk and branches of the facial artery, except that the facial vein is rather more superficial and further from the median line than the artery; 2. the *transverse facial vein* and some other small branches of the temporal; 3. veins corresponding to the branches of the internal maxillary artery already mentioned; and, lastly, some veins about the nose and brow, which are connected with the *ophthalmic vein* within the orbit. Both arteries and veins are imbedded in the adipose tissue, and are often remarkably tortuous, more especially the arteries, in old persons. Their trunks and branches open in a direction towards the median line, particularly at the upper part of the face.

The *lymphatics* are much more numerous than those of the cranium, and follow principally the course of the bloodvessels, and terminate in the submaxillary and parotid lymphatic ganglions; in their course they traverse some ganglions, which are situated on the buccinator.

The superficial lymphatics arise from all parts of the face, and, accompanying the superficial vessels, end in the submaxillary ganglions; some of them traverse the smaller buccal ganglions.

The *deep lymphatics* are situated in the zygomatic and pterygo-maxillary fossæ; they also accompany the bloodvessels, and terminate in the deep parotid and submaxillary ganglions.

The *lymphatic ganglions* of the face are principally situated along the base of the jaw, and are termed the *submaxillary ganglions*. Others are placed on the jaw and buccinator, in front of the masseter (the buccal ganglions), and follow the facial vessels. Some lymphatic ganglions are situated underneath the zygoma (the zygomatic ganglions); and others, more numerous, are placed upon, within, or underneath the parotid gland, and are termed the parotid ganglions. The deep lymphatics of the orbits, nose, and mouth, will be described with those cavities.

The *nerves of the face* are derived from the three divisions of the fifth and from the portio dura of the seventh cerebral nerves. The branches from the fifth emerge on the face, 1. from the orbit; these come from the ophthalmic or first division of the fifth, and are the frontal, the supra-trochlear, the infra-trochlear, and the lachrymal: 2. from the infra-orbitar foramen escape the infra-orbitar nerve, from the second division of the fifth or superior maxillary, and from the same source, emerging from underneath the ramus of the jaw, the buccal nerves: 3. from the mental foramen emerge branches of the inferior dental nerve, derived from the third division of the fifth or the inferior maxillary; and from the same source, piercing the masseter, the masseteric nerves. The portio dura, after turning over the posterior border of the lower jaw, forms a plexus (the pes anserinus) within the parotid gland, and divides into a great number of branches, which are distributed on the face, and which have received various names corresponding to the regions where they run. The branches of the fifth nerve which are distributed to the face principally supply the integuments, and those of the portio dura the muscles. Some filaments, however, of the fifth, such as the buccal branch, derived from the ganglionous portion, supply muscles; and, on the other hand, some cutaneous twigs are sent from the portio dura of the seventh to the commissure of the lips. Both nerves freely anastomose with each other on the face. For a more particular account of these nerves and of their functions, see FIFTH PAIR OF NERVES, SEVENTH PAIR OF CEREBRAL NERVES, and PHYSIOGNOMY.

Abnormal conditions of the soft parts of the face.—The *muscles* of the face offer nothing very remarkable in their abnormal conditions; like others, they become much developed by constant exercise, and on the other hand, when paralytic, they waste and lose both their colour and consistence; their fibres have been observed occasionally to have degenerated into a fatty substance, and the *trichina spiralis* has also been found among them as among those of other voluntary muscles.

The *bloodvessels* of the face are subject to no anomalies in their course which call for notice in this place. It may be remarked, however, that they vary in size in different individuals, and are sometimes superficially and sometimes more deeply situated among the soft parts around; their tortuosity in old age has already been adverted to.

Vascular nævi are not unfrequently found on the face, in some cases deeply situated within the cavities or underneath the bones; in others, and more commonly, they lie superficially in the skin and subcutaneous tissues. They occur of the venous, arterial, or mixed kinds. The first sometimes attain a considerable magnitude, as I have witnessed in the case of an old woman, in whom such a nævus grew on one cheek and lip, and exceeded in size the whole face. Such swellings are easily compressed, and often produce no other inconvenience than that of their deformity and weight. The arterial nævus, however, and more especially when deeply seated, is sometimes a formidable disease, which may involve all the surrounding structures and ultimately prove fatal. The cutaneous capillaries of the cheeks, and about the tip and alæ of the nose, often become enlarged and varicose, presenting a peculiar appearance, which is not uncommon in hard drinkers.

The *lymphatic glands* of the face are particularly liable to inflammation, enlargement, and suppuration. In scrofula they often form immense swellings along the base of the jaw and about the parotid gland, sometimes remaining permanently enlarged, and sometimes suppurating and terminating in abscesses difficult to heal.

The *nerves of the face* are liable to be pressed upon and irritated by the enlarged glands and by the tumours in this part of the body. The face is also subject to a most distressing complaint, termed *tic doulouroux*, which may arise spontaneously or from injury, and which appears to affect particularly, if not exclusively, the branches of the fifth pair of nerves, and more especially the infra-orbitar. Neuralgia of the lower part of the face seems, however, in some instances to follow the course of those branches of the cervical plexus which proceed toward this region. Division of the nerves, though it sometimes checks, seldom cures this painful affection, for the divided nerves speedily reunite, and the complaint returns; and this takes place even after a portion of the nerve has been removed. Spasmodic affections of the face are connected with the branches of the portio dura: both nerves are of course subject to palsy.

The *cellular tissue* of the face is abundant, vascular, mingled generally with more or less fat, and in some places, as on the eyelids, is so lax as to be peculiarly liable to infiltration with fluids. Sometimes it becomes *emphysematous*, in cases of wounds of the frontal sinuses and larynx. It is easily affected by erysipelas, and is the common seat of abscesses, which, however, as there is no fascia to confine the matter, rarely attain any considerable size, but soon make their way towards the surface of the skin. When, indeed, the pus forms on the forehead between the muscles and the pericranium, or beneath the fascia covering the parotid gland, or beneath that investing the masseter and posterior part of the buccinator muscles, the matter being more confined is longer in arriving at the surface, and is productive of more pain than in the former instance. Encysted tumours are not unfrequently formed in this structure of the face.

The *skin* of the face, from its vascularity and the almost homogeneous mass which it forms with the subjacent tissues, readily unites after incised wounds, and hence the success which has attended the attempts at reparation of some parts of this region, such as the nose, cheek, and lips; the extensibility of the skin also favours such operations. Punctured and contused wounds of the face are apt to produce erysipelas when they affect those parts where the cellular tissue is most dense, as on the nose and the prominence of the cheek. Abscesses are the more common result where the cellular tissue is looser. The skin of the face becomes swollen and thickened in some complaints which attack it, such as scrofula, which produces enlargement of the lips and nose, and elephantiasis, cancer, and a few other diseases which affect it more permanently. It is subject also to freckles, stains, and discolorations of various kinds, enlargement, inflammation, and induration of its follicles; to a variety of cutaneous eruptions; to ulcerations from scrofula, scirrhus, lupus, &c. which frequently make great ravages not only in the soft parts of the face, but even in the bones; to tubercles, warts, tumours, and anomalous growths of various kinds; and finally to boils. Its vascularity renders it more liable than in other parts of the body to receive the impression of small-pox pustules. Like the bones, the soft parts of the face are subject to congenital malformation. 1. Its apertures may be closed more or less firmly; this happens with the eyelids, nostrils, and lips. 2. There may be defects of growth, as fissures in the lips, or hare-lip, which may be single or double, and exist alone or in combination with fissures of the palate. The fissure may vary in depth, sometimes, in the upper lip, extending into one of the nostrils, and at others only affecting the border of the lip. Congenital cleft of the lower lip is very rare, and is never combined with fissure of the bone. The nose is sometimes fissured, presenting no cartilaginous septum, and but one large orifice or nostril. Occasionally a congenital fissure has been observed in the cheek. The abnormal conditions of the teeth, the orbits and their contents, of the lachrymal apparatus, and of the cavities of the nose and mouth, will be found under the several articles on these subjects.

For the Bibliography of this article, see Anatomy (Introduction).

(*R. Partridge.*)

FASCIA, (in general anatomy,) (*Binde, sehinge Scheide, Flechsenhäute*, Germ.) This term is applied to certain membranous expansions, existing in various regions of the body, and forming coverings to particular parts. These expansions are composed either of cellular tissue, more or less condensed, or of fibrous tissue, the former being the *cellular fasciæ*, the latter the *aponeuroses* or *aponeurotic fasciæ*. The structure and connexions of a considerable number of the fasciæ are highly interesting, as well with reference to correct diagnosis and prognosis in surgical disease, as in regard to the mode of proceeding in various operations.

1. *Cellular fasciæ.*—These are lamellæ of cellular membrane of variable density, sometimes loaded with fat, at other times totally devoid of it. The best example of this form of fascia is the layer of cellular membrane which is immediately subjacent to the subcutaneous cellular tissue all over the body, and in most places so intimately connected with it as to be inseparable; these in fact form but one membrane, which, although essentially the same everywhere, yet exhibits characters peculiar almost to each region of the body; it is generally known under the name of the *superficial fascia*. Although this fascia is universal, there are, nevertheless, certain regions where, from its greater importance, it has been more carefully examined than in others, and to which we may best refer in order to investigate its peculiar characters. Of these regions those of the abdomen and the neck stand pre-eminent; here this fascia constitutes a distinct membraniform expansion, and the principal variety it presents in different subjects is as regards the greater or less quantity of fat deposited in it. Where a tendinous or fibrous expansion does not lie immediately under it, this fascia sends processes from its deep surface to invest the subjacent muscles and other parts; this is very manifest in the case of the fascia of the neck; and in general it may be stated that the superficial fascia has a more or less intimate connection with the proper cellular covering of subjacent organs, whether muscles or tendons.

The arrangement to which we allude in the fascia of the neck may be satisfactorily traced from the median line on the anterior surface of the neck, proceeding outwards on each side. On the median line the fasciæ of opposite sides are intimately united so as to form a dense line, called by some anatomists *linea alba cervicalis;* thence on each side the fascia divides into laminæ, investing the sterno-hyoid and thyroid muscles, the carotid artery and jugular vein, the sterno-mastoid, and other muscles; and thus anatomists come to describe a superficial and a deep layer of the cervical fascia; the former being continuous with the superficial fascia covering the muscles on the anterior part of the thorax, the latter, intimately connected with all the deep-seated structures in the neck, may be traced outwards behind the sterno-mastoid muscle, along the posterior edge of which it becomes again united with the superficial layer; the fascia, thus re-constructed, passes through the triangular space which intervenes between the muscle last-named and the trapezius, and may be traced over that muscle to become continuous with the superficial fascia on the back. It is the deep layer of this fascia which was described by Godman of Philadelphia* as passing downwards behind the sternum to be continuous with the fibrous pericardium. This description has been subsequently confirmed by more than one anatomist in France, although denied by Cruveilhier, and in this country by Sir Astley Cooper,† who has described it in the same manner, apparently without being acquainted with the previously recorded statements of the anatomists above referred to; I may add that I have myself in many instances proved the accuracy of Godman's description. The cervical fascia is continuous superiorly with the superficial fascia on the face; and inferiorly, besides tracing it into the pectoral region, we can follow it over the shoulder into the arm. The cervical fascia, in a great part of its extent, is not, as the superficial fascia elsewhere, in intimate connexion with the subcutaneous cellular tissue, but is separated from it on each side of the neck by the fibres of the platysma myoides. From this brief accouut of the cervical fascia, (we refer for the more particular description to the article on the surgical anatomy of the NECK,) we learn one characteristic of the superficial fascia, namely, its continuity all over the body.

The superficial fascia of the abdomen has attracted the attention of anatomists and surgeons from its connexion with all herniary tumours in that region. In its arrangement it is much less complex than the cervical fascia, being a uniform membranous expansion spread over the superficial muscular and aponeurotic structures of the abomen, continuous on either side and posteriorly with the superficial fascia of the lumbar regions, and inferiorly with that of the inferior extremities. See the description of it in the article ABDOMEN.

* Anatomical Investigations, Philadelph. 1824.
† On the thymus gland.

The superficial fascia of the limbs is completely confounded with the subcutaneous cellular tissue, and wants that condensation by which on the trunk generally, but particularly in the neck and abdomen, it is distinguished.

There can be no doubt that the superficial fascia is no more than condensed cellular membrane, and its variety of appearance in different regions depends in a great measure upon peculiarities in the motions and arrangement of the parts contained in those regions, *e.g.* wherever the muscles of a part are in very frequent action, and at the same time the fascia is compressed between the integument and the muscles, it suffers condensation; this is conspicuous in the abdomen, where there is almost incessant muscular action in consequence of the respiratory movements, and where the weight of the viscera, thrown forwards in the erect posture, occasions a considerable pressure upon the anterior and lateral portions of the abdominal parietes. The deposition of adeps to any great extent is unfavourable to the existence of a distinct fascia superficialis, which is thereby, as it were, decomposed, and hence this fascia is not distinct from the subcutaneous cellular tissue in those regions where, either habitually or preternaturally, this substance is largely deposited.

The superficial fascia is identified with the subcutaneous cellular membrane in the cranial regions, a circumstance which seems attributable to the firm adhesion of the aponeurotic expansion of the occipito-frontalis muscle to the subcutaneous tissue, and also the cutaneous insertion of other muscles; to a similar cause we may ascribe the indistinctness of this fascia in the face also, as likewise to the great deposition of fat in some parts of this region. In the pectoral region it is attenuated, and is more intimately connected with the proper cellular covering of the great muscles than with the subcutaneous cellular tissue.

Where the superficial fascia has suffered condensation to a considerable extent, and there is a complete absence of adipose substance, it assumes an appearance which has given rise to the designation "fibro-cellular," in consequence of the existence of thick, white, and opaque bundles intersecting the membrane in various directions; these bundles seem to be produced by the close application of the walls of the cells to each other, and the consequent obliteration of their cavities. This, however, I believe is the nearest approach that the superficial fascia makes to fibrous membrane; and I am strongly disposed to question the accuracy of Velpeau's assertion, that it is sometimes transformed into the yellow fibrous or into muscular tissue. The elastic abdominal expansion, described by Girard, is certainly not a conversion of the superficial fascia, but of the muscular aponeurosis.

Among the cellular fasciæ, Velpeau* describes a layer of cellular membrane, pretty uniform in its characters, and in some localities of great practical importance, and gives it the

* Anat. Chirurg. t. i. p. 42.

name *fascia superficialis interna*. It is in contact with the serous membranes of the principal cavities in the body, with those of the abdomen, thorax, and pelvis in particular; in the former of which it has attracted most attention under the denomination of the *fascia propria*. This cellular layer lies between the serous membrane and the fibrous layer which lines the parietes of the cavities, as for instance the fascia transversalis in the abdomen; and consequently in this last cavity, when any viscus is protruded, carrying a peritoneal sac before it, this cellular layer uniformly forms the immediate investment of the sac, and is therefore called *fascia propria*, a hernial covering which every practical surgeon well knows is often of considerable density and thickness, and to which indeed is attributable the so-called thickening of the sac itself.

2. *Aponeuroses* or *aponeurotic fasciæ*.—This appellation should be confined to those textures which are purely fibrous, and belong to either the white fibrous tissue or the yellow. In man, they belong entirely to the former class, but we see some interesting examples among the lower animals, where, while the same characters as to intimate texture are preserved, they assume a yellow colour, and exhibit most manifestly the property of elasticity.

The greatest number of the fibrous aponeuroses are connected with muscular fibres, and in fact serve as tendons to them, and are described as such. Of these we have the best examples in the fibrous aponeuroses of the abdominal muscles, by which a considerable portion of the paries of this cavity is constructed of a resisting inelastic material, which is at the same time under the control and regulation of muscular fibre. These expansions are composed of silvery white parallel fibres, in many places strengthened by bundles which cross and interlace with the fibres last named, e. g. the intercolumnar bands at the apex of the external abdominal ring. It is interesting to notice that in the larger quadrupeds, when the weight of the viscera is imposed on these aponeuroses, they are composed of the yellow elastic fibrous tissue. I have also seen the fascia lata thus converted.

A second class of these aponeuroses consists of those which cover the soft parts in particular regions. In general we find that where there are many muscles covered, the aponeurosis sends in processes by which each muscle is separately invested, these processes being ultimately inserted into the periosteum of the bone. Thus the fascia lata of the thigh separates by means of processes prolonged from its deep surface, the various muscles to which it forms an external envelope, in such a manner that, if the muscles be carefully dissected away from a thigh, without opening the fascia more than is sufficient for their removal, it will appear to form a series of channels in which the muscles are lodged. A similar arrangement is found in the leg and foot, and in each of the segments of the upper extremity. The fascia lata has the peculiarity of being in a great degree influenced in its tension by a muscle, called from that office, *tensor vaginæ femoris*, and the fascia which covers the palm of the hand is likewise governed by the *palmaris longus*, the connection of which, however, with the fascia seems to have reference, not to the functions of the fascia, but to the power of the muscle, in aid of the other flexors of the wrist; the fasciæ of the leg and arm too receive the terminal expansion of the tendons of muscles. The strength of these aponeurotic sheaths is proportionate to the strength of the muscles they cover; this is apparent, by comparing the fasciæ of the arm and of the thigh; the strength of the latter greatly exceeds that of the former, and in the thigh itself the vastus externus muscle is covered by a portion of the fascia lata, much stronger than those which cover the muscles on its posterior and inner aspects.

In a third class of aponeuroses are enumerated simple lamellæ of fibrous membrane, which are found for the most part in connexion with the walls of cavities: such are the fascia transversalis, connected with the abdomen; the fascia iliaca and pelvica, connected with the pelvis; and the fibrous expansion lining the thorax, which has not received a name.

The aponeurotic fasciæ are most valuable in their power of resistance, and thus efficacious in maintaining organs in their proper situations; that they exert a considerable degree of compression upon the muscles is rendered evident by the hernia of the muscular fibres which takes place when an incision is made into the fascia lata of the thigh; they thus regulate the combined action of muscles and render more complete their isolated action. It is incumbent on the surgeon to remember how they confine purulent collections and oppose their progress to the surface, a property which is likewise observable in the cellular fasciæ, whose power of resistance is, however, much less, but their elasticity much greater.

Such is a brief notice of the generalities connected with the fasciæ of the body: the situation, connections, and structure of many of them are of great interest to the surgical anatomist, and will be found fully detailed in the articles devoted to the surgical anatomy of the regions. The subject is also very comprehensively treated in the following works, *Godman*, Anatomical Investigations, Philadelph. 1824; *Velpeau*, Anat. Chirurgicale, t. i. ed. 2de; *Paillard*, Description complete des Membranes fibreuses, Par. 1827; *Cruveilhier*, Anat. Descript. t. ii. Aponeurologie, Par. 1834; *Bourgery*, Anatomie de l'homme, t. ii.

(R. B. Todd.)

FAT. (*στεαρ*, *πιμελη*, *adeps*, *pinguedo*; Fr. *graisse*; Germ. *Fett*; Ital. *grasso*.) Under this term we include a variety of animal products which bear a general resemblance to each other, and to a series of corresponding substances in the vegetable kingdom; the fats of animals being, like the vegetable oils, ternary compounds of carbon, hydrogen, and oxygen, and not, apparently in any instance, containing nitrogen, except as an adventitious or accidental ingredient.

Fat is a deposition in the cellular membrane of certain parts of the body, especially under the skin, in the omentum, in the region of the kidneys, and within the cylindrical bones: it also occurs here and there among the muscles, and sometimes is accumulated to an extent so unnatural as to form a species of disease. In birds it is chiefly seated immediately below the skin, and in water-fowl it is largely secreted by the glands of the rump: in the whale and other warm-blooded inhabitants of the deep, it is chiefly contained in the head and jaw-bones, and abundantly interposed between the skin and the flesh; in fish it abounds in the liver, as in the shark, cod, and ling, or is distributed over the whole body, as in the pilchard, herring, and sprat.

Various opinions have been entertained respecting the *formation* of fat, and its insolubility in water has led to the idea of its *production* in the places in which it occurs; but as it is found in the blood and in some other of the fluids of the body, it is probably partly received with the food, and partly formed by the process of secretion. Its remarkable absorption in certain cases of disease of the chylopoietic viscera, and of deficiency of proper food, seems to point it out as a source of nutriment of which the animal economy may avail itself on emergency; and accordingly in cases of emaciation or atrophy, it is the first substance which disappears. It varies in consistency and characters in the different tribes of animals, and in the greater number of amphibia and fishes it is usually liquid at ordinary temperatures. (See Adipose Tissue.)

The general chemical characters of fat have been long known, as well as its important property of saponification by means of the alkalis; but the real nature of the changes which it undergoes in this process, and the essential distinctive characters of its varieties, were first satisfactorily investigated by Chevreul,* whose essay upon the subject has been justly cited as a model of chemical research. It is chiefly from this source, and from the abstract of its contents given by Berzelius,† that we have taken the following details.

All the varieties of fat are resolvable into mixtures of stearin and elain, (from στεαρ, *suet*, and ελαιον, *oil*,) that is, into a solid and liquid; but there are peculiar differences belonging to these products in each individual species, which sometimes seem to depend upon very trifling causes, and at others to be connected with distinct ultimate composition.

There are two modes by which the stearin and elain of fat may be separated: the one consists in subjecting it to pressure, (having previously softened it by heat, if necessary;) and the other, by the action of boiling alcohol, which, on cooling, deposits the stearin, and retains the elain in solution; the latter separates on the addition of water, still however retaining a little stearin; they may be ultimately separated by digestion in cold alcohol, sp. gr. .835, which takes up the elain, and leaves it after careful distillation; the stearin remains undissolved.

Fat may be separated from its associated cellular texture, by cutting it into small pieces and melting it in boiling water; it collects upon the surface, and when cold is removed, and again fused in a water-bath, and strained through fine cambric. Many varieties of fat, when dissolved in boiling alcohol and precipitated by water, leave a peculiar and slightly acid and saline extract in solution, apparently derived from the enveloping membranes.

1. The softer kinds of fat are termed *lard*, of which *hog's-lard* furnishes a good example: it is white, fusible at a temperature between 75° and 85°, and of a specific gravity = about 0.938. When cooled to 32°, and pressed between folds of bibulous paper, it gives out 62 per cent. of colourless *elain*, which remains fluid at very low temperatures, has a sp. gr. = .915, and is soluble in less than its weight of boiling alcohol, the solution becoming turbid when cooled to about 140°. The residuary *stearin* is inodorous, hard, and granular: when fused, it remains liquid at the temperature of 100°, but, on congealing, it rises to 130°, and assumes a crystalline appearance.

When hog's-lard becomes rancid, a peculiar volatile acid forms in it, which has not been examined. 100 parts of hog's-lard yield, when saponified, 94.65 margaric and oleic acid, which when fused concrete at 150°; and 9. of glycerine. According to Chevreul's analysis, the ultimate elements of hog's-lard are—

Carbon..........	79.098
Hydrogen........	11.146
Oxygen	9.756
	100.000

2. *Human fat* is another species of lard; but it differs in different parts of the body. The fat from the kidney, when melted, is yellow, inodorous, begins to concrete at 77°, and is solid at about 60°. It requires 40 parts of boiling alcohol of 0.841 for solution, and this deposits *stearin* as it cools, which, when purified by pressure between folds of filtering paper at 77°, is colourless, fusible at 122°, and may then be cooled down to 105°, before it concretes; in the act of concreting its temperature rises to 120°, and it becomes crystalline, and soluble in about four parts of boiling alcohol, the greater part being deposited in acicular crystals as the solution cools. The *elain* of human fat, obtained by the action of hot water upon the paper by which it had been absorbed, is colourless, remains fluid at 40°, and concretes at a lower temperature. Its specific gravity at 60° is .913; it is inodorous, and has a sweetish taste. It is soluble in less than its weight of boiling alcohol, and the solution becomes turbid when cooled to about 62°. 100 parts of human fat yield, when saponified, about 96 of margaric and oleic acids fusible at about 90°, and from 9 to 10 of glycerin.

According to Chevreul, human fat and its elain are composed as follows:—

* Recherches chimiques sur les corps gras d'origine animale. Paris, 1823.

† Lehrbuch der Chemie. B. 3 and 4. Dresden, 1827.

	FAT.	ELAIN.
Carbon........	79.000	78.566
Hydrogen......	11.416	11.447
Oxygen	9.584	9.987
	100.000	100.000

3. *The fat of beef* when melted begins to concrete at 100°: it requires for solution 40 parts of boiling alcohol, and contains about three-fourths its weight of stearin, which is obtained by stirring the melted fat whilst it is concreting, and then pressing it in woollen cloths at a temperature of about 95°, by which the elain is squeezed out, together with a portion of stearin, which is deposited at a lower temperature, for the elain does not congeal at 32°. The *stearin* is white, granularly crystalline, fusible at 112°, and may be cooled to 100° before it congeals, when its temperature rises to 112°. It looks and burns like wax. 100 parts of alcohol dissolve 15 of this stearin: when saponified, it yields 0.95 of fat acids, which fuse at 130°. The *elain* of beef fat is colourless and almost inodorous, and soluble in less than its weight of boiling alcohol. Candles made of the stearin of this fat, with a small addition of wax to destroy its brittle and crystalline texture, are little inferior to wax candles.

4. *Neat's foot oil* is obtained by boiling the lower ends of the shin-bones of the ox, after the removal of the hair and hoofs, in water. This oil remains fluid below 32°, and after the separation of the stearin, is used for greasing turret-clocks, which are often so exposed to cold as to freeze other oils.

5. *Goat's fat* is characterized by its peculiar colour, which seems to depend upon the presence of a distinct fatty matter, which, in the separation of the stearin and elain, is associated with the latter, and which Chevreul has called *hircin*. When the elain is saponified, a liquid volatile acid is formed, which may be separated as follows: four parts of the fat are made into soap with one of hydrate of potassa dissolved in four of water: the soap is afterwards diluted, and decomposed by phosphoric or tartaric acid, by which the fat acids are separated: these are distilled with water, taking care that the contents of the retort do not boil over: the distilled liquid is saturated with hydrate of baryta, evaporated to dryness, and decomposed by distillation with sulphuric acid diluted with its weight of water: the acid is separated in the form of a colourless volatile oil which floats upon the distilled liquid; Chevreul terms it *hircic acid:* it congeals at 32°: it has the odour of the goat, blended with that of acetic acid; it reddens litmus, dissolves difficultly in water, and readily in alcohol: it forms distinct salts with the bases: the salt of ammonia has a strong hircine odour: that of potassa is deliquescent, and that of baryta difficultly soluble in water.

6. *Mutton fat* is whiter than that of beef, and acquires a peculiar odour by exposure to air; when melted it begins to concrete at about 100°. It requires 44 parts of boiling alcohol for solution. Its *stearin*, when fused, begins to congeal at 100°, and its temperature rises on solidification to 113°. 100 parts of alcohol dissolve 16 of it. Its *elain* is colourless, slightly odorous, sp. gr. 0.913, and 80 parts of it are soluble in 100 of boiling alcohol. When saponified, it yields a very small quantity of hircic acid. This species of fat, together with its stearin and elain, are composed as follows:—

	FAT.	STEARIN.	ELAIN.
Carbon	78.996	78.776	79.354
Hydrogen ..	11.700	11.770	11.090
Oxygen	9.304	9.454	9.556
	100.000	100.000	100.000

7. *Whale oil, or train oil,* (from whale blubber,) sp. gr. .927, when cooled to 32°, deposits *stearin;* the filtered oil is then soluble in 0.82 of boiling alcohol. Aided by heat it dissolves arsenious acid, oxide of copper, and oxide of lead; sulphuric and muriatic acids render the latter combination turbid, nitric acid tinges it dark brown with effervescence; and it is coagulated by potassa and soda. This oil is easily saponified when mixed with 0.6 its weight of hydrated potassa, and five parts of water; the soap is brown, soluble in water, and when decomposed by tartaric acid and the sour liquid distilled, it yields traces of *phocenic acid,* also glycerine, and oleic and margaric, but no stearic acid: these acids are accompanied by a greasy substance which has the odour of the oil. The stearic portion of train oil, when freed from adhering elain by washing with weak alcohol, concretes, after having been fused, at a temperature between 70° and 80°; it is soluble in 1.8 parts of boiling alcohol, and is deposited in crystals as it cools, leaving a dark thick mother-liquor. When saponified, 100 parts yield 85 of margaric and oleic acids, 4 of a brown substance infusible at 212°, and perfectly soluble in boiling alcohol, 7 of bitterish glycerine, and traces of phocenic acid.

8. *Spermaceti oil,* the produce of the spermaceti whale,* is lodged in the cartilaginous cells of a bony cavity on the upper part of the head; as it cools, it deposits its peculiar stearic portion in the form of *spermaceti;* this substance is further separated by pressure in woollen bags from the oil, and is then washed with a weak solution of caustic potassa, melted in boiling water, and strained; it is commonly cast into oblong blocks, and if the interior liquid portion is drawn off when the exterior has concreted, the cavity exhibits upon its surfaces a beautiful crystalline texture. Spermaceti, as it occurs in commerce, is in semi-transparent brittle masses of a foliated fracture, and soapy to the touch; it has a slight odour and a greasy taste, and when long kept becomes yellowish and rancid. Its specific gravity is .943; it fuses at about 114°. 100 parts of boiling alcohol, sp. gr. .823, dissolve 3.5 spermaceti, and about 0.9 is deposited on cooling. Warm ether dissolves it so copiously, that the solution concretes on cooling; by the aid of heat, it

* Physeter macrocephalus, or Cachalot.

dissolves in the fat and volatile oils, and is in part deposited as the solution cools. Alcohol always extracts a small portion of oil from the spermaceti of commerce; as the boiling alcoholic solution cools, it deposits the purified spermaceti in white crystalline scales, and in this state, Chevreul terms it *cetine*. Cetine does not fuse under 120°; it forms, on cooling, a lamellar, shining, inodorous, and insipid mass, which is volatile at high temperatures, and may be distilled without decomposition. It burns with a brilliant white flame, and dissolves in about four parts of absolute alcohol; it is very difficultly saponified; digested for several days at a temperature between 120° and 190°, with its weight of caustic potassa and two parts of water, it yields margarate and oleate of potassa, and a peculiar fatty matter, which Chevreul calls *ethal*,* and which amounts to about 40 *per cent.* of the cetine used. To obtain it in an insulated state the results of the saponification of cetine are decomposed by tartaric acid, which separates the margaric and oleic acid, together with the ethal; the fat acids are saturated with hydrate of baryta, and the resulting mixture well washed with water to separate all excess of base; it is then well dried, and digested in cold alcohol or ether, which takes up the ethal and leaves the barytic salts; the former is then obtained by evaporation of the solvent. Ethal is a solid, transparent, crystalline, fatty matter, without smell or taste; when melted alone it congeals at 120° into a crystalline cake; it is so volatile that it passes over in vapour when distilled with water. It burns like wax, and is soluble in all proportions in pure alcohol at a temperature below 140°. It readily unites by fusion with fat and the fat acids, and when pure is not acted upon by a solution of caustic potassa; but if mixed with a little soap it then forms a flexible yellowish compound, fusible at about 145°, and yielding an emulsive hydrate with boiling water.

The ultimate composition of train oil, spermaceti oil, spermaceti, cetine, and ethal, are shewn in the following tables :—

	TRAIN OIL. *Berard.*	SPERMACETI OIL. *Ure.*
Carbon....	76.1	79.0
Hydrogen..	12.4	10.5
Oxygen....	11.5	10.5
	100.0	100.0

	SPERMACETI. *Berard.*	CETINE. *Chevreul.*
Carbon....	79.5	81.660
Hydrogen..	11.6	12.862
Oxygen	8.9	5.478
	100.0	100.000

* From the first syllables of the words *ether* and *alcohol*, in consequence of a resemblance in ultimate composition to those liquids.

ETHAL. (*Chevreul.*)

	Atoms.	*Equivalents.*	*Theory.*	*Experiment.*
Carbon..	17	102	79.69	79.766
Hydrogen	18	18	14.06	13.945
Oxygen..	1	8	6.25	6.289
	1	128	100.00	100.000

9. *Phocenine* is a peculiar fatty substance contained in the oil of certain species of porpoise (*Delphinus phocena* and *globiceps*). When this oil is saponified, it yields margaric and oleic acid and cetine, and a peculiar *volatile* acid obtained by a process similar to that for separating hircic acid, and which has been termed *phocenic acid*.* It is a thin, colourless, strong-smelling oil, of a peculiar acrid, acid, and aromatic taste; its specific gravity is .932; it does not congeal when cooled down to 14°. Its boiling point is above 212°. In this state it is an hydrate, containing 9 *per cent.* of water, from which it has not been freed. It is soluble in all proportions in pure alcohol.

The neutral salts of this acid (*phocenates*) are inodorous, but any free acid, even the carbonic, in a gentle heat, evolves the odour of the phocenic acid. Heated in the air they exhale an aromatic odour, dependent upon the formation of a peculiar product. By dry distillation they blacken, evolve olefiant gas and carbonic acid, and a thin, odorous, yellow oil, insoluble in potassa. The phocenates of potassa, soda, and ammonia, are deliquescent; the phocenate of baryta forms efflorescent prismatic crystals; and that of lime, small acicular prisms. The neutral phocenate of lead, evaporated in vacuo, yields flexible lamellar crystals, which are fusible and easily become basic when heated; the subphocenate of lead is difficultly soluble and crystallisable, and decomposed by the carbonic acid of the air.

According to Chevreul, the anhydrous phocenic acid (as existing in its anhydrous salts) consists of

	Atoms.	*Equivalents.*	*Theory.*	*Experiment.*
Carbon..	10	60	65.93	65.00
Hydrogen	7	7	7.69	8 25
Oxygen..	3	24	26.38	26.75
	1	91	100.00	100.00

And the oily hydrated acid is a compound of 1 atom of dry acid and 1 atom of water, or 91 + 9 = 100.

10. *The fat of birds* has been but little examined; Chevreul states that the fat of *geese* concretes after fusion at about 80° into a granular mass of the consistency of butter. According to Braconnot it yields by pressure at 32°, 0.68 of yellowish *elain*, having the odour and taste peculiar to this kind of fat, and 0.32 of *stearin*, fusible at 110°, and soluble in rather more than three parts of anhydrous alcohol. When saponified, it yields margaric and oleic acid and glycerine.

* The same acid is contained, according to Chevreul, in the ripe berries of the *Viburnum opulus*.

The fat of the *duck* and the *turkey* nearly resembles the above.

11. Among insects, peculiar kinds of fat have been obtained from *ants*, and from the *cochineal* insect. The latter has been examined by Pelletier and Caventou. (Ann. de Ch. et Phys. viii. 271.) It is obtained by digesting bruised cochineal in ether, evaporating and redissolving the residue in alcohol, till it remains upon evaporation in the form of colourless pearly scales, insipid and inodorous, and fusible at 104°.

12. Under the term *adipocere*, we have elsewhere described a species of fatty matter which appears to result from the slow decomposition of fibrine; and in some diseased states of the body, a large proportion of the flesh occasionally puts on the appearance of fat. In the former case, it has been supposed that the product is the fat originally existing in the body, which, during the putrefaction of the other parts, has become acidified, that is, converted into margaric, stearic, and oleic acids; and that these acids are more or less saturated by the ammonia which is at the same time generated, and by small quantities of lime and magnesia resulting from the decomposition of certain salts of those earths pre-existing in the animal matter. This view of the nature of adipocere appears so far correct; but the quantity of the altered fatty matter which was found in the cases alluded to, and in others where heaps of refuse flesh have been exposed to humid putrefaction, is sometimes such as to render it highly probable that a portion of the fatty matter is an actual *product* of the decay, and not merely an educt or residue.

In regard to the apparent morbid conversion of muscle into fat in the living body, Berzelius observes that, because the muscles become white, it has been assumed that they are actually converted into fat, but that the appearance depends solely upon the absence of red blood, for the muscles under such circumstances do not lose their power of motion. The truth is that, in these cases, the accumulation of fat goes on to such an extent in the interstitial cellular membrane of the muscular fibre, as gradually to occasion its almost entire absorption, and such of the muscles as undergo this change gradually lose their contractile powers. Two mutton-chops, which have undergone this change, and in which the altered muscle and the ordinary external layer of adipose membrane are quite distinct, are preserved in the Museum of the College of Surgeons, and there is a printed pamphlet giving an account of the symptoms under which the sheep laboured. What may be the chemical peculiarities of the fat deposited among the fibres, as compared with the ordinary fat, has not been ascertained.

The above is an enumeration of such of the varieties of animal fat as have been chemically examined. In their general characters they closely resemble the corresponding compounds of the vegetable kingdom; and, with the exceptions specified, the process of saponification effects upon them very similar changes: they are also similarly acted on by the acids. Some of them seem to afford distinct products when subjected to destructive distillation, and during the decomposition of whale oil for the production of carburetted hydrogen for the purposes of gas illumination, a variety of binary compounds of hydrogen and carbon, with some other products, are obtained, the nature of which has been ably investigated by Professor Faraday.*

(W. T. Brande.)

FEMORAL ARTERY *(arteria cruralis;* Germ. *die Schenkelarterie).* The femoral artery is the main channel through which the lower extremity is supplied with blood: in an extended sense it might, with propriety, be understood to comprehend so much of the artery of the extremity as is contained within the thigh, intermediate to those of the abdomen and the leg; but the variety in the situation and relations of that vessel in different stages of its course is so great that it has been distinguished into two, the proper *femoral* and the *popliteal;* the former appellation being applied to so much of the vessel as is situate in the superior part of the limb, and the latter to that portion which is contained in the lower, in the popliteal region. The comparative extent of the two divisions of the artery differs considerably, the femoral predominating much in this respect, and occupying two-thirds of the thigh, while the popliteal occupies but one; hence the particular extent of each may be exactly defined by dividing the thigh, longitudinally, into three equal parts, of which the two superior will appertain to the former, and the inferior to the latter.

The proper femoral artery, then, engages the two superior thirds of the main artery of the thigh, continued from the external iliac artery above, and into the popliteal below. It emerges from beneath Poupart's ligament into the thigh, external to the femoral vein, and on the outside of the ilio-pectineal eminence of the os innominatum, and it passes into the popliteal region below through an aperture circumscribed by the tendons of the adductor magnus and vastus internus muscles. Its course is oblique from above downward, and from before backward, corresponding to a line reaching from a point midway between the anterior superior spinous process of the ilium, and the symphysis pubis upon the front of the limb above, to another midway between the two condyles of the femur, on the posterior aspect of the bone below. Its mean direction is straight, or nearly so, corresponding to the line which has been mentioned, or, according to Harrison,† to a line drawn from the centre of Poupart's ligament to the inner edge of the patella; but its course is, for the most part, more or less serpentine, the vessel forming as it descends curvatures directed inward and outward. The presence and degree of these curvatures, however, are influenced very much

* Phil. Trans. 1825.

† Surgical Anatomy of the Arteries, vol. ii. p. 137.

by the state of the vessel and by the position of the limb; when the artery is empty, they are less marked than when it is full; and when the limb is extended, they are removed; when flexed, they are reproduced; while in some subjects again, they appear to be absent, the line of the vessel's course being almost direct. The degree to which the artery passes backward is not equally great at all parts of its course: in its upper half, i. e. from Poupart's ligament until it lies upon the adductor longus muscle, the vessel inclines much more backward than in the remainder, and at the same time describes a curve concave forward, but both the latter particulars are more remarkable when the thigh is flexed, and in thin subjects, than when the limb is extended and in subjects which are in good condition; in the last case the vessel is supported and held forward by the deep fat of the groin situate behind it. In its lower half the artery inclines less backward, being supported by the muscles against which it rests.

The femoral artery is also described as inclining inward* during its descent; but this statement requires correction, or at least explanation. The vessel certainly does incline inward at some parts of its course, and for the most part it does so as it descends from the os innominatum into the inguinal space, forming thereby the curvatures which have been mentioned; but the general direction of it is either slightly outward, or at the most directly downward, not inward: the opinion that it is inward has arisen, it is to be supposed, from a partial view of its course, which, in consequence of its serpentine direction, is likely to mislead, and is at variance with that of the popliteal artery, (the lower part of the same vessel,) which is decidedly outward. In order to be assured of the true direction of the vessel, the writer has tested it carefully by means of the plumb-line, and he has always found that it inclined somewhat outward from the perpendicular: the degree, however, to which the proper femoral artery does so, is not considerable, though sufficient to place the matter beyond doubt.

It is to be borne in mind that, in determining the direction of the vessel's course, the limb must be placed in the bearing which it holds naturally in the erect posture, inasmuch as an inclination to either side will influence materially the direction of the artery: thus an inclination of the limb inward will at once give it the same tendency, and render it spiral, both which conditions are removed by placing the limb in its ordinary position.

In consequence of the course which the vessel pursues, and of the oblique position of the femur conjointly, the femoral and popliteal arteries hold very different relations to the shaft of that bone; the former, in the first stage of its course, being in a plane anterior to the femur, and in the middle of the limb being upon its inside; while the latter is situate behind the bone, and at the inferior part of the popliteal region corresponds to the axis of its shaft: hence the artery is said* to pass somewhat in a spiral manner in reference to the thigh bone; but this is incorrect, the spiral course being only apparent and resulting from the combined effect of the obliquity of the artery itself backward and outward, and of the shaft of the femur inward and forward: that this is so may be satisfactorily shewn by the application of the plumb-line to the course of the artery, upon the different aspects of the limb; from which it will appear that, allowance being made for the serpentine deviations already adverted to, the general course of the vessel is, *quam proximè*, straight, and that it cannot, at all with propriety, be said to be spiral, this being not a real but an apparent direction, the result of the circumstances which have been mentioned.

The point at which the femoral artery commences is referred by most writers to Poupart's ligament; this method of demarcation is attended with the inconvenience, that during life the exact situation of the ligament is difficult to determine, inasmuch as it does not run direct from one attachment to the other, and that in dissection its position is immediately altered on the division of its connections with the adjoining fasciæ: hence the student, not having a fixed point of reference, is often at a loss to distinguish between the iliac and femoral arteries, and mistakes affecting the relations of the most important branches of those vessels are liable to be made. For those reasons it appears to me that it would be much preferable to select some fixed and unchanging point to which to refer the commencement of the artery; and for this purpose I would suggest the ilio-pectineal eminence of the os innominatum, which, to the student at least, if not to the practical surgeon, will afford an unerring guide to the distinction of the one vessel from the other; the femoral artery, at its entrance into the thigh, being situate immediately external to the inferior part of that prominence,† with which point the middle of the line connecting the anterior superior spinous process of the ilium and the symphysis of the pubis will also be found to correspond. The precise situation of the vessel is referred by some to the centre of Poupart's ligament, or a point midway between the anterior superior spinous process of the ilium and the spinous process of the pubes; by others to a point midway between the spinous process of the ilium and the symphysis of the pubes. With regard to this question it is to be observed that the relation of the artery to the points between which it is situate is not strictly the same in all instances; that in some it will be found to correspond to the former, and in others to the latter account; but that the latter relation appears to prevail in so much the greater number, that it ought to be adopted as the rule. According to Velpeau it is distant two inches and a quarter from the spinous pro-

* Boyer, Cloquet, Harrison.

* Harrison, op. cit. p. 137.

† This point will be discussed again.

cess of the pubes, and from two and a half to two and three quarters from the superior anterior spinous process of the ilium.

The femoral artery is attended through its entire course by the femoral vein, the two vessels lying in apposition and inclosed within a fibro-cellular investment, to which the appellation *femoral sheath* will be applied. It is also related to the crural nerve or its branches, and it is contained, together with the vein, in a canal of fascia, which will be denominated the *femoral canal.*

It is necessary to dwell here, for a little, upon the distinction between the two appellations *femoral canal* and *femoral sheath*, that a confusion of the one with the other may not arise. The vessels have in fact, throughout their course, two distinct sheaths, which may be considered peculiar to them, contained the one within the other: the external is formed by the fascia lata in a manner to be presently explained, and is in all respects analogous to the canal furnished by the cervical fascia to the carotid artery and jugular vein. This outer sheath, which many may regard as *the* sheath of the vessels, extends from Poupart's ligament to the aperture by which they escape into the popliteal region, and will, for reasons which will appear more fully by-and-bye, be here called *the femoral canal.* The second or internal sheath is situate within the former, is of variable thickness, according to the point at which it may be examined, being for the most part very thin; adheres in general closely to the vessels, in which particular it differs from the outer one, within which they are comparatively free; and not only covers, but also separates them by a thin internal process, which by its density and intimate adhesion to the vessels connects them straitly to each other; it is further not confined, as the other is, to the vessels, while called *femoral*, but is prolonged upon them into the popliteal region, where in like manner it invests and connects them: to this investment the denomination *femoral sheath* will be applied. A distinction between the two structures is necessary in a description of the relations of the femoral artery, were it only to mark their existence, but that which I have adopted is rendered imperative by the use already made of the latter appellation with reference to the anatomy of hernia, in the history of which it is applied not to the canal as formed by the fascia lata, but to that, through which the femoral vessels escape from the abdomen, and as formed by the fasciæ transversalis and iliaca; and the prolongation of the former of these two fasciæ being, in my opinion, continued into the internal and immediate investment of the vessels, it has appeared to me justifiable to extend the signification of the title *femoral sheath*, and to apply it to that investment throughout their entire course, as well below as above the saphenic opening of the fascia lata; while his application of the former appellation, *femoral canal*, is sanctioned by Cloquet, by whom it is used in the same sense.

Beside those which have been already mentioned, the femoral artery has also, during its course, the following general relations:—posteriorly it corresponds in succession to the psoas magnus, the pectinalis, the adductor brevis, adductor longus and adductor magnus muscles; anteriorly it is, in the first part of its course, not covered by any muscle and is comparatively superficial; and through the remainder and more extensive portion it is covered by the sartorius. Externally it corresponds to the psoas and iliacus, to the sartorius, the rectus, and lastly to the vastus internus muscles; the latter of which is interposed between it and the inside of the femur: internally it corresponds to the pectinalis and the adductor longus muscles; and lastly it is overlapped by the sartorius.

It is contained, through its upper half, in the inguinal region. This region is of a triangular prismatic form, the base of the triangle represented by it being above formed by Poupart's ligament, or by a line connecting the anterior superior spinous process of the ilium and the symphysis pubis; its apex below by the meeting of the sartorius and the adductor longus muscles. The sides of the prism are external and internal, inclined, the former backward and inward, the latter backward and outward, and meeting each other along the internal and posterior side of the femur; they are formed, the external by the iliacus and psoas, the rectus, the vastus internus and the sartorius muscles, and the internal by the pectinalis and the adductors. The base of the prism is in front, consisting of the coverings of the space. During its descent from the os innominatum into the inguinal region, the artery generally inclines inward, describing a curve convex outward; and hence, as it seems to me, the entire course of the vessel has been assumed to be inward; but this first curve, when present, is soon compensated by another in the opposite direction. In its lower half the artery is enclosed between muscles, the vastus internus upon its outside, the adductors longus and magnus behind it, and the sartorius in front.

The course of the femoral artery may be advantageously divided into three parts or stages, to be distinguished as first, second, and third, or as superior, middle, and inferior thirds; in each of which will be found such peculiarities in the relations of the vessel as will justify the number of subdivisions. They may be defined with sufficient precision by dividing the two superior thirds of the thigh into three equal parts, and they will occupy each, according to the stature, from three to five inches.

The superior stage reaches from Poupart's ligament to the point at which the artery is first covered by the sartorius: during this, its upper third, the vessel is not covered by muscle, except at its termination, where it is overlapped by the inner margin of the sartorius: it is therefore comparatively superficial, and its pulsations can be felt during life with greater or less facility according to circumstances, to be explained. It has, however, four structures interposed between it and the surface, and forming its coverings; viz. the skin, the subcutaneous cellular stratum, the anterior wall of the femoral canal, and the prolongation of the fascia transversalis or the femoral sheath.

The subcutaneous cellular structure presents a remarkable difference according to the condition of the subject or certain other circumstances. When the body is devoid of fat or emaciated, this structure appears a thin, condensed, dry and lamelliform stratum, continued from the abdomen downward upon the lower extremity, and generally denominated the *superficial fascia of the thigh;* but when, on the contrary, the body is in good condition, and the quantity of superficial adeps is considerable, the appearance of a membranous expansion is removed, and in its stead a thick and uniform stratum of fat is found interposed between the skin and the fascia lata. In other cases presenting a medium condition, the stratum of fat and the membranous expansion may be both observed: in such case the former is generally superficial, and the latter underneath; but when the accumulation of adeps in the subcutaneous structure is more considerable, e.g. in the healthy infant or in many adults, particularly among females, no trace of superficial fascia is to be found. So much for the varieties which the subcutaneous cellular structure presents naturally. It is also found frequently in abnormal conditions deserving of attention: at times it is divisible to a greater or less extent into a succession of expansions, having each the appearances of fasciæ and being of indeterminate number: this disposition, which occurs not unfrequently, and is of considerable importance in a practical point of view, appears due to the influence of pressure exerted by tumours, e.g. that of hernia. Again, in anasarca the subcutaneous structure becomes greatly increased in depth, and loses all appearance of membrane, seeming then a deep gelatinous stratum, consisting of the cellular structure and the effused serum.

The depth, therefore, of the femoral artery from the surface, and the number of coverings which it may have in individual cases, must be materially influenced by those several conditions of the subcutaneous cellular structure when present, and they should never be lost sight of; else uncertainty and embarrassment must arise in the conduct of operations. It is further to be borne in mind that the account of the coverings of the artery given in this description has reference to the natural and most simple arrangement of those structures. The subcutaneous structure also encloses within it the superficial vessels, nerves, and glands, the relation of some of which to the artery requires notice. The superficial vessels are the saphena vein, the superficial femoral veins, and those veins and arteries by which the inguinal glands are supplied.

The saphena vein ascends, from the inner and back part of the knee, along the inner and anterior aspects of the thigh to its upper extremity, where it joins the femoral vein upon its anterior and internal side, at the distance of from one inch to an inch and a half below Poupart's ligament. During its ascent the vein passes forward and outward, and is situate internal to the femoral artery: at the lower extremity of the middle third of the thigh, (the point at which the artery is about to pass into the ham,) it is placed superficial to the vessel, between it and the internal surface of the limb, near to the inner, or at this part the posterior margin of the sartorius muscle; but as the vein ascends, the distance between the vessels increases, partly because of the greater width of the thigh at its upper part, and partly because the course of the vein describes a curve convex inward; and at the termination of the latter it amounts to the width of the femoral vein or somewhat more; lower down it is still greater in consequence of the curve formed by the saphena. Hence, in operations upon the superior part of the artery, the saphena ought to be exempt from danger; while at the lower part it must be very much exposed, if the inner margin of the sartorius be cut upon as the guide to the vessel.

The superficial femoral veins next claim attention: they are very irregular in their course and destination, and therefore are the more likely to prove a source of embarrassment in operation. They are smaller than the saphena, but yet are in many cases of considerable size: they present, according to the subject, two dispositions; either they join the saphena during its ascent at variable points in the course of the thigh, and in such case cross the limb and the artery obliquely from without inward, at different heights; or they form one or two considerable vessels, which ascend external to the saphena, and open into the femoral vein in front, at the same time with the former vessel, passing through the superficial lamina of the fascia lata in the same manner as it does. When there are two such veins, the inner one is generally situate internal to the artery, between it and the saphena, and consequently very near to it; while the external one, or the vein, if there be but one, runs upward and inward, and crosses the artery in its upper third, between the point at which the saphena joins the femoral vein and that at which the artery is overlapped by the sartorius: the last-described vein, when present, must obviously be much endangered in exposing the femoral artery at this part of its course, and perhaps is the vessel which has given rise to the idea that the saphena itself may be encountered in cutting upon the artery in this situation.

The superficial inguinal glands are distinguished into two sets, a superior and an inferior: those of the former are more numerous, and nearer to the integuments than the latter. They are ranged immediately below Poupart's ligament, having their longer diameter parallel to it, and in greatest number superficial to that part of the iliac portion of the fascia lata, which is called its *cribriform portion*, and over the course of the femoral artery, across which they are placed obliquely: they are separated from the vessel by the superficial lamina of the iliac portion of the fascia, and by the prolongation of the fascia transversalis, with the interposed cellular structure; and they derive numerous arterial and venous branches from the main trunks beneath: those branches, which are given off partly by the vessels themselves, and partly by their superficial pudic, superficial epigastric, and superficial anterior iliac branches, pass through the interposed structures in order to reach the glands; in doing so they carry with them sheaths from the fascia lata, which is prolonged upon each as it escapes, and thus they become the means of establishing that connection between the fascia in the groin and the subcutaneous stratum, in which the glands are enveloped, which is considered to influence so remarkably the course of femoral hernia. The glands of the second set are less numerous, are situate farther from Poupart's ligament than the former, being below the entrance of the saphena; they are also deeper seated, lying upon the fascia lata, and they are placed with their longer diameter parallel, or nearly so, to the femur and to the course of the artery. Their relation to the artery is not in all cases the same, inasmuch as the disposition of neither part is strictly uniform, but usually one or two of them lie over the vessel, or immediately on either side of its course; their relation to it, however, is, in the natural condition of the parts, not of great consequence; for in such case they may be easily held aside during operation if necessary, and thus both they and their lymphatic vessels be saved from injury.

The relation of the inguinal glands, more particularly the superior, to the femoral artery suggests several inferences. 1st, That the very commencement of the artery's course, although the situation in which the vessel is nearest to the surface, and that in which it can be most easily distinguished by its pulsation, is yet not the most eligible part at which to expose it, since the glands and their vessels cannot, by any precaution of the surgeon, be protected certainly from injury. 2dly, That phagedenic ulceration of the glands of the groin must be attended with great danger from the vicinity of the great vessels. 3dly, That hemorrhage consequent upon such ulceration does not necessarily proceed from those vessels themselves; but that it may, and in the majority of cases in the first instance probably does arise from the branches supplying the glands; and, 4th, That the groin is likely to be the seat of pulsating tumours requiring to be distinguished from aneurism.

The third covering of the artery is the superficial lamina of the iliac portion of the fascia lata. This portion having covered the anterior surface of the iliacus and psoas muscles as far as the middle of Poupart's ligament, along which it is attached from without inward, divides at that point into two laminæ, a deep one and a superficial one; the former passes inward and backward from the ligament, upon the psoas muscle, to the ilio-pectineal eminence of the os innominatum, into which it is inserted, continued thence upward, upon the inside of the muscle, along the brim of the pelvis into the fascia iliaca, and downward across the capsule of the ilio-femoral articulation, to which it is also attached: it is in fact that part of the fascia iliaca, (for the fascia iliaca and the iliac portion of the fascia lata are one and the same expansion, distinguished from each other only by Poupart's ligament,) which is situate upon the inside of the psoas magnus, and which forms the outer wall of the femoral canal, being interposed between the femoral artery and the muscle. At the ilio-pectineal eminence it also meets and is identified with the pubic portion of the fascia lata, which is attached to the pectineal line of the pubis, in continuation with this deep lamina of the iliac portion, covers the pectinalis muscle, and is situated immediately behind the vessels. When that part of the deep lamina of the iliac portion of the fascia lata which extends from Poupart's ligament to the ilio-pectineal eminence has had the prolongation of the fascia downward detached from it, it appears as an oblique partition dividing the crural arch into two parts, an external containing the iliacus and psoas muscles with the crural nerve, and an internal containing the femoral vessels.

The second lamina of the iliac portion of the fascia lata — the superficial one — passes inward across the femoral vessels, superficial to them and to the prolongation of the fascia transversalis, until it has reached the inside of the vessels: it is at the same time attached above, in front of the vessels, and in continuation with the iliac portion itself, to the inferior margin of Poupart's ligament, from its middle to the base of its third insertion — Gimbernat's ligament, and upon their inside along the base of the latter ligament as far as the pectineal line of the pubis, into which it is finally inserted, external to the base of Gimbernat, between it and the insertion of the fascia transversalis upon the inside of the aperture of the femoral sheath, and where it is also identified with the pubic portion of the fascia attached along the same line: from thence it is united to the anterior surface of the pubic portion of the fascia lata, downward along the inside of the vessels. The superficial lamina of the iliac portion is thus thrown across the front of the vessels, and by the disposition, which has been detailed, the fascia lata encloses the vessels between the two laminæ, and forms, by means of them and their connection at either side, a canal, within which are contained the vessels and the prolongation of the fascia transversalis covering them in front. The constitution of the canal, as described, may be considered to extend from Poupart's ligament until the artery is about to be covered by the sartorius, from whence its anterior wall is formed, through the remainder of the vessel's course, by another and deeper layer of the fascia. The canal thus formed, to which the author would apply, with Cloquet, the term *femoral canal*, is widest at its upper extremity, *i. e.* at Poupart's ligament; from whence, as it descends, it contracts in width until it has passed the entrance of the saphena, beyond which it continues of nearly uniform capacity to its termination. The diminution in the transverse extent of the canal is due to the direction of the line of union between the superficial lamina of the iliac portion and the pubic portion of the fascia, which, as has been already stated, inclines outward as it descends from the pectineal line of the pubis to the point at which the saphena joins the femoral vein. In the interval between Poupart's ligament and the junction of the two veins the superficial lamina is thinner, less aponeurotic, and more of a cellular character than other parts of the fascia; but it is subject to much variety in this respect: in all cases it is thinner and weaker internally than externally, but in some it is throughout distinct and unbroken, unless by the passage of vessels, and presents aponeurotic characters as decidedly as many other parts of the expansion; while in others it is cellular, indistinct, and even fatty, not easily distinguishable from the subcutaneous structure, and so thin as to seem deficient toward its inner part, or to have its line of union with the pubic portion interrupted at one or more points. The extent and connections of this portion of the fascia will be most satisfactorily displayed by first detaching Poupart's ligament, upon its abdominal side, from the fascia transversalis as it descends beneath the ligament, and then carefully insinuating the handle of a knife downward beneath the ligament and the superficial lamina of the iliac portion of the fascia lata, between them and the prolongation of the fascia transversalis: this done, the superficial lamina may, with the guidance of the instrument beneath it, be satisfactorily traced.

The fourth structure, by which the femoral artery is covered in the first stage of its course, is the prolongation of the fascia transversalis. The two abdominal fasciæ, the transversalis and the iliaca, which are, at every other part of the crural arch, either identified and united, or inserted into bone, are separated in the interval between the middle of Poupart's and the base of Gimbernat's ligament, and descend into the thigh, the former in front of or superficial to the femoral vessels, beneath Poupart's ligament and the superficial lamina of the iliac portion of the fascia lata; the latter behind or deeper than the vessels, between them and the psoas and pectinalis muscles, constituting or continued into the pubic or deep portion of the fascia lata. The two fasciæ thus leave an aperture beneath Poupart's ligament, through which the vessels escape from the abdomen, and at the same time inclose them between them; the prolongation of the transversalis covering them in front, the iliac and pubic portion of the fascia lata situate behind them. As it descends upon the vessels, the prolongation from the transversalis is united to the fascia iliaca and iliac portion of the fascia lata upon their outside; and to the pubic portion upon their inside, in the same manner as the superficial lamina of the iliac portion, and within it in reference to the femoral canal: it may therefore be viewed in one of two lights with regard to that canal, viz. either as descending into it superficial to the vessels, and entering into the constitution of its anterior wall, or as concurring with the other fasciæ to form, beneath the superficial lamina of the iliac portion of the fascia lata, a sheath, in which the vessels are immediately contained. The latter is the view which has been adopted by anatomists, and the appellation *femoral* has been given to the sheath so formed. Like the superficial lamina of the iliac portion of the fascia lata, the prolongation of the fascia transversalis is wider at Poupart's ligament, and diminishes in width as it descends to the junction of the saphena and femoral veins: hence the femoral sheath is considerably larger superiorly than inferiorly, does not embrace the vessels closely at their entrance into the thigh, and but for the aponeurotic expansion described by Colles, and termed by Cloquet the *crural septum*, would be open toward the abdomen; but in proportion as they descend, it invests them more closely until it reaches the entrance of the saphena, at which point its connection to them is intimate, and from whence the prolongation seems to the author to be continued downward into the dense thin cellular or fibro-cellular investment, by which the artery and vein are surrounded and connected together within the femoral canal during the remainder of their course through the thigh. From Sir A. Cooper's account of the prolongation it would appear that it terminated, or cannot be traced further than two inches below Poupart's ligament. Sir Astley says, " these vessels pass down within the sheath for about two inches, after which they carry with them a closely investing fascia derived from the fascia lata." By the " closely investing fascia," the author understands the proper sheath of the vessels, which has been adverted to, and with which the prolongation of the fascia transversalis appears to him to be identified. According to Professor Harrison,* " it soon becomes thin and indistinct, and is lost in the cribriform part of the fascia lata;" but in this view of its termination the author cannot concur; the prolongation is doubtless connected to the cribriform fascia (the superficial lamina of the iliac portion of the fascia lata) by the vessels, which traverse both structures, but it is notwithstanding separable, without much difficulty, from it, by means of the proceeding already recommended for the display of that part—a proceeding equally applicable to that of the distinct existence and the connections of the expansion in question; the superficial lamina being at the same time, as directed by Colles, divided from above downward, and its parts held to either side, inasmuch as a thin cellular

* Dublin Dissector, p. 153.

or adipose stratum is interposed between them. The last particular in the disposition of the prolongation of the fascia transversalis, having reference to the femoral artery, is, that it is connected to the back of the femoral canal (the pubic portion of the fascia lata posterior to the vessels) by two septa or partitions, placed, one between the artery and vein, upon the inside of the former; the other internal to the latter, between it and the femoral ring: by those the abdominal aperture of the femoral sheath is divided into three compartments: an external one occupied by the artery, a middle one by the vein, and an internal by the lymphatics, and at times by a gland. The two former are so protected that the occurrence of hernia through them is rare; in the case of the first probably impossible; but the internal, whether from weakness or deficiency of protecting provisions, allows its protrusion, and hence the relation of the femoral vessels, and more particularly of the artery to the neck of the sac of femoral hernia, upon the outer side of which it is always situate, separated from it by the vein.

At the lower part of the first stage the artery is crossed obliquely by the most internal of the deep branches of the crural nerve, which for distinction sake might be called *internal genicular:* it enters the femoral canal on the outside of the vessels above, at a variable distance from Poupart's ligament; descends from without inward upon the front of the artery within the canal; and escapes from it below on the inside of the vessel under cover of the sartorius. Situate, as the nerve is, within the femoral canal, upon the front of the artery, and closely connected to it by the femoral sheath, it is very likely, unless care be taken to avoid it, to be included in a ligature at the same time with the vessel: it will not, however, be always encountered, inasmuch as it crosses the artery, and at a point higher or lower in different subjects.

At times a second branch of the crural nerve crosses the artery in like manner as the former and lower down, but it is not to be always observed.

Posteriorly in its first stage the artery rests, first upon the inner margin of the psoas magnus, from which it is separated by the deep lamina of the iliac portion of the fascia lata: while so related, it is situate over the anterior surface of the os innominatum, external to the iliopectineal eminence, having the two structures, already mentioned, interposed.* Below the os innominatum it is placed over the head of the femur, from which it is separated by the same parts, and also by the capsular ligament of the articulation, and the synovial bursa, which exists between the front of the capsule, and the psoas and iliacus muscles. There are then in this situation two resisting surfaces against which compression of the vessel may be effected; and here also, as observed by Harrison, a tumour with pulsation may occur in case of effusion either into the bursa simply, or into the joint, when a communication exists between the former and the synovial membrane of the latter.

Having passed the margin of the psoas and the head of the femur, the artery corresponds to the tendon of the psoas and iliacus, to the pectinalis, and to a small portion of the adductor brevis, which parts it crosses obliquely in its descent: it is not, however, in contact with them, but is separated from them by a space of some depth occupied by cellular structure and vessels. The distance of the artery from the muscles varies according to circumstances: when the thigh is extended or rotated inward, it is increased; when, on the other hand, it is flexed or rotated outward,* it is diminished: in the former case, the artery is brought nearer to the anterior surface of the thigh by the extension, and by the rotation the lesser trochanter, which is in the middle and deepest part of the space, is carried backward from that surface.

The vessels which occupy the interval between the artery and the muscles are the profunda vein, the circumflex veins, and the femoral vein in part, they being next to the artery and immediately behind it; posterior to them are, at times, the profunda artery, and at the upper part, according to circumstances, one or other of the circumflex arteries, when arising, as in ordinary, from it.

External to the artery in its first stage are the psoas and iliacus muscles, the sartorius, the rectus, and the upper extremity of the vastus internus muscles; from all which it is separated by the wall of the femoral canal. At the entrance of the artery into the thigh, and for about an inch below Poupart's ligament, the crural portion of the genito-crural nerve is contained within the femoral canal in immediate apposition with the vessel upon its outer side. External to it are situate also the crural nerve above, and its saphena branch below. Except in rare instances, the profunda artery lies on the outer side of the femoral during a greater or less extent of its first stage; but it is, unless occasionally near to its origin, at the same time posterior to it, and is subject to varieties in its relation which will be more particularly detailed in the description of that vessel.

Internally the artery corresponds, though at a distance, to the pectinalis and adductor muscles. The femoral vein at the upper part is very nearly upon the same level; the artery, however, is somewhat anterior to it, probably

* In this the author has ventured to differ from the account usually given of the relation of the artery to the os innominatum, according to which (Boyer, Cloquet,) the vessel must be understood to be situate internal to the point mentioned, being said to lie upon the os pubis; but in his opinion this is not correct. The artery lies on the psoas, which is not internal to the eminence, and upon the deep lamina of the iliac portion of the fascia lata covering the muscle, which at its most internal part is inserted into the eminence; consequently the vessel, which lies on the lamina, must be external to that point of bone, and observation will be found to confirm this view.

* Harrison.

from resting upon the psoas, while the vein corresponds to the pubes between that muscle and the pectinalis: hence the two vessels at their entrance into the thigh, allowance being made for the trifling difference which has been mentioned, lie side by side, the vein internal to the artery; but as the former descends from the pubes, it recedes from the surface more than the artery, and at the same time inclines outward, and thus it becomes posterior to it at the lower part of the stage, so as to be concealed by the artery by the time it has reached its termination. It is included with the artery in the femoral sheath, and is separated from it by the external of the two septa, which have been described.

In its *second stage* the relations of the artery differ considerably from those in its first. In the first place it is covered throughout by the sartorius, the muscle crossing it obliquely from without inward, and thence first overlapping it by its inner edge, and gradually extending over it until the vessel is directly covered by it. Secondly, it is in consequence covered by two laminæ of the fascia lata enclosing the muscle; one superficial to it, the other beneath it, forming the front of the femoral canal; it has then two new coverings, the muscle and the second lamina of the fascia. Thirdly, the femoral vein, which is very closely connected to the artery, is directly behind it, between it and the adductor longus muscle, to which the artery corresponds posteriorly. Fourthly, it has no part deserving of attention upon its inside; and, lastly, the saphenus nerve is within the femoral canal, along the outer side of the artery and anterior to it.

The inferior third of the artery also presents some peculiarities of relation. The vessel is still covered by the sartorius; but here the muscle is more to the inner, as in the second stage it is more to the outer side of the vessel, not only connecting it in front, but also lying against its inner side, and the more so the nearer we approach the termination of the stage; so much so indeed, that at its termination, the artery, when injected, may be felt beneath the outer margin of the muscle; and hence the difference between the mode of proceeding with regard to the sartorius recommended generally to be adopted, when occasion arises for seeking the artery in its inferior third, and that to be pursued when the vessel is to be exposed in its second stage; it being advised, in the latter case, to displace the inner edge of the muscle outward, and in the former the outer inward, in order to reach the vessel with the greatest ease and certainty. The vessel is also covered by the same two laminæ of the fascia; but the deep one presents at this part remarkable features: it increases in thickness and is more aponeurotic in proportion as it descends, and hence it is stronger the nearer we approach the termination of the course of the artery; but in the inferior third its thickness is still further augmented by numerous tendinous fibres, which pass from the tendons of the adductors longus and magnus to that of the vastus internus, add very much to the thickness of the fascia, and give to it the appearance of a tendinous expansion of great strength, connecting the tendons of the muscles, which have been mentioned, and covering the artery upon its anterior and internal sides. It is also to be observed that this accession of fibres from the tendons exists only in the inferior third of the artery's course, and not in its middle stage, and hence the covering of the vessel beneath the sartorius, or the anterior wall of the canal, is much thicker and stronger in the former than in the latter; and hence also one of the difficulties encountered in getting at the vessel in the third stage. The artery in this third stage is situate upon the inside of the shaft of the femur, crossing it obliquely from before backward: it is not, however, in contact with the bone, but is separated from it by the vastus internus muscle: it is enclosed, as before stated, between muscles; the sartorius before and internal to it, the adductors longus and magnus behind it, and the vastus internus on its outside.

The other relations of the vessel in this stage are to the saphena vein, the saphenus nerve, the femoral vein, and the superficial superior internal articular artery. The first is situate between the femoral artery and the internal face of the thigh, for the most part along the inner margin of the sartorius, but varying somewhat in this respect, lying at times upon the muscle, from its middle to its inner edge, and at others posterior to it. The saphenus nerve is placed at first, as in the second stage, external and anterior to the artery, but it crosses it at its termination and escapes from the canal, upon its inside, in company with the superficial articular artery, as the vessel is about to pass into the popliteal space. The femoral vein is behind the artery and somewhat external to it: the latter relation of the vein is expressly denied by Velpeau,* but after careful examination the author does not hesitate to affirm it.

The superficial superior internal articular artery, a branch of the femoral, is given off by the artery immediately before its termination; it arises from the front of the vessel, descends nearly in the course of it, escapes from the femoral canal in company with the saphenus nerve, and, holding generally the same relation to that nerve which the femoral itself does, may hence be mistaken for that artery at the inferior part of its course.

Thus the relations of the vessel are here in several particulars the reverse of those in its former stages, and the methods most eligible for adoption in operation ought to be varied accordingly. Operation in its last stage is seldom required, but it may be necessary, as in wounds of the artery at that part, in which case the mode of proceeding with regard to the sartorius and to the artery should be the reverse of that recommended for the upper stage, the muscle being to be displaced inward in order to expose the artery, and the separation of the latter from the vein to be effected in the same direction.

* Anatomie des Regions, t. ii. p. 485. ed. 1.

At the termination of its third stage the artery passes into the ham and there receives the name of *popliteal:* it enters the popliteal region through an elliptical aperture situate to the inside of the femur at the junction of its middle and inferior thirds, and upon a plane with its posterior face, the longer diameter of which corresponds to the course of the artery, and which is circumscribed by the lower margin of the united tendons of the adductor longus and the adductor magnus above, by the connection between the tendon of the adductor magnus and that of the vastus internus below; by the tendon of the adductor magnus internally, and by that of the vastus internus externally: in passing through, the artery carries with it a prolongation of the femoral sheath, by which the popliteal vessels become invested and connected.

Varieties.—The superficial femoral artery seldom presents a variation from its accustomed disposition, so much so that it may almost be held to be uniform in this respect: however two forms of deviation have been observed, rare in occurrence, but of great importance in a practical point of view. Two instances of the first abnormal arrangement are recorded, one of which occurred to Sir Charles Bell, and has been published by him in Anderson's Quarterly Journal for the year 1826: the second is preserved in the Museum of the College of Surgeons, and has been described in the fourth volume of the Dublin Hospital Reports by Dr. Houston, Conservator to the Museum. In these cases the femoral artery divided into two vessels of nearly equal size, which pursued the usual course of the artery side by side and very close together, not, however, in contact, but contained in distinct compartments of the sheath and separated by a septum: hence the existence of the second artery might in operation easily pass unobserved, it not being brought into view by opening the sheath of the other. One was also larger than the other, and situate internal and on a plane posterior to it. In Bell's case the discovery was the consequence of the unfortunate event of an operation for popliteal aneurism; the operation was performed in the middle third of the thigh. The pulsation of the aneurism, which was arrested on the application of the ligature, returned after an interval of some seconds, and became nearly as distinct as before: it ceased again upon the third day, but the patient was carried off on the sixth day by an erysipelatous inflammation of the thigh. On examination after death, it was ascertained that the disposition, which has been described, was present, and that but one of the two vessels had been tied.

The second form of deviation is a high bifurcation into the posterior tibial and peroneal arteries: of this an instance* has been recorded by Sandifort, in which the division took place immediately below Poupart's ligament; and Portal† states that the crural artery has been seen to divide into two large branches shortly after its escape from the abdomen, and then there were two popliteal arteries: he further states that among individuals, in which the brachial artery was bifurcated higher than usual, the crural artery was so also in a remarkable proportion.*

A division of the femoral artery into two trunks of equal size, running parallel and so near together, that they might be conveniently included in one ligature, is recorded by Gooch in the Philosophical Transactions for the year 1775, it being the third instance in amputations of the thigh, in which he had observed such a *lusus naturæ* in the arterial system; but it is not mentioned whether they were instances of the first or of the second kind of variety: he himself, whether from examination or from inference, appears to have concluded that both trunks were prolonged into the lower part of the limb.

Those deviations have been accounted repetitions of similar irregularities in the brachial artery, than which, however, they are far less frequent. It is a matter to be regretted that neither in the case of Bell, nor in that of Houston, has any account been given of the disposition of the artery of the upper extremities or of the other thigh.

Branches of the femoral artery.—The branches given off by the femoral artery are numerous; but the trunk of the vessel being itself intended for the supply of the leg and foot, the branches which it gives to the thigh are, with the exception of one intended specially for the nutrition of that part, inconsiderable in size. The artery gives branches to the integuments of the abdomen, to the glands and other structures in the groin, to the external organs of generation, to the muscles in the vicinity of which it passes, to the inner side of the knee; and, lastly, it gives the large branch, adverted to, for the supply of the thigh, and by which those inosculations with other arteries are formed, by means of which chiefly an interruption in the course of the main vessel is compensated. Those which have received names are five, viz. 1. *the superficial epigastric;* 2. *the superficial* or *external pudic;* 3. *the superficial anterior iliac;* 4. *the profunda;* and 5. *the superficial superior internal articular arteries.*

Of those the first four arise from the artery within its first stage; the epigastric, iliac, and pudic being given off immediately or at a very short distance below Poupart's ligament; and the profunda at a greater although a variable distance from that part.

1. *The superficial epigastric artery (artère sous-cutanée abdominale,* Cloquet; *inguinale,* Chaussier;) ordinarily arises from the front of the femoral, immediately below Poupart's ligament. Sometimes it is given off from a branch common to it and either one or both the external pudics; or it may proceed from the profunda.† It first comes forward through the fascia lata, and then ascends over Poupart's

* Green on the Varieties in the Arterial System, and Sandifort, Observ. Anat. Pathol. iv. 97.
† Anatomie Médicale, t. iii. p. 326.

* Ibid. p. 239.
† Boyer.

ligament upon the inferior part of the abdomen, superficial to the aponeurosis of the external oblique muscle, and enclosed in the subcutaneous cellular stratum. Its course is irregular, at times nearly parallel* to that of the deep epigastric within the abdominal wall; at others ascending directly upon the abdomen; in general it pursues the latter course. It is considerably smaller than the deep epigastric artery, and is concerned altogether in the supply of superficial parts, and in establishing communications with other vessels. Its first branches are distributed to the inguinal glands and coverings: during its ascent upon the abdomen it gives to either side branches which supply the superficial structures, and inosculate through the ventral foramina with branches of the internal epigastric from within; and it terminates by communicating with the same and with those of the internal mammary, and of the inferior intercostals. It is, unless in case of disease, a small vessel, and of consequence only from being exposed to be divided in certain operations, viz. that for inguinal hernia, or that for tying the external iliac artery.

2. *The superficial* or *external pudic* arteries (*scrotales ou vulvaires*, Chauss.) are generally two, distinguished into *superficial*† and *deep*, or *superior*‡ and *inferior:* of those distinctions the latter seems preferable, inasmuch as they are both equally superficial in their distribution, and the difference between them in this particular amounts to no more than that the second continues longer beneath the fascia lata than the first. They arise in general either directly from the femoral, or from a trunk common to them with the superficial epigastric, with which they are of nearly equal size.

The *superior* is given off immediately below Poupart's ligament; comes through the fascia lata, and at the same time gives branches to the inguinal glands; runs, superficial to the fascia, inward and also upward toward the pubes; and either divides into two, one of which ascends above, the other, the more considerable, continues below that part; or, as it proceeds, it gives off small branches which ascend above the pubis, and supply the superficial structures upon the inferior middle part of the abdominal wall; while it is itself continued to the scrotum and side of the penis, the coverings of which it supplies; or into the labium in the female. Its branches communicate with those, which the external organs of generation receive also from the internal pudic artery, and with branches of the epigastric arteries. This branch is usually divided in the operations for either inguinal or femoral hernia.

The *inferior* external pudic artery arises from the femoral at a greater distance from Poupart's ligament than the former: at times it is given off by the profunda§ artery, or from the internal circumflex,‖ or from the superior branch:¶ at others it is absent.** It is situate beneath the fascia lata through a greater extent of its course than the superior; runs inward across the pectinalis muscle, covered by the fascia; passes then through the fascia, and gains the scrotum or the labium and the perineum, in which it is distributed, communicating with the inferior branch of the former and with the perineal artery. Its course is at times so far from Poupart's ligament that it crosses behind the saphena vein.

Occasionally a third* external pudic artery is present, arising either from the femoral itself, the profunda, or the internal circumflex artery.

3. *The superficial anterior iliac artery (arteria circumflexa ilii superficialis*, Harrison; *external cutaneous*, Scarpa; *artère musculaire superficielle*, Cloquet;) arises from the outer side of the femoral artery, or at times from the profunda:† it runs outward in front of the crural nerve, and after a short course divides into three branches. Its first comes from within the fascia lata and is distributed to the superficial inguinal glands: its second branch also comes through the fascia, runs round the anterior and outer side of the thigh, below the spinous process of the ilium, and is distributed superficially: and its third runs outward and upward, beneath the fascia lata, toward the superior anterior spinous process of the ilium; supplies the sartorius and tensor vaginæ muscles at their origin, and also gives branches to the iliacus internus. This artery communicates with branches of the gluteal, the deep anterior iliac, and the external circumflex arteries.

4. *The profunda artery (arteria profunda femoris; intermusculaire*, Chauss.) is the vessel by which the muscles and other structures of the thigh are for the greater part supplied, whence it may be regarded as in strictness the femoral artery, the trunk of the *femoral*, in its general acceptation, being distributed to the leg and foot: it is also the channel through which the communications between the femoral artery and the main arteries of the trunk on the one hand, and of the lower part of the limb on the other, are established, and by which, in case of interruption of the first vessel, either below or above the origin of the profunda, the circulation is to be restored: it is therefore an artery of great importance, and also of great size, being nearly equal to, though for the most part somewhat smaller than, the femoral itself, while in many cases it is fully equal to it. Hence, probably, it has received the name *profunda femoris*, deep femoral artery; and by many the femoral artery is distinguished into the *common femoral* and the *superficial* and *deep femorals;* the first extending from the entrance of the vessel into the thigh to the origin of the profunda; the second being the vessel from the point last mentioned to that at which it becomes popliteal; and the third the artery which is at present under consideration.

The profunda artery for the most part arises from the posterior and outer side of the femoral

* Harrison. † Cloquet. ‡ Harrison.
§ Boyer, Cloquet, Tiedemann.
‖ Harrison.
¶ Ibid. ** Ibid.

* Scarpa, Boyer.
† Cloquet, Scarpa.

at a distance, varying from one to two inches, below Poupart's ligament: it descends thence backward into the inguinal region, posterior to the femoral artery, and corresponding to the muscles situate behind them in the same order as the femoral itself until it reaches the adductor longus: it then passes behind that muscle and continues its descent between it and the adductor magnus, until after it has given off its last perforating branch, when it also perforates the magnus at the lower part of the middle third of the thigh, and finally is distributed to the short head of the biceps and the vastus externus, gives to the femur its inferior nutritious artery, and anastomoses with the descending branches of the external circumflex artery, and with branches of the popliteal. During its descent the profunda recedes from the surface more than the femoral artery, so that it lies nearer to the bottom of the inguinal space, and when placed directly behind it, is separated from that vessel by an interval, which is occupied by the femoral, the profunda, and the circumflex veins. It is accompanied by a corresponding single vein of considerable size, the *profunda vein*, which in the upper part of the thigh is situate before the artery, intervening, as has been mentioned, between it and the femoral artery. It is contained at first within the same sheath with the femoral; but it is presently received into a proper sheath, an offset from the back of that which encloses the other vessel. It has not an immediate relation to any nerve.

Such are the general relations of the profunda artery; but it presents frequent varieties, which derive importance from the practical connections of the femoral vessels. The particulars, in which it is subject to diversity, are the precise situation and relation of its point of origin, and the relation of its course to that of the femoral artery.

The profunda arises generally, as has been stated, from the posterior and outer side of the femoral; but at times its origin is directly behind that vessel, at others directly from its outer side, and occasionally again from its inner side, as may be seen from fig. 3, tab. xxxiii. of Tiedemann. The situation of its origin also is variable, at times being close to Poupart's ligament, at others at some distance from it. According to Boyer* it corresponds to "the middle of the space comprised between the pubis and the little trochanter; sometimes higher, but rarely lower." According to Scarpa,† the division of the femoral artery takes place "at the distance of one inch, or one and a half, very rarely two inches, below the crural arch in a well-formed adult, of the ordinary stature." According to Harrison,‡ the profunda arises "in general about two inches below Poupart's ligament, sometimes an inch or two lower down, and sometimes much nearer to this ligament." Of those three accounts that of Scarpa appears preferable: the "distance between the pubis and the lesser trochanter" is variable, and affords no guide for the living subject, and the author has never witnessed the origin of the vessel by any means so far from Poupart's ligament as the statement of Harrison would imply: a distance of four inches, which may be understood from it sometimes to occur, would bring the origin down to the point at which the sartorius generally commences to overlap the femoral artery, and this is manifestly altogether too low; while on the other hand Scarpa* states expressly that it is never below the maximum point which he has laid down, viz. two inches from the ligament, and Hodgson† asserts that "it very rarely arises so low as two inches." The maximum distance implied in the description of Harrison is that which has been laid down by Bell as the medium point of origin, on which Burns‡ remarks, "I infer that Mr. Bell has described this artery from dried preparations, in which, from the retraction of Poupart's ligament, the origin of the profunda seems to take place lower than on the recent subject." The only objection which can be made to the view of Scarpa, is that the vessel not unfrequently arises nearer to the ligament than one inch from it, its origin being at times absolutely at it, and having been in some few instances observed even above the ligament, before the femoral had escaped from the abdomen, or more properly from the external iliac artery: of this extraordinarily high origin four instances have been recorded by Burns,§ and Tiedemann‖ has met with it in a female, upon both sides. Tiedemann¶ has also inferred from his researches that the profunda arises nearer than usual to Poupart's ligament more frequently in females and in subjects of small stature than in others.

The relation of the course of the profunda to that of the femoral is the next point of variety.

The main course of the former is external to that of the latter; in arriving at its destination, however, it does not at all times pursue an uniform course, but presents diversities in this respect, which affect very much its relation to the femoral artery. Its general direction is downward, backward, and outward; still more outward than the femoral: it is seldom however direct, but describes one or more inflections, by which its course is made at times to cross once or oftener that of the other vessel; and hence the diversities in its relation to the femoral which have been adverted to. When the course of the vessel is direct or little tortuous, the profunda is situate throughout, external to the femoral, and this relation would appear to prevail at least as frequently as any

* Traité complet d'Anatomie, tom. iii. p. 150.
† Treatise on Aneurism, Wishart's translation, p. 3.
‡ Op. cit. vol. ii. p. 144.

* Op. cit. p. 328.
† Treatise on Diseases of Arteries and Veins, p. 434.
‡ On Diseases of the Heart, &c. p. 319, 20.
§ Ibid.
‖ Explicatio Tabularum Arteriarum, p. 323.
¶ Ibid.

other, or to be the most prevalent, for such is the view of the course of the artery given by Haller,* in two of three views in which the relative course of the two vessels is represented, and by Tiedemann † in two of four views. But at other times, when the artery is more tortuous, after descending for a little way external to the femoral, it makes a turn, and passes inward behind it, and thus frequently gains the inner side of that vessel before it reaches the adductor longus, after which it again inclines outward toward its destination. Such is the view given of its course by Scarpa,‡ with which the description of Harrison coincides: it is similarly represented by Tiedemann in fig. 4, tab. xxxiii., and also by Haller § in one instance; but the author is disposed to regard this as a less common disposition, as well from the frequency with which he has observed the former one to occur, as from the weight of the authorities which have been adduced in favour of that opinion. In other but rare instances the profunda, arising from the inside of the femoral, inclines at first inward and becomes internal to it, and then bending outward crosses behind the femoral to its outer side: of this arrangement an instance is furnished by Tiedemann in fig. 3, tab. xxxiii. And in others the artery does not in the first instance incline sensibly to either side; but arising from the back of the femoral it descends behind that vessel, and does not gain its outer side until it has reached the lower part of the inguinal region.

When the profunda artery arises very near to or above Poupart's ligament, and from the outer side of the femoral, is large and pursues its ordinary course, two arteries of equal or nearly equal size may be found, at the upper part of the inguinal region, side by side, and upon the same level, and thence liable to be taken, either of them, for the femoral artery. When such an arrangement occurs, the external‖ of the two vessels will almost certainly be found to be *the profunda*, for if that artery have once passed inward behind the femoral, it cannot afterward gain the same level with it, so as to be situate at the same time internal to and on the same plane with it: further, as the profunda descends, it recedes from the anterior surface more than the femoral, in order to pass behind the adductor longus, and thus it gains at the lower part of the region a deeper situation than the other. But inasmuch as the profunda occasionally arises from the inside of the femoral artery, it may be possible for it, in case of high origin, to be the inner of the two vessels adverted to. Such a circumstance, however, if it ever occur, must be extremely rare, but in order to guard against it, the precaution recommended of alternately compressing the vessels and ascertaining the effect previous to the application of a ligature, should never be neglected.

Branches of the profunda artery.—The profunda gives off a considerable number of branches, some of which being distributed to the muscles, by which the artery passes, and not being remarkable either for their size or their communications, have not received particular names. Those which are most deserving of attention, whether for their size, the extent and peculiarity of their course, or the anastomoses which they form with other arteries, are five or six in number, viz. two *circumflex arteries*, and three or at times four *perforating arteries*. The circumflex arteries are so named because they wind round the upper extremity of the femur, and form an arterial circle around it: they are distinguished by the epithets *external and internal*, being destined, one to the outer, the other to the inner side of the limb: they are vessels of considerable size and importance because both of the extent of parts which they supply, and of the communications which are established through them between the femoral, the arteries of the pelvis, and those of the lower parts of the limb.

1. *The external circumflex artery* at times is the first branch of the profunda; at others it is preceded by the internal circumflex: it is given off from the profunda while it lies on the outside of the femoral at a variable distance from Poupart's ligament, and arises from the outer side of the artery: occasionally it is given off by the femoral itself; it runs directly outward, or outward and downward, in front of the psoas and iliacus muscles; beneath the sartorius and rectus, and either between or behind the divisions of the crural nerve; and divides after a short course into three branches, viz. an ascending, a descending, and a circumflex.

a. The first, the *ascending* branch, runs upward and outward toward the superior anterior spinous process of the ilium, between the iliacus internus and the glutœus medius muscles, and concealed by the tensor vaginæ femoris: as it proceeds, it gives branches to those muscles; and having reached the outer and back part of the spinous process, it terminates in an anastomosis with a branch of the glutœal, and also with the deep circumflex ilii arteries. The anastomosis with the glutœal artery becomes remarkably enlarged when the main vessel is interrupted above the origin of the profunda, as may be seen from Sir A. Cooper's case of femoral aneurism.*

b. The second, the *descending* branch, runs downward and outward beneath the rectus muscle, between it and the triceps crural, and divides after a short course for the most part into several branches of considerable size and great length for the supply of those muscles and for establishing communications: the branches are

* Icones Anatomicæ.

† Tabulæ Arteriarum. Tab. xxxi. and fig. 2. tab. xxxiii.

‡ Reflexions et Observations Anatomico-chirurgicales sur l'Aneurisme, tab. 1ère.

§ Op. cit.

‖ Harrison, op. cit. vol. ii. p. 165. Hargrave, System of Operative Surgery.

* Guy's Hospital Reports, Jan. 1836, pl. 1.

at times so many as five or six, and are distributed one or more to the rectus, entering the muscle upon its deep surface, and prolonged to a great length within its substance; one to the vastus internus, one to the cruræus, and one or two to the vastus externus: they are accompanied, several of them, by branches of the crural nerve, and they run for a considerable distance, particularly the inferior branch to the vastus externus, between the divisions of the triceps crural muscle, before entering their substance: they are prolonged very low down, and may be followed some of them to near the knee, where they anastomose with branches of the femoral in the vastus internus, and with the superior articular arteries. But the branches of the descending division of the external circumflex artery are by no means uniform in number or destination, more or fewer of the arteries just described being at times branches of the profunda itself; thus, at times that to the vastus internus, that to the cruræus, and that to the rectus, arise from the profunda below the circumflex, and in such case the descending branch of the latter consists solely of the branch or branches destined to the vastus externus muscle.

c. The third, the *circumflex* branch, pursues at first the course of the original vessel, and runs outward across the upper extremity of the shaft of the femur below the great trochanter, beneath the rectus and tensor vaginæ muscles, and superficial to the cruræus. It gives, in this situation, branches to the cruræus, the iliacus, the rectus and tensor muscles. It then passes backward upon the outside of the femur to its posterior part, and thus surrounds the bone upon its anterior and external sides. In the latter part of its course it traverses the upper extremity of the vastus externus, and gives off, 1. branches upward and downward into the muscle; 2. a branch or branches which run between the vastus and the bone, and supply the periosteum; 3. a branch to the glutœus maximus at its insertion, which, after furnishing it branches, perforates the muscle and becomes superficial. The circumflex division of the external circumflex anastomoses with the internal circumflex, the glutœal, the sciatic, and the perforating arteries. The external circumflex artery is accompanied by a large vein, which crosses between the femoral and profunda arteries, superficial to the latter, in order to join the femoral or the profunda vein.

2. *The internal circumflex artery* is a larger vessel than the external: it is given off by the profunda usually after the external, and arises from the inner side of the artery, but at times it arises before the external. According to Harrison it " very frequently proceeds from the femoral artery, prior to the origin of the profunda;" it has been found by Burns* arising from the external iliac artery, and also from the femoral artery a little below the crural arch. In the former case " it ran along the front of the lymphatic sheath;" and in the second " it traversed the front of the common sheath of the great vein and also of the lymphatics;" and in either case, as observed by Burns, it must be exposed to great danger in operation for femoral hernia. According to Green,* both circumflex arteries sometimes are furnished from a common trunk. It runs inward, backward, and downward toward the lesser trochanter into the deepest part of the inguinal region, and escapes from that space posteriorly between the tendon of the psoas and the pectinalis muscles; continues its course backward, on the inside of the neck of the femur and the capsular ligament, below the obturator externus, behind the pectinalis, and anterior to the adductor magnus and the quadratus muscles, until it has got behind the neck of the bone; and lastly, it passes through the internal, which separates the inferior margin of the quadratus femoris from the upper margin of the adductor magnus, and thus gains the posterior region of the thigh, where it terminates as will be described.

The internal circumflex artery is the vessel which gains the deepest situation in the groin: it is internal and posterior to the profunda, and when it arises from that artery, while external to the femoral, it crosses the latter vessel posteriorly in its course. While within the inguinal region the internal circumflex artery gives off first a branch to the iliacus and psoas muscles: then a considerable branch, denominated by Tiedemann *superficial circumflex branch*, which contributes to supply the pectinalis, the adductor longus, and the adductor brevis: it runs upward and inward upon the pectinalis, at the same time giving branches to it and to the adductor longus, until it reaches the interval between these muscles: it then divides into two, of which one ascends in the course of the original branch, between the muscles mentioned, toward the origin of the adductor longus, supplying the two muscles, and ultimately anastomosing with branches of the obturator artery: small branches of it traverse the adductor, and become cutaneous upon the upper and inner part of the thigh. The second branch passes downward and backward, also between the pectinalis and the adductor longus, gains the anterior surface of the adductor brevis, and there meets the obturator vessels and nerves: it divides into several branches, of which some are distributed to the last muscle, some anastomose with the obturator artery, and others with the upper perforating artery.

Behind the pectinalis the internal circumflex artery gives several branches. Downward it gives a considerable one to the adductor magnus, which descends into that muscle, supplies it and anastomoses with the perforating arteries. Upward and forward it gives to the adductor brevis and the obturator externus branches which communicate freely with the obturator artery after its escape from the pelvis. Outward it gives the articular artery of the hip a branch, small, but remarkable for its course and

* Op. cit. p. 319.

* Op. cit. p. 31.

destination; it enters the articulation beneath the transverse ligament, through the notch at the internal and inferior part of the margin of the acetabulum, over which the ligament is thrown; supplies the adipose structure which occupies the bottom of the socket, and is conducted by the ligamentum teres to the head of the femur, in which it is ultimately distributed. That part of the artery which reaches the head of the femur is of very inconsiderable size, and is the source upon which the nutrition of that part depends in fracture of the neck of the bone within the capsule. Lastly, upward and backward the artery sends off a considerable and regular branch which is usually described as one of its terminating branches, but which, in the opinion of the author, may with more propriety be considered as belonging to its middle stage. It passes upward and outward between the obturator externus and the quadratus muscles to the trochanteric fossa, where it is distributed to the muscles inserted behind the trochanter, viz. to those which have been just mentioned; to the obturator internus, the gemelli, the pyriformis, the glutœi medius and minimus, and to the back of the ilio-femoral articulation, and where it inosculates with the glutœal, sciatic, and external circumflex arteries. It may be appropriately called the *posterior trochanteric** *branch.*

After its passage between the quadratus and the adductor magnus, the circumflex artery divides, in the posterior region of the thigh, into an ascending and a descending branch. The former passes upward to the origin of the biceps, semi-membranosus and tendinosus muscles, and to the glutœus maximus; the latter downward to the former muscles, to the adductor magnus, and to the sciatic nerve. They communicate with the sciatic, the external circumflex, and superior perforating arteries.

The perforating arteries are three or four in number. They are given off backward by the profunda, below the origin of the circumflex arteries, and are denominated numerically first, second, third, &c. They all pass from the anterior to the posterior region of the thigh by perforating the adductor magnus, and at times also the adductor brevis, whence their name; they divide for the most part into ascending and descending branches, and are consumed partly in the supply of that region, and partly in establishing a chain of communications between the arteries of the trunk and the main artery at the upper and the lower parts of the thigh.

3. *The first perforating artery* arises from the profunda immediately below the lesser trochanter, nearly opposite the lower margin of the pectinalis: it passes backward, descending a little below the lower margin of the pectinalis, either between it and the upper one of the adductor brevis, or through an aperture in the latter muscle: it next perforates the adductor magnus close to the linea aspera, and so gains the posterior region of the thigh, where it divides into two or three large branches, of which one ascends and is distributed to the glutœus maximus, communicating with the glutœal, sciatic, and circumflex arteries; another descends, supplies the long head of the biceps, the semi-membranosus and semi-tendinosus, and communicates with the inferior perforating arteries; and the third runs downward and outward into the vastus externus, through which it descends, communicating at the same time with the external circumflex artery. The artery also gives branches to the sciatic nerve, and, during its passage from the front to the back of the thigh, to the pectinalis and the adductors. According to Harrison, "this artery is sometimes a branch of the internal circumflex; its course is nearly parallel to that vessel, and is separated from it by the tendon of the pectinæus muscle, the first perforating artery passing below that tendon, while the circumflex artery runs superior to it."

4. *The second perforating artery* is generally the largest of those vessels: it arises a short distance below the first, and passes through both the adductors brevis and magnus; it then divides, like the former, into ascending and descending branches: the former are distributed to the glutœus maximus, the vastus externus, and the tensor vaginæ, likewise anastomosing with the first perforating, the glutœal, sciatic, and circumflex arteries: the latter are distributed to the biceps, semi-membranosus, and semi-tendinosus, the vastus externus, and the integuments of the back of the thigh, and inosculate with the inferior perforating and with branches of the popliteal artery. The artery also gives branches to the adductor muscles and to the sciatic nerve and the nutritious artery of the femur, which enters a canal to be observed in the linea aspera, at the junction of the first and second thirds of the thigh, leading obliquely upward into the bone. The second perforating artery at times does not pass through the adductor brevis, but when the first does so, it generally runs inferior to it, perforating the adductor magnus only.

5. *The third perforating artery* is smaller than either of the former, and arises lower down; according to Harrison, at the upper edge of the adductor longus muscles, it passes through the adductor magnus, and divides in the same manner as the others: its branches are also similarly distributed, and anastomose with the second perforating artery from above, and with branches of the popliteal from below.

When a fourth perforating artery exists, it pursues a similar course and is distributed similarly to the last. The perforating branches of the profunda are subject to much variety with regard to number, size, and precise course and distribution; so much so that they hardly admit a definite description: the preceding account has been taken from a comparison of the most approved authorities with the subject, in order, as far as possible, to embrace their numerous irregularities.

Beside those branches, which have been enumerated, to which proper names have been given, the profunda artery gives off during its

* Scarpa, op. cit.

course others less regular and less considerable, which are distributed to the muscles in its vicinity. Those are a branch to the pectinalis and adductor muscles, and one or more to the vastus internus and cruræus muscles: it has been elsewhere stated that the descending branches of the external circumflex, destined to the last-named muscles, and one of those to the vastus externus, at times also arise from the profunda itself. After having given off the last perforating artery, the profunda, very much reduced in size, continues its descent behind the adductor longus muscle, inclining at the same time outward, and external to the femoral artery: it passes through the adductor magnus a little above the passage of the femoral into the ham, giving it small branches; then traverses the origin of the short head of the biceps, giving it also branches; and, lastly, enters into the outer part of the vastus externus, through which it descends frequently to near the knee, distributing branches to the muscle, and anastomosing with the descending branches of the external circumflex and with the external articular artery. The termination of the profunda is by some* called the *fourth perforating artery*.

The profunda resembles very much in its course and termination the superior profunda or musculo-spiral branch of the brachial artery, to which it may be considered analogous.

Immediately before the femoral artery passes into the popliteal space, it gives off its fifth and lowest branch. This is usually called the *anastomotica magna artery*, but there being no more reason to apply the epithet *anastomotic* to it than to the other branches of the femora, and the great anastomotic artery of the thigh being in reality the profunda, the name given to it by Tiedemann seems much to be preferred, viz. *superficial superior internal articular*. It arises from the front of the femoral at the inferior part of its last stage, and immediately escapes from within the femoral canal, passing through its anterior wall at the same time with the saphenus nerve, as the femoral itself is about to pass into the ham. Having come through the aponeurosis forming the wall of the canal, it descends for some distance toward the inside of the knee parallel to the tendon of the adductor magnus and anterior to it in company with the saphenus nerve, and covered by the sartorius muscle. After a short course it divides into two branches. One of these runs downward and forward, in front of the adductor magnus, toward the patella; enters the vastus internus and traverses it in its course; divides within it into two branches, of which one runs between the muscle and the bone, and supplies the periosteum of the femur and the capsule of the articulation, anastomosing at the same time with the deep articulars; the other continues its course through the vastus, supplying the muscle, until it reaches the side of the tendon of the extensors: it then becomes superficial to the tendon, and descends upon the front of the patella, ramifying freely upon it, supplies the integuments and other superficial structures of the articulation on its anterior part, and communicates freely with the other articular arteries.

The second branch, into which the superficial articular divides, descends posterior to the tendon of the adductor, in company with the saphenus nerve, and covered by the sartorius: as it descends, it gives branches to the hamstring muscles, the semi-membranosus and semi-tendinosus, and also to the sartorius: when it has reached the inner side of the knee, it divides into two, of which one passes forward beneath the aponeurosis, upon the internal condyle of the femur, divides into branches which supply the superficial structures of the joint upon its inside, can be traced forward beneath the patella, and form free communications with the other articular arteries, more particularly with the inferior internal one: the second descends to the leg, escapes from beneath the tendon of the sartorius, and then, turning forward, ramifies over the internal surface of the tibia below its tubercle, supplies the insertions of the muscles and the coverings, and communicates with branches of the internal articular and of the tibial recurrent arteries. The superficial superior internal articular artery is variable in size: at times it is of very considerable magnitude; at others it is small, or even absent altogether, its place being supplied by a branch of the popliteal artery. Its distribution also varies with its size, the extent of the former being proportioned to the latter.

The course of the artery diverges but little from that of the femoral, and the relation of the saphenus nerve to it is almost the same as that which the nerve holds to the latter vessel: hence, when the branch is large, it is liable to be mistaken in the operation of tying the main vessel, particularly in case of wound of the artery, for the femoral itself. The description of the articular artery here given has been taken from the plate of Tiedemann, in which the vessel is represented with its most extended distribution.

The femoral artery also gives off, during its descent through the thigh, beside the branches which have been described, several others to the muscles which are in its vicinity; above, it sends branches to the sartorius, iliacus, and pectinalis; and in the middle of the thigh to the vastus internus on the one hand, and to the adductor muscles on the other. Those branches are for the most part inconsiderable in size, and have not received names, but they are deserving of attention, inasmuch as they cooperate in the collateral circulation, more particularly the second set, through which the femoral artery is generally preserved pervious, after ligature below the origin of the profunda, during a greater or less extent of the interval between the ligature and the popliteal artery, by means of the anastomoses between the branches in question and the circumflex arteries.

The adequacy of the collateral circulation in the thigh to the maintenance and nutrition of the limb after the interruption of the femoral artery, has been so long established that it is

* Scarpa, op. cit. p. 17, 18.

at present unnecessary to insist upon it. But the channels through which the circulation of the blood becomes in such cases restored, as well as the relations of the new circulation, are deserving of attention.

The collateral connections of the femoral artery are distinguishable into those between it and the arteries of the trunk, those between it and the popliteal and arteries of the leg, and those between different parts of its own course.

The communication of the femoral artery with the arteries of the trunk are established between it and both the internal and the external iliacs.

Those with the internal iliac are formed, 1. by means of the inosculations of the branches of the profunda, the circumflex and perforating arteries with the obturator, glutœal, and sciatic arteries, all branches of the latter; 2. by those between the internal and external pudics; and, 3. by the communications of the ilio-lumbar artery with the deep anterior iliac, by which the blood may be transferred to the superficial anterior iliac or the external circumflex.

From the obturator artery the blood is transmitted through the ascending branches of the internal circumflex: this channel of communication becomes, in cases of interruption of the external iliac artery, remarkably free, the branches establishing it being much enlarged and tortuous: instances and representations of it may be found in the Medico-Chirurgical Transactions, vol. iv. and in Guy's Hospital Reports, No. 1, Jan. 1836, from the experience of Sir Astley Cooper.

Through the glutœal artery the femoral communicates with the internal iliac by the inosculations between that vessel, the posterior trochanteric and the ascending terminal branches of the internal circumflex, and by those between it and the ascending and circumflex branches of the external circumflex artery: those connections are displayed also in the works just referred to.

The communication of the femoral with the internal iliac through the sciatic artery is established by the anastomosis of that vessel with the internal circumflex and the perforating arteries, for which also see the same works.

The alteration in the condition of the sciatic artery or its branches caused by ligature of the femoral or of the external iliac artery presents one of the most remarkable results of that circumstance: its branch to the sciatic nerve becomes greatly enlarged, very tortuous, and so much elongated as to form at times a communication between the sciatic artery and the posterior tibial. The connections established through the pudic and ilio-lumbar arteries are set forth, in the event of a case of ligature of the external iliac artery published in the Medico-Chirurgical Transactions, vol. xx. by Mr. Norman.

The femoral artery communicates with the external iliac through means of the anastomoses between the anterior iliac arteries, internal and external, between the internal anterior iliac and the external circumflex; and also by those between the superficial and internal epigastrics.

By the communications, which have been mentioned, the transmission of blood through the femoral artery may be restored, after the interruption of the external iliac artery, or of the femoral above the origin of the profunda, with sufficient freedom for the perfect nutrition of the limb; of which numerous instances have been observed by different writers.

The upper and lower parts of the femoral artery are also connected by collateral channels. Those are established by the communications which exist between the branches of the profunda artery arising from the upper extremity of the femoral, and branches of the latter given off during its course or from its lower extremity; thus the blood may pass from the femoral artery above into the middle part of the vessel through the anastomosis existing between the descending branches of the external circumflex artery, and the branches given by the femoral to the vastus internus muscle about the middle of the thigh.

A similar communication exists upon the internal side of the femoral by means of the anastomoses by which descending branches of the internal circumflex are connected with those given by the femoral itself to the adductors.

The collateral connection of the femoral with the popliteal artery is established through two channels: 1. through the anastomoses between the branches of the profunda, as well the external circumflex as the perforating arteries, with the branches of the popliteal; whence the femoral may be interrupted at any part below the origin of the profunda, and the blood thus find a ready passage from it into the popliteal: 2. through those of the branches given by the femoral to the vastus internus and the superficial superior internal articular with the same.

To the channels of communication which have been described are to be added, as pointed out by Scarpa, those established, by the arteries of the periosteum and of the internal structure of the femur, between the main arteries above and below. The former are well represented by Scarpa,* and are formed by anastomoses between branches of the external circumflex, the profunda, the femoral and the popliteal distributed to the periosteum.

Upon a review of the anastomotic connections of the femoral artery, its course presents two stations at which communications are established, on the one hand with the main artery above, and on the other with that below, while in the interval they are connected the one with the other. Those are, 1. the first part of the vessel's course from its commencement to below the origin of the profunda; and, 2. its lower part for so much of it as includes the origins of the branches to the triceps crural and adductor muscles, and the superficial superior internal articular.

Again, it appears that through the first station, not only is the femoral connected with the arteries of the trunk and with the lower part of the vessel, but also it is connected

* Réflexions sur l'Aneurisme, tab. ii.

without the intermedium of the second with the popliteal artery, the latter forming by much the more free channel of communication between the two vessels, whence the circulation of the lower part of the limb may be preserved independent of the communication between the upper and lower parts of the femoral artery, as has been exemplified in the case of Sir A. Cooper given in the Medico-Chirurgical Transactions, vol. ii.; and, lastly, a communication exists by which the blood may be conveyed from the arteries of the trunk into the popliteal artery and the arteries of the leg, independent of the femoral and without transmission through any part of its canal.

Hence varieties may be expected in the condition of the femoral artery in cases of interruption, according to the situation of the interruption, and the influence of it or other circumstances in determining the course which the circulation is to take.

When the artery is obstructed above the origin of the profunda independent of aneurism, the origin of that vessel being free from disease, it would appear that the trunk of the femoral does not undergo any alteration in its capacity, at least from the origin of the profunda downward: when an interval exists between the point of interruption and the origin of that vessel, the trunk may be diminished for so much, while again it may continue unaltered; thus in Sir A. Cooper's case* already referred to, the vessel was found reduced to about half its natural size between the origins of the epigastric and circumflex ilii arteries and that of the profunda, and from the latter it preserved its ordinary size through the remainder of its course: in Mr. Norman's case† on the other hand, it was of its natural size in the interval adverted to, but inasmuch as the origin of the profunda was obstructed in the latter case, it cannot be considered so fair an instance of the influence of the simple interruption at the part specified as the former, in which the femoral artery remained pervious after the cure of the aneurism. It is hence to be inferred, 1. that interruption of the femoral above the origin of the profunda or of the external iliac artery is not necessarily followed by obliteration of the former, unless it be of so much of the femoral as might intervene between the interruption and the origin of the profunda, where the ligature has been applied to the former: 2. that in such case the internal iliac is thenceforward the principal source from which the supply of blood to the lower extremity is to be derived; and that the profunda artery through its inosculations with the branches of the internal iliac, constitutes the chief channel through which the transmission of the blood to the trunk of the femoral and the limb takes place: 3. that the external iliac artery contributes, but in an inferior degree, to the supply of the limb, when the interruption is in the femoral itself: 4. that the femoral artery and its branches thenceforward are to be considered branches of the iliac arteries, rather of the internal than of the external, the trunk of the femoral itself being secondary to its own branches, by which the blood is transmitted into it from the iliacs.

When the interruption of the femoral occurs below the origin of the profunda, the obliteration of the trunk is no farther necessary than between the interruption and the origin of the profunda on the one hand, if no other branch intervene, and that of the next considerable branch upon the other. In such case the profunda artery becomes the main channel of the circulation through the lower extremity from its origin downward, and the femoral with its branches thenceforth are to be regarded as branches of it.

But when the interruption arises from aneurism and the operation necessary for its cure, obliteration of the femoral, to a greater or less extent according to the case, for the most part ensues: this appears to depend upon the influence, which the mode of cure of the disease exerts upon the circulation through the vessel, for the coagulation of the contents of the sac being generally produced by the interruption of the current of blood, the passage through the sac becomes obstructed, and along with it an extent of the artery upon both sides of the seat of the aneurism greater or less according to the disposition of the adjoining branches. The extent to which the obliteration of the artery has been found to proceed, has been different in different cases, but the varieties observed have been the following: 1. As regards that part of the vessel which is above the ligature, when the femoral artery has been tied below the origin of the profunda for popliteal aneurism, the vessel has been found, when the ligature has been applied to the lower part of the artery, either obliterated from the ligature to the origin of the profunda, as occurred in the first subject upon whom Mr. Hunter* operated for popliteal aneurism according to his method, or obliterated upward only as far as the origin of those muscular branches of the artery, which arise below the profunda and anastomose with the articular arteries. 2. When the ligature has been applied near to the origin of the profunda, as in the operation of Scarpa, between it and the origin of the branches alluded to, the artery has been found obliterated from the point of interruption to the origin of the profunda.

The condition of the artery below the seat of the ligature is equally subject to variety according to circumstances, and is still more deserving of attention than the former: it has been found in one of three states, either obliterated throughout from the origin of the profunda down to the extremity of the popliteal artery, as occurred in the case reported by Sir A. Cooper in the Medico-Chirurgical Transactions, vol. ii., or pervious throughout from the point of application of the ligature to the seat of the aneurism, where it was

* Guy's Hospital Reports.

† Med.-Chir. Trans. vol. xx.

* Transactions of a Society for the improvement of Medical and Chirurgical Knowledge, vol. i.

obliterated. Of this condition several instances are cited by Hodgson,* and a most remarkable one is in the possession of Mr. Adams of this city, through whose liberality the author is permitted to introduce a notice of it. It was obtained from a patient who had been operated on by the late Professor Todd, and is remarkable, 1. because the operation had been performed upon both limbs, and the condition of both is, as nearly as may be, the same; 2. because the obliteration at the seat of the ligature does not on either side exceed an inch, on one not being more than half that length; and, 3. because the artery is pervious on both sides from the obliteration of the ligature to the lower part of the popliteal artery, the obliteration at the seat of the disease appearing not to have extended beyond it; and being, on both sides, about two inches long. Thirdly, the artery has been found partially and irregularly obliterated, the vessel being closed at and for some distance below the seat of the ligature; being then pervious, the blood being conveyed into it by the inosculations between the minor branches of the artery arising below the interruption and those of the profunda from above; and again impervious below, the blood being conveyed from it by similar branches anastomosing with the articular arteries.

The effect of ligature of the external iliac upon the femoral artery, independent of the influence of aneurism, has been already adverted to. That effect is liable to be modified by the presence of the disease; thus in a case related by Sir A. Cooper in the fourth volume of the Medico-Chirurgical Transactions, in which the iliac was tied for aneurism of the femoral artery at the middle of the thigh, the latter vessel was obliterated from the origin of the profunda downward. The case, recorded by Mr. Norman, already referred to, in which the external iliac was also tied, presents another remarkable modification: in it the femoral remained pervious, but the root of the profunda was obliterated, while its branches were open.

Operative relations of the femoral artery.— The femoral artery may be the subject of operation at any part of its course, there being nothing either in its situation or relations to forbid the exposure of it at any point, if circumstances should require it. All parts, however, are not equally eligible, the vessel being in some situations more deeply situate, covered by a greater number and depth of parts, and its relations more complicated than at others. It has been taken up in each of the three stages into which its course has been divided, and the operations, which may according to circumstances be performed upon it, may with advantage be referred to those. The propriety of thus distinguishing them will appear in a strong light, when those modifications, which the anatomical relations of the vessel may justify, shall have been discussed, as also from the history of the operations, which have been and are proposed to be performed upon the femoral artery.

* Op. cit. 278, 9.

In its first stage the vessel may be tied at two points, viz. either above or below the origin of the profunda artery: the operation at the former point, being performed under circumstances different from those in which that at the latter is admissible, may be considered apart from the others, and the detail of it be postponed until they have been disposed of; while the operation in the second case, and those in the second and third stages have been at different times performed for the same purpose—the cure of popliteal aneurism —and therefore a comparison of their several details and advantages merits attention. The situation in which the femoral artery was first taken up for popliteal aneurism is the third stage of its course: here it was tied, as is generally known, by J. Hunter. In his operation Hunter made "an incision on the anterior and inner part of the thigh rather below its middle;" i.e. in the third stage; "which incision was continued obliquely across the inner edge of the sartorius muscle and made large:" the other steps of his operation it is not necessary at present to particularize; the author would only remark, as a matter of history, that Hunter's application of ligatures has been misunderstood: he applied in his first operation four ligatures to the artery, and it is commonly, if not generally, said that they were drawn with various degrees of tightness; but such was not the case, they were tied all equally tight: the account given in the report of the operation being, "the artery was now tied by both these ligatures," viz. the two upper, "but so slightly as only to compress the sides together. A similar application of ligatures was made a little lower. The reason for having four ligatures was to compress such a length of artery, as might make up for the want of tightness, it being wished to avoid great pressure on the vessel at any one part."

The artery may be and has been frequently taken up in the middle stage, and the operation, as described in several surgical works, will be found to belong to, if not to be intended for, that stage. During its two latter stages the artery is covered by the sartorius: in its uppermost it is not covered by the muscle, and consequently if it be necessary to displace the muscle to bring the artery into view above the last stage, it must be in the middle one, and in the account of the operation given by some of the highest authorities, the displacement of the sartorius is stated as one of the steps. This the author refers to not in a spirit of criticism, but in order to mark more strongly the distinction between the operations at the several stages, and to direct attention to the advantages possessed by that in the first over the others; more particularly since descriptions, which in strictness apply to the operation in the middle stage, and at a part of the artery's course below the first, may be found so put forward that the operations at the two points must be confounded; and thus the advantages contemplated by the proposer of the latter be lost. It will be recollected that in the two inferior stages the artery is covered by the sartorius and by two laminæ of the fascia lata, between which the muscle is situate: the vessel is, therefore, similarly circumstanced in this particular throughout both, but in some other important respects the relations of the artery are different. 1. In its middle stage the vessel is nearer to the anterior plane of the limb. 2. The deep layer of fascia, by which it is covered, is far less thick and strong, particularly at its upper part. 3. The artery is not so completely covered by the sartorius; and for those reasons the vessel may be more easily reached from before. These constitute the principal anatomical considerations why the middle stage should be preferred to the lower for operation, but, since it is at times requisite to tie the vessel in its last stage, it is necessary to examine the influence which its anatomical relations may have upon the conduct of the operation at that part. 1. The greater depth of the artery from the anterior surface of the limb renders a more extended incision necessary: in cutting upon arteries "the centre of the incision should be," as directed by Guthrie, "if possible directly over that part of the artery on which it is intended to apply the ligature." In the case of the femoral artery in its third stage, the length of the incision should not be less than from four to five inches according to the volume of the limb; its direction should correspond to that of the sartorius, but it must be varied somewhat according to the side of the muscle upon which the operator may purpose to seek the vessel. It should commence somewhat below the middle of the thigh, and be continued as much upon the lower as upon the middle third of the limb. 2. The artery is situate, in its third stage, nearer to the outer than the inner margin of the sartorius, and the more so the nearer to its termination; hence it may be exposed with greater ease and certainty by cutting upon the outer edge of the muscle and displacing it inward. Hunter, in his operations, selected the inner margin, and displaced it forward and outward; but this proceeding is attended with disadvantages. 1. The saphena vein is more in the way and exposed to danger of being divided since it lies at this part, along or near the inner margin of the sartorius. 2. The muscle lying more to the inner than the outer side of the artery must be more displaced, and the depth of the wound for the same reason greater when the vessel is sought from its inside.* 3. The operation must be more inconvenient and embarrassing, as well because of the former difficulties as because it must be performed more from the inside of the limb, and from within outward, than in the method by the outer margin of the sartorius. Those objections are avoided by cutting upon the outer edge of the muscle, against which, however, it has been advanced that in that method the vastus internus may be mistaken for the sartorius, and that the wound being made from before, there is not a depending and ready outlet afforded to matter should it form, while by the other there is. The former of these objections cannot carry much weight, and for the second the best plan for obviating the dangers of inflammation and suppuration is, as much as possible, to render them unnecessary, which is best accomplished by selecting that method by which the artery may be exposed most easily, and with least disturbance to the parts in its vicinity. To the writer, therefore, it seems that the method by the outer margin of the sartorius, which appears to have been suggested by Hutchison, is the more eligible in the operation for taking up the femoral in its third stage. 2. The great thickness and strength of the anterior wall of the femoral canal both increase the difficulty of opening the canal, and render it desirable that that structure should be freely divided for the double purpose of facilitating the taking up of the artery, and preventing the injurious effect which must be produced by the confinement caused by the structure in question in the event of inflammation extending along the vessel. 3. The relation of the vein to the artery at this part, viz. posterior and external, will make it more safe to pass the needle round the latter from without than from the outside; this, however, is a rule which cannot be strictly adhered to, for the direction in which the instrument shall be passed must be varied according to circumstances; it would be difficult to pass it from the outside in case the artery were exposed from the inside of the sartorius; but attention to the caution demanded by the position of the vein is, for this reason, only the more necessary. 4. The saphenus nerve being here within the femoral canal is to be carefully avoided; it will be so with certainty, if the needle be carried from the outside. 5. The mistake of confounding the superficial superior internal articular artery with the femoral must be also avoided.* This mistake, which has occurred, ought not however to occur again in the hands of a well-informed surgeon, for the possibility of it ought not to be lost sight of in operations at the lower part of the thigh; and it may be easily avoided by recollecting, first, that the femoral itself is within the femoral canal, and therefore that any vessel, which presents before the division of the anterior wall of the canal, which is so remarkably thick in this situation that it can hardly be overlooked, cannot be the one which is sought for; and, secondly, that the course of the branch within the canal, after its origin, is very short, and therefore that in case of doubt the vessel which presents, must, if the articular, conduct us directly to the trunk itself,

* The contrary is maintained by Lisfranc and others; but, according to the experience of the author, without sufficient reason. He has carefully compared the depth of the wounds as made upon the opposite sides of the muscle, and in the subjects of examination that by the inside appeared to him the deeper.

* See that vessel.

when followed upward for a very short distance.

Lastly, the structures to be divided or put aside in order to expose the artery are,—1. the skin; 2. the subcutaneous cellular stratum; 3. the superficial lamina of the fascia lata, forming the anterior wall of the sheath of the sartorius; 4. the sartorius itself; 5. the deep lamina of the fascia forming the posterior wall of the sheath of the sartorius, and the anterior wall of the femoral canal; and, 6. the proper sheath of the vessels.

The difference between the anatomical relations of the operation in the middle and inferior stages of the artery depends upon the modifications to be observed in the relations of the vessel at the two points, and also in some of the parts concerned. The number and order of the structures interposed between the surface and the artery are the same as in the third, but their disposition and relations differ in some important particulars so much as to authorize a difference in the proceedings to be adopted, and to justify a preference in favour of the former. 1. The artery is nearer to the anterior surface of the limb, and the more so the nearer to the commencement of the stage: it is therefore more easily reached and in the same proportion. 2. It is nearer to the inner than the outer margin of the sartorius, and, in like manner, the more so, the nearer to its upper extremity; and hence it may be brought into view with more ease and with less disturbance of the muscle by displacing its inner margin outward, than its outer inward.

The latter proceeding is advocated by Hutchison for the purpose of avoiding the saphena vein and the lymphatics. That the vein will be effectually secured from danger by cutting upon the outside of the sartorius will be at once admitted; but it appears to the author that the advantage contemplated will be more than counterbalanced by the disadvantages attending it, and on the other hand that the proceeding is not necessary: for, 1. if the outer margin of the muscle be cut upon in the middle of the vessel, the incision must be made considerably external to the line of the artery's course, and thereby the guide to the vessel otherwise afforded by that line must be lost, and uncertainty and consequently embarrassment be likely to ensue in seeking for the artery after having displaced the muscle. 2. Much more disturbance and violence are likely to be inflicted upon the artery and the adjoining parts by the plan in question, inasmuch as the vessel is so much nearer to the inner than the outer margin of the muscle; in consequence of which the muscle must be displaced to a much greater extent in proceeding from without inward, and the obstruction offered by it to the performance of the other steps of the operation must lead to greater violence either to the artery or to the muscle; and afterward a valvular wound must be left, a circumstance very unfavourable in the event of the occurrence of inflammation and suppuration in the vicinity of the track of the vessel, and those objections are the stronger because the artery is usually sought at the upper part of the stage, where it is but little overlapped by the muscle. On the other hand the saphena vein ought not to be endangered in the operation, for it is situate so far internal to the artery that the incision ought not to fall upon it. The case is different from that of cutting upon the inner margin of the sartorius during the third stage of the vessel; for there the vein is for the most part close to the edge of the muscle, and the wound must be inclined in depth from within outward, by which direction the vein is interposed between the surface and the artery; whereas, in the second stage, whether the operator, in proceeding by the inner margin of the muscle, cut directly upon the artery's course or upon the edge of the sartorius, there is sufficient space between it and the vein to leave the latter safe. The course of the artery may be crossed at any part by the superficial femoral veins, as has been explained, and they, if they present, will be in danger of division; but this inconvenience would not be removed by the plan in question, whereas both it and the danger to the saphena may be avoided by an easier and less objectionable proceeding than that of cutting upon the outer edge of the sartorius, viz. 1. by ascertaining, through means of pressure, the situation and course of the veins; and, 2. by proceeding with somewhat more caution, where there is reason to expect their presence, dividing first only the skin and continuing the incision through the subcutaneous structure, not by a single stroke, by which the vein if in the way must necessarily be divided, but gradually, until the vessel has been exposed and drawn aside. It seems therefore to the author not only unnecessary, but very objectionable to cut upon the outer margin of the sartorius, in exposing the femoral artery above the middle of the thigh. 3. The anterior wall of the femoral canal is much thinner than in the third stage, and therefore more easily managed. 4. The vein is directly behind the artery, and therefore the needle may be passed with equal safety from either side, according to circumstances: in operating by the inner margin of the sartorius it will be more easily done from the inside: the position of the vein and its close connection to the artery render it especially necessary that the extremity of the needle be kept in contact with the artery in being carried behind it. The saphenus nerve requires the same attention as in the third stage.

But the situation in which it is at present generally considered most eligible to expose the artery for the application of a ligature, when circumstances do not forbid a choice, is that recommended by Scarpa, viz. in the upper third of the thigh, and in the first stage of the artery's course as described in the account of the anatomical relations of the vessel. In his description of the details of the operation, Scarpa directs thus: "The surgeon pressing with his fore-finger will explore the course of the *superficial* femoral artery, from the crural arch downward, and when he comes to the place where he does not feel any more, or very confusedly, the vibration of the artery, he will *there* fix with his eye the inferior angle or extremity of the incision which he proposes to make for bringing the artery into view. This lower angle of the incision will fall nearly on the internal margin of the sartorius muscle, just where this muscle crosses the course of the femoral artery. A little more than three inches above the place pointed out, the surgeon will begin his incision and carry it along the thigh in a slightly oblique line from without inwards, following the course of the femoral artery as far as the point fixed with the eye." By this incision the skin and cellular substance are to be divided, and the fascia lata exposed, " then with another stroke of the bistoury, with his hand free and unsupported, or upon a furrowed probe, he will divide along the thigh, and in the same direction as the external wound the fascia, and introducing the fore-finger of his left hand into the bottom of the incision, he will immediately feel the strong beating of the artery, and this *without the necessity of removing the internal margin of the sartorius from its position, or at least very little.* With the point of the fore-finger of the left hand already touching the artery, the surgeon will separate it from its lateral connexions and from the vein;" after which the ligature is to be carried round it by means of a blunt aneurism-needle. The author has introduced the preceding account in order to fix the precise situation of the operation as performed by Scarpa, because it appears to him that it has been to a certain degree lost sight of, and also to direct attention more strongly to the advantage proposed by that distinguished surgeon in the adoption of the method which he has recommended. A very brief consideration of the descriptions given by several writers* of the proceedings to be adopted in the operation of taking up the artery in the upper part of the thigh will suffice to shew either that Scarpa's method has been confounded more or less with the operation at a lower point, or that its advantages have been disregarded: thus, while it is stated that the part of the limb in which the femoral artery can be tied with the greatest facility is between four and five inches below Poupart's ligament, and which is Scarpa's point,† the displacement of the sartorius is accounted a part of the operation, and it has even been debated whether the incision should not be made on the outer edge of the sartorius, and the artery exposed by drawing the muscle inward; but the displacement of the sartorius is not only not a necessary part of Scarpa's plan, but is that particular the avoidance of which he proposed to himself by the method he selected; from whence it will appear that the operation, as described in the accounts alluded to, refers, strictly speaking, to the second and not to the first third of the vessel's course, within the latter of which it must be performed in order to avoid the sartorius. The structures to be divided in this operation are, 1. the skin, 2. the subcutaneous cellular structure, 3. the fascia lata, forming the anterior wall of the femoral canal. The extent of the superficial incisions need not exceed three inches, commencing above either according to the rule of Scarpa or about two inches below Poupart's ligament: the direction in which they should be made ought to correspond as nearly as possible with the course of the artery. The extent to which the fascia lata is to be divided is stated differently by different writers: by some it is directed to be divided to the extent of about an inch: the direction of Scarpa is not precise upon the point in the text, though it is plain that he intended it should be divided to a much greater length than an inch, but in a note it is strongly insisted that the division of the fascia should correspond in extent to that of the external wound. Two reasons present for this: 1. greater facility in the performance of the operation, and less disturbance in consequence to the artery; 2. the avoiding the injurious effects which must be produced by the confinement consequent upon too limited a division of the fascia in the event of the supervention of inflammation. It cannot be doubted that a division of an inch is altogether too short to meet those considerations, and that the fascia ought to be divided to a greater extent; on the other hand it does not appear that advantage would be gained by so free a division as that recommended by Scarpa; and the rule of Guthrie seems the best calculated to accomplish the ends in view: he advises the fascia to be divided for the space of two inches. The division may be effected either with or without the assistance of the director. It will be well to recollect here that, at the point at which the sartorius is about to overlap the artery, a duplicature of the fascia takes place in order to enclose the muscle, and hence that, if the opening of the canal be attempted at the lower extremity of the stage, and close to the muscle, two layers of the fascia may require to be divided before this purpose can be accomplished. The femoral canal having been opened by the division of the fascia lata, the next step in the operation is the division of the proper sheath of the vessels and the insulation of the artery. Previous to this, should the internal genicular nerve be found to cross the canal superficial to the artery at the part, at which the vessel is to be detached from the contiguous parts, it should be separated and drawn outward. The insulation of the artery Scarpa recommends to be effected with the finger, raising the vessel from the wound even along with the vein if necessary; such a proceeding, however, must be very objectionable, as inflicting great disturbance and violence upon the artery. It is to be recollected that in order to insulate the artery it is necessary to divide or lacerate the investment, which immediately encloses the two vessels and connects them to each other, and which has been elsewhere denominated *the femoral sheath*; this, though thin, is dense, and is to be expected to offer resistance to the

* Hodgson, &c.

† The distance at which the sartorius crosses the artery varies according to the stature.

separation of the artery from the vein: the best method of effecting this, as it seems to the author, will be, after having opened the sheath directly over the centre of the artery either by a touch of the knife or first nipping up a part of it with the forceps; making an aperture into it with the blade of the knife held horizontally, and extending the opening upon a director to the length of "three-quarters or an inch," as recommended by Guthrie; then with the forceps to take hold of each portion of the sheath in turn and drawing it to its own side, outward or inward as the case may be, to detach the artery from it with the extremity of a director or of the aneurism-needle, moving the extremity of the instrument gently upward and downward at the same time that the vessel is carried, by means of it, in the opposite direction from the side of the sheath which is in the forceps; by this proceeding the artery may be easily and safely insulated almost, if not quite, round, and with little if any disturbance to it. That done, the needle and ligature may be carried round the artery: the performance of this, which is the most delicate step in the operation, will be found much facilitated by the separation of the artery as recommended; in fact, little more will then remain than to pass the needle, the passage having been already opened. In doing so it will be well to hold the inner portion of the sheath, with the forceps, inward and backward, by which the vein will be drawn away from the artery, and at the same time to insinuate the blunt extremity of the aneurism-needle round the artery from within outward, because of the situation of the vein, moving it, if any obstruction be encountered, upward and downward, while it is also carried forward, and bearing the artery somewhat outward with it at the same time; when the extremity of the needle has appeared on the outside of the artery it may be liberated, if necessary, by a touch of the scalpel upon it. In the execution of this manœuvre two accidents are to be avoided, viz. injury of the vein, and inclusion of the saphenus nerve: the close juxta-position and attachment of the former to the artery render much care necessary to leave it uninjured; but the proceeding recommended will, if carefully executed, certainly preserve it from being wounded. The saphenus nerve is here on the outside of the artery, and might be included within the ligature if the extremity of the needle were carried too far outward; the operator should therefore assure himself, before tying the ligature, that the nerve has not been included; but the risk of this accident ought not to be great at this part of the artery's course, certainly not so much so as at a lower point, inasmuch as the nerve has as yet hardly entered the femoral canal, and is therefore separated from the artery by more or less of its outer wall; and with the precautions recommended in insulating the vessel and passing the ligature it will almost certainly be excluded at every part: the possibility of the accident is, however, not to be lost sight of. The needle having been carried round the artery, the ligature is to be taken hold of with the forceps, and one end drawn out, after which the needle is to be withdrawn. The advantages of the part chosen by Scarpa for this operation are numerous and obvious: 1. the artery is nearer to the surface and has fewer coverings; there is therefore less to be divided in order to bring it into view; 2. the vessel being more superficial, its pulsations can be more distinctly felt and its course ascertained previous to operation, a guide wanting in the lower parts of the thigh; 3. "the operation is done," as Guthrie observes, "on that part of the artery which is not covered by muscle, and all interference with the sartorius is avoided: this method obviates all discussion as to placing the ligature on the outside of the muscle." The plan of cutting upon the outside of the sartorius in the upper stage of the artery must be, if contemplated by any, a proceeding hardly defensible in the ordinary disposition of the muscle, for all the reasons advanced already against its use in the second stage apply with much greater force to it in the former case; but it is at the same time to be observed that the distance of the point at which the muscle crosses the femoral artery is not absolutely regular, and that great deviation in this respect might render it necessary even to cut upon the outer margin of the muscle in order to expose the artery in the first third of its course. The distance from Poupart's ligament at which the muscle ordinarily crosses is, according to the stature, from three and a half to five inches, but it may in certain cases be found to cross so much sooner that the artery could not be exposed below the origin of the profunda without displacing the muscle; thus Burns* mentions that he has seen, in consequence of malformation of the pelvis, the artery covered by the muscle, before it had reached two inches below the ligament, and the author has witnessed the same from retraction of the thighs, consequent apparently upon long confinement to bed; in the latter case it would certainly have been more easy to expose the vessel from the outer than from the inner side of the muscle; but such cases are to be regarded only as exceptions to be borne in mind, but not to influence our general conduct.

4. The performance of the last and most delicate parts of the operation must be much more easy and less embarrassed, the interference of the sartorius being avoided; while, on the other hand, all apprehension on account of the profunda is removed, since that vessel seldom, if ever, arises farther than two inches from Poupart's ligament, and the course of the case after operation is more likely to be favourable and exempt from untoward occurrences, since much less violence must be done, and the supervention of injurious inflammation or its consequences thereby prevented.

The operation for taking up the femoral artery above the origin of the profunda is not often required, and, except in case of wound, may probably give place altogether to that of tying the external iliac: it presents no advantage over

* Op. cit. p. 321.

the latter, it does not promise more successful results: should secondary hemorrhage succeed to it, there is little prospect that the ligature of the iliac would afterward succeed, and the uncertainty existing with regard to the point of origin of the profunda raises a very strong objection against it, inasmuch as we cannot know whether the origin of that vessel be above, below, or at the point at which the ligature is to be applied: it is further exposed to the difficulty, before adverted to, which is likely to arise in cases of high origin of the profunda, in which that vessel may be taken for the femoral, and thus another source of embarrassment be encountered.

In the performance of it the following structures will present: 1. the skin; 2. the subcutaneous cellular stratum along with the inguinal glands and the superficial inguinal vessels of the latter: those which are most exposed to be divided are the superficial epigastric and its branches; the superficial anterior iliac and the superficial pudics may be encountered, but they are less likely; 3. the superficial lamina of the iliac portion of the fascia lata; and 4. the prolongation of the fascia transversalis, which forms the front of the femoral sheath.

An incision three inches long will suffice; it should commence above Poupart's ligament, and be continued in the line of the vessel for two inches below it.

If the superficial vessels bleed, on division, so much as to interfere with the course of the operation, they should be at once secured; otherwise they will probably cease themselves, and give no further trouble.

The lymphatic glands, if in the way of the incisions, may be either held aside or removed. The fascia lata and sheath may be treated in the same manner as in the other operations described; they can be easily distinguished in consequence of the thin stratum of fat which is usually interposed.

The insulation of the artery and the passage of the needle require the same precautions as in the operations at other parts of the vessel's course. The vein being placed along the inside of the artery the needle should be passed from that side.

The crural nerve and its branches are here altogether safe, as they lie without the femoral canal, but, as has been before pointed out, the crural branch of the genito-crural nerve may be included in the ligature; it will be most certainly avoided by the careful insulation of the artery: the operator should also assure himself, before tying the ligature, that no filament is enclosed.

Should two arteries present, as described in the anatomy of the profunda, and a question arise as to which is the femoral, the criteria pointed out will enable the operator to decide (see *profunda artery*); and the difficulty will, almost certainly, be altogether avoided by cutting directly upon the centre line of the femoral as ascertained by its pulsations.

Operation on the profunda artery.—From the anatomical details it follows that in the majority of cases the profunda is situate, in the first stage of its course at least, at the outer or iliac side of the femoral artery, though upon a plane posterior to that vessel: it has also, at the same time, the same coverings, differing only in being contained in a sheath proper to itself; and hence, if necessary, the profunda might be reached in that situation by an operation similar to that for exposing the femoral itself at the same place, in which much advantage would be obtained by first exposing the latter vessel, and following it as a guide to the origin of the former; which, if in its usual situation, will be exposed by displacing the femoral inward, and then the proper sheath of the profunda should be opened to a certain extent, in order to allow the application of the ligature at a sufficient distance from the origin of the vessel. But in the inferior stages of its course it may be laid down, as a general rule, that it cannot be reached from the front of the thigh, inasmuch as, with the exception of those cases in which it is throughout external to the femoral, and in which, from its deep position and the want of a guide to its exact situation, the rule will yet equally apply, it is not only more deeply seated, but it is separated from the anterior surface of the limb by the superficial femoral artery, and by the femoral, profunda, and circumflex veins, as well as by the coverings of the femoral vessels, and lastly by the adductor longus muscle. In any case, did circumstances render necessary the attempt to tie the profunda, it would be an operation in which much uncertainty and difficulty must be anticipated, in consequence of the varieties presented by that artery in its origin and course.

For Bibliography see ANATOMY (INTRODUCTION), and ARTERY.

(B. Alcock.)

FIBRINE, (Fr. *fibrine*; Germ. *Faserstoff.*) Under this name physiologists and chemists have generally described the animal proximate principle constituting that part of *muscular fibre* which is insoluble in cold water, and that portion of the coagulum of blood which remains after the removal of its colouring matter.

The fibrine of blood is best obtained by stirring a quantity of fresh-drawn blood with a piece of wood, to which the coagulum adheres, and may afterwards be washed in large and repeated portions of water till it loses its colouring particles, and remains in the form of a buff-coloured, fibrous, and somewhat elastic substance; this may then be partially dried by pressure between folds of blotting-paper, digested in alcohol to remove fat, and then carefully dried, during which process it loses about three-fourths of its weight, and becomes brittle and of a yellowish colour: it is insipid and inodorous. In cold water it slowly resumes its original appearance but does not dissolve: when, however, it is subjected to the long-continued action of boiling water it shrinks and becomes friable, and a portion of a newly-formed substance is at the same time taken up by the water, which gives it a yellowish colour and the smell and taste of boiled meat, and which, when obtained by evaporation, is brittle, yellow, and again soluble in water: this solution is rendered turbid by infusion of galls, but the precipitate differs from that yielded by gelatin, and appears to be a distinct product. The insoluble residue has lost its original characters; it no longer gelatinises with acids or alkalies, and is insoluble in acetic acid and in caustic ammonia.

The action of acids and alkalies upon the fibrine of blood has been studied in detail by Berzelius and others; the following is an abstract of their results.*

All the acids, except the nitric, render fibrine transparent and gelatinous: the diluted acids cause it to shrink up. In sulphuric acid it acquires the appearance of a bulky yellow jelly, which immediately shrinks upon the addition of water, and is a combination of the acid and fibrine; when well washed upon a filter it gradually becomes transparent and soluble, and in that state is a neutral *sulphate of fibrine*. It is again rendered opaque by dilute sulphuric acid, and is precipitated from its aqueous solution by that acid in the form of white flakes, which appear to be a supersulphate. When fibrine is heated in sulphuric acid, both are decomposed, the mass blackens, and sulphurous acid is evolved. If the colouring matter has not been entirely washed out of the fibrine, the sulphuric solution is of a brown or purple colour.

Nitric acid communicates a yellow colour to fibrine, and, if cold and dilute, combines with it to form a neutral nitrate, analogous to the sulphate When fibrine is digested in nitric acid, nitrogen is evolved, and its composition considerably changed, as we shall more particularly mention in describing the action of this acid on muscular fibre.

Muriatic acid gelatinises fibrine and then gradually dissolves it, forming a dark blue liquid, or purple and violet, if retaining any hæmatosin. This solution, when diluted with water, deposits a white *muriate of fibrine*, which, like the sulphate, gelatinises when the excess of acid is washed away, and becomes soluble, and is again thrown down from its aqueous solution by excess of acid. The blue liquid, after the separation of the precipitate by dilution, retains its colour, but loses it when saturated with ammonia, and with excess of ammonia becomes yellow. Fibrine digested in dilute muriatic acid is converted into the same white compound as that precipitated by water from the concentrated muriatic solution. When boiled in the acid, nitrogen is evolved, and a solution is obtained, which, after the saturation of the acid, is precipitated by infusion of galls, but not by alkali or ferrocyanuret of potassium; on evaporating the solution to dryness a dark brown saline mass remains, so that the fibrine appears to have undergone some decomposition.

* Berzelius, Lehrbuch der Thier-Chemie, Wöhler's German translation. Dresden, 1831. See also Medico-Chirurgical Transactions, vol. iii. p. 201.

A solution of recently-fused phosphoric acid acts upon fibrine in the same way as the sulphuric acid; but if the acid solution has been kept for some weeks, the fibrine then forms with it a soluble jelly, which is not precipitated by excess of acid.

Concentrated acetic acid converts fibrine into a jelly easily soluble in warm water. When this solution is boiled, a little nitrogen is evolved, but nothing is precipitated; when gently evaporated, it gelatinises, and leaves, on desiccation, an opaque insoluble residue. The other acids added to this acetic solution produce precipitates which are compounds of fibrine with the added acid. Fibrine is also precipitated from the acetic solution by caustic potassa, but is redissolved by excess of alkali.

The acetic solution of fibrine is precipitated in white flakes by ferrocyanuret of potassium: this precipitate, when dried, appears to be a compound of fibrine with cyanuret of iron and hydrocyanic acid; it is insoluble in dilute acids, but is decomposed by caustic alkalis, which abstract the cyanuret of iron and hydrocyanic acid, and the remaining fibrine first gelatinises and then dissolves. 100 parts of this compound, carefully dried at 167°, and then incinerated in a weighed platinum crucible, gave 2.8 red oxide of iron,=7.8 of the combination of cyanuret of iron with hydrocyanic acid; whence it follows that 92.2 of fibrine were contained in the white precipitated compound.

Caustic potassa, even much diluted, dissolves fibrine. If the solution is very dilute, the fibrine gradually forms a bulky jelly, which, heated in a close vessel to about 130°, dissolves into a pale yellow liquid, not quite transparent, and which soon clogs a filter. The yellow tint appears to arise from the presence of a small portion of adhering hæmatosin. When this alkaline solution is saturated by muriatic or acetic acid, it exhales a peculiar fetid odour and blackens silver, announcing the presence of sulphur, so that the animal matter seems to have suffered some slight change. It is stated by Berzelius that fibrine is capable of *neutralizing* the alkali, and that such neutral compound may be obtained by dissolving the fibrine in the alkaline solution, and adding acetic acid till it begins to occasion a precipitate; the filtered liquid is then perfectly neutral, but the potassa bears a very small proportion to the fibrine. This neutral solution, he says, much resembles white of egg, and is coagulated by alcohol and acids, though not by heat. Gently evaporated, it gelatinises, and, when dry, assumes the appearance of albumen dried without coagulation. In this state it dissolves in warm water, and is first thrown down, and then redissolved by the acids when added in excess. Alcohol throws down nearly the whole of the fibrine from its neutral alkaline solution: if there be excess of alkali, much of the fibrine is retained. Mr. Hatchett found that fibrine, when digested in strong caustic potassa, evolved ammonia and yielded a species of soap; acids occasion a precipitate in this solution which is altered fibrine, for it neither gelatinises nor dissolves in acetic acid: ammonia acts as potassa, but less energetically.

When fibrine is digested in solution of persulphate of iron, or of copper, or of perchloride of mercury, it combines with those salts, shrinks up, and loses all tendency to putrefaction. When the alkaline solution of fibrine is decomposed by metallic salts, the precipitate consists of the fibrine in combination with the metallic oxide; some of these compounds are soluble in caustic potassa.

Tannin combines with fibrine, and occasions a precipitate both in its alkaline and acid solutions: the tanned fibrine resists putrefaction.

The ultimate composition of fibrine has been determined by Gay Lussac and Thenard, and by Michaelis, who made a comparative analysis of that of arterial and venous blood: the following are their results:—

	Gay Lussac and Thenard.	Michaelis. Arterial.	Venous.
Nitrogen	19.934	17.587	17.267
Carbon	53.360	51.374	50.440
Hydrogen	7·021	7.254	8.228
Oxygen	19.685	23.785	24.065
	100.000	100.000	100.000

The mean of these results gives nearly the following atomic composition:—

	Atoms.	Equivalents.	Theory.
Nitrogen	1	14	19.72
Carbon	6	36	50.70
Hydrogen	5	5	7.04
Oxygen	2	16	22.54
	1	71	100.00

In reference to this atomic estimate, which is suggested by Leopold Gmelin,* Berzelius observes, that from the feeble saturating power of fibrine, its equivalent number is probably very high, that is, that it includes a larger number of simple atoms; but as we have at present no accurate means of determining its combining proportion or saturating power, its atomic constitution cannot be satisfactorily determined. Moreover, it appears that in the above analyses the fat was not separated, nor is any notice taken of the minute portion of sulphur, the presence of which has been above adverted to.

When Berzelius first obtained fat from fibrine by digesting it in alcohol and in ether, he concluded that it arose from the decomposition of a portion of the fibrine by those agents; that it was a *product* and not an educt; but the subsequent experiments of Chevreul leave no doubt that the fat exists ready formed in the blood. This fat is very soluble in alcohol, and the solution is slightly acid; when it is burned, the ash, instead of being acid, like that of the fatty matter of the brain, is alkaline, whence it appears that it existed saponified, or partly so, in the blood.

Another important variety of fibrine is that which constitutes *muscular fibre*, but it is so interwoven with the nerves and vessels and cellular and adipose membrane, that its properties are probably always more or less modified by foreign matters. The colour of muscles appears to depend upon that of the blood in their capillary vessels; and their moisture is referable to water, which may be expelled by drying them upon a water-bath, when they lose upon an average 75 *per cent*. If muscular fibre in thin slices is washed with water till all soluble matters are removed, the residue, when carefully dried, does not exceed 17 or 18 per cent. of the original weight.

To obtain the fibrine of a muscle, it must be finely minced and washed in repeated portions of water at 60° or 70°, till all colouring and soluble substauces are withdrawn, and till the residue is colourless, insipid, and inodorous; it is then strongly pressed between folds of linen, which renders it semitransparent and pulverulent. Berzelius observes that in this state it becomes so strongly electro-positive when triturated, that the particles repel each other and adhere to the mortar, and that it stil retains fat which is separable by alcohol or ether. When long boiled in water, it shrinks, hardens, and yields a portion of gelatine derived from the insterstitial cellular membrane; the fibrine itself is alsô modified by the continued action of boiling water, and loses its solubility in acetic acid, which, when digested with it in its previous state, forms a gelatinous mass soluble in water, but slightly turbid from the presence of fat and a portion of insoluble membrane, derived apparently from the vessels which pervaded the original muscle. It is soluble in diluted caustic potassa, and precipitated by excess of muriatic acid, the precipitate being a compound of fibrine with excess of muriatic acid, and which, when washed with distilled water, becomes gelatinous and soluble, being reduced to the state of a neutral muriate of fibrine.*

When the fibrine of muscle is mixed with its weight of sulphuric acid, it swells and dissolves, and, when gently heated, a little fat rises to the surface and may be separated: if the mass is then diluted with twice its weight of water and boiled for nine hours, (occasionally replacing the loss by evaporation,) ammonia is formed, which combines with the acid, and on saturating it with carbonate of lime, filtering, and evaporating to dryness, a yellow residue remains, consisting of three distinct products: two of these are taken up by digestion in boiling alcohol of the specific gravity of .845, and are obtained upon evaporation; this residue, treated with alcohol of the specific gravity of .830, communicates to it (1) a portion of a peculiar extractive matter, and the insoluble remainder (2) is white, soluble in water and crystallisable, and has been called by Braconnot *leucine*.† It fuses at 212°, ex-

* Handbuch der Theoretischen Chemie.

* It will be observed, by reference to the article ALBUMEN, that that principle and *fibrine*, if not identical, are very closely allied, and appear rather to differ in organization than in essential chemical characters: accordingly the fibrine of the blood may be considered as a modification of seralbumen, and that of muscular fibre as little differing from the fibrine of the blood.

† Ann. de Chim. et Phys. xiii. 119.

haling the odour of roasted meat, and partly sublimes: it is difficultly soluble in alcohol. It dissolves in nitric acid, and yields on evaporation a white crystalline compound, the *nitro-leucic acid*. The portion of the original residue which is insoluble in alcohol (3) is yellow, and its aqueous solution is precipitated by infusion of galls, subacetate of lead, nitrate of mercury, and persulphate of iron. It appears therefore that the products of the action of sulphuric acid upon the fibrine of muscle, are, 1, an extractive matter soluble in alcohol; 2. leucine; and 3. extractive, insoluble in alcohol but soluble in water.

(W. T. Brande.)

FIBRO-CARTILAGE, *(Cartilago ligamentosa* v. *fibrosa;* Fr. *Tissu fibrocartilagineux;* Germ. *Faser-Knorpel* oder *Band-Knorpel).*— As early as the time of Galen we find certain organs distinguished by the appellation νευροχονδρώδεις συνδεσμοι, and Fallopius uses a similar term, namely, *chondrosyndesmos*, as denoting a substance distinct from true cartilage. Haase* also, who wrote in 1747, speaks of two structures different from true cartilage, under the names of *cartilagines ligamentosæ* and *cartilogines mixtæ*. Bichat likewise recognised a class of tissues distinct from pure cartilage, and by him it would appear that the name *fibro-cartilage* was first employed.

It is evident that no organ should be classed under the head of *fibro-cartilage* unless it consist distinctly of fibrous tissue and cartilage intermixed, and thus combine not only the structure but the properties of both, the strength and power of resistance of the one, and the elasticity of the other; nevertheless, we shall find, in examining the various structures which are admitted by anatomists to be fibro-cartilaginous, that the fibrous tissue predominates in such a manner as to justify Beclard in regarding fibro-cartilage as a portion of the ligamentous structure, which might be designated cartilaginiform ligamentous organs. The distinction was fully admitted too by Mr. Hunter in reference to the texture of the so-called inter-articular cartilages. Speaking of that of the temporo-maxillary articulation, he says, "its texture is ligamento-cartilaginous."†

The classification of fibro-cartilages adopted by Meckel seems to me to be the best; he arranges them under three classes:—1. Those whose two surfaces are free wholly or at least in great part, and whose edges are united to the synovial capsules, *the moveable fibro-cartilages of articulation*. 2. Those which are free by one of their surfaces, and which adhere to bone or tendon by the other: these are the *fibro-cartilages of tendinous sheaths*, or those which limit the articular cavities, and may be called *fibro-cartilages of circumference* or *cylindrical fibro-cartilages*. 3. Those whose two surfaces are adherent in their entire extent to the bones between which they are placed.

* De fabricâ cartilaginum, Lipsiæ, 1747.
† Hunter on the Teeth.

Of these classes the first and third and some of those which come under the second belong to the articulations. Their forms and structure have already been described in the article ARTICULATION. I may here, however, notice the statement of Weber* in regard to the discs interposed between the vertebræ, which have been generally regarded as fibro-cartilaginous. This anatomist denies that they exhibit any intermixture of cartilaginous substance, and considers that this is rendered manifest by stretching the intervertebral substance, by which it becomes reduced to a fibrous expansion *(sehnighautige Masse);* he consequently places these intervertebral discs among the fibrous tissues. There can be no doubt that the circumference of each disc is purely fibrous, and that the concentric vertical lamellæ of fibrous tissue extend for some distance towards the centre of the disc; but I am at a loss to perceive any resemblance to fibrous tissues in the soft and elastic, and yielding substance which forms the centre. It seems to me that this texture can only be regarded as a modified form of cartilage, differing in its want of density from the ordinary cartilage, whether permanent or temporary. The intervertebral substance, however, to whatever texture it may ultimately be decided to belong, does present very striking differences from the other organs which are placed among the fibro-cartilages.

It is in the fibro-cartilages of the second class that we see most uniformly the intermixture of the fibrous and cartilaginous texture, although here, likewise, the fibrous tissue predominates over the cartilaginous.

The fibro-cartilages are remarkable for their great flexibility, in virtue of which they are enabled to resist fracture, and this property is no doubt owing to the intermixture of fibrous tissue; cartilaginous laminæ, on the other hand, are easily broken by bending, and many of them exhibit a fibrous appearance on the surface of the fracture, which, however, arises from the irregular fracture and not from the existence of fibres. Fibro-cartilages are of a dull white colour and quite opaque; they have no perichondrium, but are either in immediate connexion with bone, being inserted into it by their fibrous bundles, or are covered by the synovial membrane of the joint in which they are enclosed. Their physical and vital properties are those which belong to pure cartilage and to fibrous tissue. Their force of cohesion is very great and surpasses even that of bones. They are more vascular than pure cartilage, but in the natural state they admit very few vessels carrying red blood. Bichat examined the fibro-cartilages in an animal which died asphyxiated, and found these organs not injected. The remarkable manner in which fibro-cartilages resist the influence of a compressing tumour, as a pulsating aneurism, is well known; while by such means the bodies of the vertebræ are completely destroyed, the intervertebral discs will remain quite uninjured.

* Einige Beobachtungen über das Structur der Knorpel und Faser-Knorpel, in Meckel's Archiv for 1827.

Fibro-cartilages dry readily when exposed to the air and become of a deep yellow colour; they resist for a very long time, many months, the influence of maceration, and by long-continued boiling they become converted into a gelatinous substance. Their chemical composition is said to be made up of albumen, phosphate of lime, chlorurets of sodium and of potassium, sulphate of lime and other salts, usually found in animal textures.

The microscopic characters of fibro-cartilage do not seem to have been investigated with the same care as those of many other textures. I have examined by transmitted light very thin slices of the fibro-cartilages in the knee and temporo-maxillary joint, and the appearance presented was uniformly that of a very complicated cellular structure, composed of minute meshes, very irregular in size and shape. In examining the intervertebral substance I have distinctly seen, towards the circumference of the disc, those fine and uniform cylindrical fibres with wave-like bendings described and figured by Jordan;* but towards the centre the texture exhibited the cellular appearance with larger meshes, similar to that seen in the fibro-cartilages of the knee and joint of the lower jaw.†

Of the structures placed by Bichat among the fibro-cartilages, some have been considered by Meckel, Beclard, Weber, and other anatomists to be pure cartilage, and as it seems to me with much justice. These are the membraniform cartilages of the external ear, Eustachian tube, nose, larynx, trachea, and eyelids. The cartilaginous nature of most of these textures is very apparent upon carefully dissecting off the dense perichondrium which invests them, and to which, doubtless, they owe their flexibility, or more correctly, by which they are prevented from being fractured under the influence of a bending force. Careful microscopic observation may assist materially in affording marks indicative of pure cartilage; and as the observations of Purkinje, Müller, and Miescher approach in some degree to this object, I have thought it not foreign to the subject of this article to introduce here some account of these researches. The results of Purkinje's examinations of the minute structure of bone as well as cartilage were published in the year 1834 in an inaugural dissertation by Deutsch.‡ Müller and Miescher have further investigated the subject and confirmed the statements of Purkinje.§

In examining thin slices of cartilage under the microscope by transmitted light, Purkinje observed numerous little bodies irregularly dispersed through its texture, of a round or oval form, and somewhat less transparent than the intervening substance. The annexed figure, taken from Müller's work already referred to, gives a representation of these bodies: they are denominated by Purkinje cartilaginous corpuscles (*Knorpel Körperchen*). In some cases, as in temporary cartilage, they appeared to consist of minute granules; they presented this appearance likewise in the cartilaginous part of the cranium of a frog. In the costal cartilages they were solid, and in the cartilaginous fishes, as in the lamprey, their contents were of a soft or fluid consistence. According to Purkinje, these corpuscles are found in the temporary cartilages, in permanent cartilage, in cartilage which becomes ossified in old age, as that of the ribs and larynx, in the cartilages of the nose and septum narium.

Fig. 139.

According to Miescher there are two kinds of permanent cartilage, differing from each other as well by external characters as by internal structure; one of these scarcely differs at all from the temporary cartilage, the other is very dissimilar in structure. The first class is at once distinguished by its azure whiteness and by its pellucid brightness, not unlike that of mother-of-pearl, from the second, which is yellowish in colour, not pellucid, and spongy in texture. To the former class belong all articular cartilages, those of the ribs,* that of the ensiform cartilage of the sternum, the thyroid, cricoid, and arytenoid cartilages, and those of the septum narium and alæ nasi. All the cartilages of this class are characterized by containing the microscopic corpuscles above described, variously arranged in each form of cartilage, in some placed in clusters, in others closely aggregated together in one part and separated in another. It is interesting to observe that the temporary cartilage universally contains these corpuscles, and as all the cartilages we have described are more or less prone to ossification in advanced age, we are led to the inference, that these corpuscles thus deposited are characteristic of cartilage which admits of becoming ossified.†

* Uber das Gewebe der Tunica Dartos, &c. Müller's Archiv, 1834.

† Miescher states that in infants this part of the intervertebral substance is composed of a pellucid mucus, which, under the microscope, sometimes exhibits some of the cartilaginous corpuscles to be noticed in a subsequent part of this article, but in adults it is composed of adipose tissue!

‡ De penitiori ossium structurâ. Diss. inaug. Vratisl. 1834.

§ Vid. Müller, Vergleichende Anatomie der Myxinoiden, Berlin, 1835, and Miescher, de ossium genesi, structurâ, et vitâ. Diss. inaug. Berol. 1836.

* Sic Miescher.

† The cartilages most liable to ossify by the progress of age in man, are those which most frequently exhibit, after a certain period, a permanently ossified condition in some of the inferior classes of animals. Thus, in birds, and among mammals, in monotremata, cheiroptera, and cetacea, the cartilages of the ribs show a very early disposition to ossify. In birds the laryngeal cartilages are very apt to ossify, and in swine and oxen partial ossifications of the same cartilages are not

To the second class of cartilages belong those of the external ear, of the epiglottis, and the capitula of Santorini, connected with the apices of the arytenoid cartilages, which in the ruminants, the hog tribe, and others, are of considerable size. Besides the characters already mentioned which distinguish this class of cartilage from the former, the microscope discloses some further differences. "Placed under the microscope," says Miescher, "the cartilages of this class present a very delicate network, opaque, composed of small round meshes which are filled by a uniform, pellucid substance, and each generally contains a single corpuscle somewhat roundish or oblong." The cartilages that belong to this class are contrasted with those of the former, as being never transformed into bone.

I may add, that in my own examinations of pure cartilage, from the skeletons of cartilaginous fishes, and from the human subject, I have found the foregoing descriptions correct. The cartilaginous corpuscles may be always seen under the compound microscope, with an object glass of a quarter of an inch or an eighth of an inch focus.

In man and the mammalia, the following structures may be enumerated as belonging to the class of fibro-cartilages: 1. The so-called inter-articular cartilages in the knee, sterno-clavicular, and temporo-maxillary joints; that in the wrist-joint seems to me to be purely cartilaginous. 2. The fibro-cartilages of circumference, as in the hip and shoulder-joints. 3. The fibro-cartilages of tendons, which ultimately form sesamoid bones, and those of tendinous sheaths. 4. According to Miescher, the tarsal cartilages. 5. The inter-osseous laminæ, as those between the pubes, pieces of the sacrum and coccyx, and, in a modified form, the intervertebral substance.

In the inferior vertebrata and in the invertebrata fibro-cartilage gradually disappears: in the former, the intervertebral substance seems to be the only remnant of it, excepting perhaps the sclerotic coat of the eye in some fishes. In the invertebrata, Blainville considers the three tubercular teeth of the leech as being fibro-cartilaginous.

Morbid conditions of fibro-cartilage.—As fibro-cartilage in its physical and vital properties so nearly approaches pure cartilage, it is reasonable to expect a great similarity in the phenomena of disease as they are manifested in the two tissues. Fibro-cartilage appears to be susceptible of reparation in the same manner as pure cartilage. (See Cartilage.) A substance bearing some resemblance to fibro-cartilage sometimes forms the connecting medium between the fractured portions of a bone, where bony union cannot be obtained.

The phenomena of inflammation and ulceration in fibro-cartilages are very similar to those in pure cartilage: in the joints these morbid changes are generally complicated with similar diseased conditions of the other textures, either cartilages or bones, whence they are propagated to the fibro-cartilages. It is well known that a condition of the intervertebral discs, which is commonly spoken of under the name of ulceration, is frequently coincident with caries of the vertebræ, having in some instances preceded the vertebral disease, and in others followed it. To Sir Benjamin Brodie we are indebted for the observation that the diseased state of the intervertebral substance has sometimes the precedence of that of the bones; in one case, related by him, where ulceration of the articular cartilages had begun in several other parts, those between the bodies of some of the dorsal vertebræ were found to have been very much altered from their natural structure. He adds, "I had an opportunity of noticing a similar morbid condition of two of the intervertebral cartilages in a patient who, some time after having received a blow on the loins, was affected with such symptoms as induced Mr. Keate to consider this case as one of incipient caries of the spine, and to treat it, accordingly, with caustic issues; and who under these circumstances died of another complaint. Opportunities of examining the morbid appearances in this very early stage of disease in the spine are of very rare occurrence, but they are sufficiently frequent when the disease has made a greater progress; and in such cases I have, in some instances, found the intervertebral cartilages in a state of ulceration while the bones were either in a perfectly healthy state, or merely affected with chronic inflammation, without having lost their natural texture and hardness."* Otto mentions that he has several times satisfied himself that the destruction of the spine may originally spring from the intervertebral substance; but he has never found suppuration, unless when at the same time the bones and neighbouring cellular tissue were inflamed.† The anatomical characters of this condition to which we have been alluding consist in an erosion and softening of the fibro-cartilage, frequently attended with the effusion on the surface of a dirty puriform and often fetid fluid.

Fibro-cartilage is not prone to become ossified; in very old subjects the superficial portion of the intervertebral substances is often ossified, but this is an extension of ossification from the bone or from the anterior common ligament: it is very rare to find any of the inter-articular fibro-cartilages ossified. The ossification of the interpubic fibro-cartilage in advanced age seems to be of a similar nature to that of the intervertebral substances.

Masses of a substance very similar to fibro-cartilage are sometimes met with accidentally developed; we find them in or connected with the uterus, in tumours, and in serous or synovial membranes.

(R. B. Todd.)

unfrequently found. Ossification of the nasal cartilages is extremely rare, but in the hog tribe two bones extend from the intermaxillary bone into the cartilage of the proboscis. — Vide Miescher, loc. cit. p. 27.

* Brodie on the Joints, edit. 2d, p. 231.

† Pathol. Anat. by South.

FIBROUS TISSUE,* *tela fibrosa, vel tendinea;* Germ. *das sehnige Gewebe.*

The parts comprised in the fibrous system may with propriety be referred to two separate and distinct classes.

I. White fibrous organs.—Under this head the following structures, distinguished by their whitish colour, their fibrous organization, and their great power of resistance, are included :—*a*, the periosteum and perichondrium; *b*, fasciæ or muscular aponeuroses; *c*, sheaths of the tendons; *d*, fibrous coverings of certain organs; *e*, ligaments; *f*, tendons.

II. Yellow elastic fibrous organs.—There are certain organs, ex. gr. the yellow ligaments *(ligamenta subflava)* of the spine, which resemble those of the former class by their fibrous structure, but which present so many important peculiarities in their texture and properties, that it is necessary to consider them apart from the preceding. All these organs resemble each other by possessing more or less a yellow colour, and a remarkable degree of elasticity.

I. White fibrous organs.— *Organization.* This consists of a union of white or grayish fibres more or less distinct according to the part in which they are examined; thus they are very apparent in most of the ligaments, in the fasciæ, in the periosteum, and in many tendons, as in those of the obliquus abdominis externus, pectoralis major, &c. In other structures, on the contrary, as in the greater number of tendons, the fibres are so small and so closely united that they cannot be perceived but with difficulty, although they become more evident on maceration. In most parts of the body they observe a parallel direction, whilst in other places they pass in an irregular manner, so as to cross and interlace with each other, occasionally constituting, as in the instance of the dura mater and of the tendinous centre of the diaphragm, a very intricate network of fibres.

The result of a careful examination proves that the remarkably firm and resisting threads which constitute the basis of the various fibrous organs, are composed of condensed cellular tissue. In certain regions we may perceive the gradual transformation of the cellular tissue into a fibrous organ, as in the formation of the superficial fascia of the abdomen; whilst by prolonged maceration the most dense tendon or ligament may be reduced into a pulpy cellular substance: this opinion is corroborated by Isenflamm, who conceives that this tissue is formed by cellular fibres impregnated with gluten and albumen; and also by Béclard, who regards it as being composed of cellular texture very much condensed. We may therefore conclude that the ideas of Professor Chaussier, as to the existence of an elementary organic solid, called by him the *albugineous fibre*, and which is supposed to form the basis of all the ligamentous and tendinous parts of the body, are erroneous.

The individual fibres are surrounded by processes of a more lax membrane, which penetrates between them, and which is rendered particularly apparent by maceration and in certain diseases. The differences that are observed in contrasting the various fibrous organs with each other, a ligament for example with a tendon, seem principally to result from the larger or smaller proportion of the interfibrous cellular substance and on the degree of its condensation. This combination of the common cellular tissue with the ligamentous fibres allows the fibrous organs to yield in a very slight degree when extended by the elasticity which is thus bestowed, and also slightly to contract on themselves on the removal of the extending force.

Bloodvessels.—The proper fibrous tissue receives but a small quantity of blood, the arteries being minute in size, and principally carrying a colourless fluid. The great vascularity of the dura mater and periosteum is no exception to this remark, because the vessels of these membranes are not proper to them, but to the veins they cover.

Absorbents.—The ravages of disease in the neighbourhood of joints, involving the ligaments in ulceration; the sloughing of tendons, the destruction of the periosteum by the pressure of aneurism, of the tunica albuginea in scrofulous or malignant fungus of the testis, are abundant proofs of the existence of absorbent vessels.

Nerves.—According to Monro, nervous filaments may be traced to some of the fibrous organs; and other anatomists, Cruveilhier for instance, speak of nerves being furnished to the joints; in general, however, none are to be seen; but as sensibility becomes developed in disease, we must presume that communications do exist with the encephalon.

Chemical properties.— The principal substances that have been detected in the fibrous as in the cellular tissue consist of coagulated albumen and gelatine; a small quantity of mucus and saline matter has also been discovered. The effects of desiccation are well known, tendons and ligaments becoming hard, transparent, yellowish, and fragile. This tissue resists maceration for a long time, but at length it is rendered soft and flocculent, so that the fibres can be separated and unravelled; ultimately it is converted into a pulpy and filamentous cellular mass.

Properties.—The offices which these organs are designed to fulfil in the economy being, with the exception of the periosteum and its analogous membrane the dura mater, of a mechanical character, the properties by which they are distinguished are almost entirely of a physical nature. They offer great resistance to rupture, and thus the ligaments are capable of opposing the shocks to which, in the violent movements of the joints, they are so frequently

* The expression fibrous tissue is by no means well chosen, as it is equally applicable to other and dissimilar organs, such as muscles, nerves, &c. all of which are eminently distinguished by a fibrous structure. It is, however, preferable to retain a received though inaccurate term, than to add to that multitude of names which already so much encumbers the science of anatomy.

exposed; whilst the same cohesive property enables the tendons, under all ordinary circumstances, to bear the immense force of muscular contraction.

Having considered the general characters of these organs, I shall proceed to describe the most essential properties of each individual class.

1. *Of the periosteum.*—This may be regarded as the most important of the fibrous tissues; indeed so universal are its connexions, that if any common centre of this system were sought for, we should certainly coincide with Bichat in considering this to be the periosteum. Discarding the erroneous ideas of the ancients and Arabian physicians, who imagined that the membranes of the body were all continued from those of the head, we shall find that, with the exception of the perichondrium of the larynx and the fibrous tunics of some glandular bodies, all the fibrous organs are in connexion with the periosteum.

The inner surface of the periosteum firmly adheres to the several bones by a multitude of delicate processes passing into the openings observed on their external surface. These processes convey into the bones an amazing number of fine arteries and veins, called therefore periosteal, and which may be regarded as the principal, or as some anatomists contend, the only proper vessels of the osseous tissue.

The outer surface is rough, and is united by the cellular tissue to the surrounding muscles, tendons, ligaments, and fasciæ; in the nostrils, sinuses, and tympanum, the periosteum is, however, joined to the mucous membranes, and in the skull the surface unattached to the bones is lined by the arachnoid.

The periosteum constitutes the nutrient membrane of the bones, and thus bears an important part in the process of ossification and in the reparation of fractured and diseased bones; it also serves as a medium for the attachment of the ligaments, tendons, and fasciæ to the skeleton.

2. *Fasciæ.*—The fibrous fasciæ or aponeuroses not only invest the surface of the limbs, but also furnish a number of processes, which, penetrating deeply among the several muscles, form sheaths to those organs, by which they as well as the bloodvessels and nerves are maintained in their proper situation. It is evident that these partitions must exert a great influence on the growth of various kinds of tumours, on effusion of blood, on the extravasation of urine, and on the formation of matter; so that their relations form an important branch of surgical anatomy.

In order to give to these muscular envelopes the necessary degree of tension, they are either provided with special muscles, as in the case of the tensor vaginæ femoris and the palmaris longus, or they receive processes from the neighbouring tendons, as from the biceps cubiti, semi-tendinosus, and so forth.

The aponeuroses thus braced afford a firm support to the parts they cover, and in this manner they increase the powers of the muscular system; whilst by their resistance they efficiently protect the vessels and nerves from external violence, and at the same time probably assist in the circulation of the blood and lymph, and so prevent varicose enlargement of the deep-seated veins and œdema of the extremities. See Fascia.

3. *Tendinous sheaths.*—These are in their office analogous with the last, excepting that, instead of fixing the muscles, they secure the tendons during muscular action. The thecal ligaments of the hand and foot, the annular ligaments of the wrist and ankle, and the fascial sheaths around the knee are of this character. They are distinguished by their great strength, and as they are internally lined by synovial membrane, they facilitate the play of the tendons; and in many instances, as in the trochlea of the os frontis and the sulci of the carpal extremity of the radius, they also modify the action of the muscles whose tendons they transmit.

4. *Fibrous coverings.*—Certain organs are provided, for the purpose of protection, with dense ligamentous coverings; of this order are the dura mater, the sclerotic coat of the eye, the loose portion of the pericardium, the proper covering of the kidney, of the salivary glands, mamma, spleen, thyroid gland, thymus, lymphatic glands, of the prostate, testicle and ovary; probably the exterior investment of the nervous ganglia is of the same character. Some of these envelopes, as the dura mater, pericardium, and tunica albuginea testis, are lined on one surface by a serous membrane, and thus constitute *fibro-serous membranes*, or as they are called by Béclard, *compound fibrous membranes.*

5. *Ligaments.*—These bodies possess in an eminent degree those properties by which the whole fibrous system is distinguished; and consequently the term *ligamentous* is often employed to designate the whole of the fibrous organs.

The ligaments fulfil a very important office in the animal economy by binding together the various bones of the skeleton, an object which they are enabled to effect in consequence of their fibres being very firmly attached, and as it were consolidated with the osseous system through the medium of the periosteum. It is stated by Portal, that after the bones have been softened by the influence of an acid, the ligaments are observed to send processes into their substance, which cause the ligaments to adhere so firmly that, although by very great force they may be torn, yet they cannot be separated from the bones.

Although these organs are dissimilar in shape, yet there are three forms among them which predominate: 1. the capsular, 2. the funicular, 3. what, for want of a better expression, may be called laminated. The true fibrous capsules which consist of cylindrical bags lined internally by synovial membrane, are confined to the shoulder and hip-joints, although imperfect capsules exist in many other articulations. The funicular and laminated ligaments are much more universally diffused, assisting in fact in the formation of every joint in the skeleton.

6. *Tendons.*—These organs, which serve to connect the muscles to the osseous system, are composed of fibres so closely disposed that some anatomists, but erroneously, doubt their identity with the other fibrous organs. This compactness is owing to the extreme condensation of the intervening cellular tissue, which is also the cause of these bodies resisting for a longer period than the ligamentous or fascial structures, the influence of maceration.

Every tendon is united by one of its extremities to the fibres of the muscle to which it belongs, and by the other it is connected with the bone or other part on which the muscle is destined to act. The exact mode of connexion between the tendinous and muscular tissues is difficult to determine. Ocular and microscopical inspection seem to prove that the tendinous fibres result from the continuation and condensation of those cellular sheaths, which inclose and in part form the muscular fibrils. It has, however, been stated that there is an intermediate substance between the muscle and the tendon, different from both of them, and serving to connect them together. The details relative to the mechanical disposition of these organs belong to the consideration of the muscular system.—See Muscle.

II. Yellow elastic fibrous organs.—(*Tela elastica.*) It was justly observed by Bichat that the ligaments placed between the arches of the vertebræ differ in their nature from the other ligaments of the body; and modern anatomists, admitting this distinction, have enumerated the following structures as a separate class of the fibrous organs: the yellow ligaments of the spine; the external and especially the middle or proper membrane of the arteries, the fibrous covering of the excretory ducts; the ligamentous tissue joining the cartilages of the air-passages; the fibrous envelope of the cavernous bodies of the penis and clitoris, and of the vesiculæ seminales.

Although the highest authorities consider that the middle tunic of the arteries is composed of this tissue, yet the correctness of this opinion is very doubtful. It is true that, as far as colour is concerned, the similarity is well founded; but the arterial fibrous coat is endowed with a power of contraction, evidently distinct from mere elastic contraction, which is totally wanting in the true yellow fibrous tissue.

In addition to the parts above named, it is necessary to add that in certain organs where great elasticity is requisite there is a peculiar yellow cellular substance, which, although it does not present the dense and fibrous character, appears to belong essentially to the organs under consideration. This texture is particularly distinct in the mucous folds which constitute the superior boundary of the glottis, a part that is remarkable for its extraordinary elasticity.*

It occasionally happens, as in the formation of the intervertebral substance, that the yellow fibrous tissue and the common ligamentous are combined. A more striking instance of this combination is seen in the construction of the connecting ligament which forms the hinge in bivalve shells, in which one part, the external, is composed of ligamentous matter, whilst another, the internal, consists of a highly elastic fibrous tissue.

Organization and properties.—If the yellow ligament of the spine or the ligamentum nuchæ in ruminants be examined, it will be seen that each is smooth on its surface, and is made up of a great number of longitudinal and highly elastic fibres, which, in the latter instance, are readily separated and unravelled by the finger. This texture is, I believe, *sui generis*, and is altogether distinct from the common ligamentous structures. In a recent publication,* M. Laurent conceives that this tissue is intermediate in its characters to the *tissus scléreux* (under which term he proposes to class the white fibrous organs, the cartilages and bones,) and the muscular tissue; he therefore calls it *tissu scléro-sarceux*. Although it is very doubtful if the elastic fibrous structures have any thing in their organization similar to the muscular fibre, yet it is certain that in function they are intermediate between the common ligaments and the muscles, a fact which is kept in view in the Hunterian Museum, in which the elastic ligaments are placed next to the muscles.

The resistance and elasticity of these organs enable them firmly to connect together the parts to which they are attached, and at the same time allow them to yield to double their length on the application of an extending force. In this manner they economise muscular action, by substituting for that force the power of elasticity.

This employment of an elastic rather than a muscular power is evinced in the yellow ligaments of the spine, which pull the vertebræ towards each other, and thus assist the muscles in maintaining the upright posture. The same thing is also seen in many of the lower animals; as in the support of the head by the ligamentum nuchæ—the retraction of the claws in the feline carnivora by an elastic ligament—and the support of the abdominal organs in many large quadrupeds by the elastic superficial fascia. But the most interesting example of this economy of muscular action is displayed in the bivalve shell of the oyster and other acephalous mollusca, in which instance not only is the shell kept open by the elastic ligament of the hinge for the purpose of admitting the nutriment of the animal; but

* It is stated by Sir E. Home (Lect. on Comp. Anat. vol. ii. p. 49,) that this tissue enters into the formation of muscle; but this is probably erroneous, as the elasticity of muscles depends on the large proportion of elastic cellular membrane which they contain. Lobstein has also published some observations in the Jour. Univer. des Sc. Méd. on the tissue of the uterus, which he regards as analogous to the so-called yellow tissue of the middle arterial coat.

* Annales Françaises et Etrangères d'Anat. et de Physiol. Jan. 1837. P. 59.

as the valves are designed by nature to be separated only to a limited extent, an elastic ligamentous structure is placed between them towards their centre, and in this manner all undue separation is prevented without any demand being made on the force of the adductor muscle.*

Morbid anatomy. I. *Inflammation.*—The low degree of organization possessed by this tissue modifies the inflammatory process, which is usually chronic in its nature, and often extremely insidious in its progress; occasionally, however, as in sprains, acute rheumatism, &c., the fibrous organs are the seat of very active disease. Owing to their great density, but little swelling takes place unless there be chronic and prolonged inflammation; in which case, as is particularly observed in disease of the joints, a quantity of jelly-like fluid is poured into the interstitial cellular tissue, the proper fibres become massed together and with the surrounding parts, till in the advanced stage all traces of the original formation being lost in the diseased mass, it becomes reduced to the pulpy consistence of diseased cellular membrane, of which the healthy structure is a modification.

This deposit and thickening are the most common products of inflammation in ligamentous parts; but it occasionally happens that a true abscess is formed, as when pus is thrown out between the dura mater and cranium. I have known one case connected with disease of the bone, in which matter was deposited in the substance of the dura mater, and in which the operation of trephining was ultimately required for the relief of the patient.

Ulceration is a frequent result of scrophulous disease of the joints, causing great ravages in the ligaments and neighbouring parts.

Mortification of ligament is not a common occurrence, whilst in the acute inflammation of tendon, especially in neglected thecal abscess, and of fascia in consequence of large abscess under it, sloughing is not unfrequently witnessed.

There are of course certain modifications in the effects of inflammation according to the part attacked. Thus, in ligament, there is a great tendency to ulceration; in tendon to mortification; in the periosteum to great induration; and, as we see in the formation of a node and of callus, to a transformation into cartilage and even bone. When fascia is the seat of disease, the consolidation arising from effusion often gives rise to a retraction of the affected part; a result which has been observed, for example, in inflammation of the aponeurosis of the fore-arm, and in that affection of the palmar fascia called by Boyer and other writers *crispatura tendinum.*†

II. *Cartilaginous transformation and ossification.*—Many parts of the fibrous system not unfrequently become cartilaginous or even osseous. The cartilaginous transformation is often observed in the ligaments of diseased and anchylosed joints; in the periosteum after fractures and in the formation of nodes; in tendons, especially those which are exposed to great friction in the fibrous covering of the spleen. I have had opportunities of seeing many specimens of cartilaginous deposit taking place between the periosteum and the bone, and evidently arising from the former. The valuable collection of my friend Mr. Liston contains a very fine specimen of a large cartilaginous tumour proceeding from the periosteum.

Ossification, although extremely common, occurs much more frequently in some than in other classes of these organs: thus it is often met with in the dura mater, in which structure, as far as I have observed, the bony excrescence always proceeds from the inner layer or that towards the arachnoid, and consequently presses against the brain. In one very remarkable specimen in my possession, nearly the whole of the falx, and a large extent of the membrane attached to the vault of the cranium, are completely ossified. In an instance, observed I believe by Dr. Barlow (Southwark), the heart was completely encased in bone, owing to the entire ossification of the pericardium. The cicatrix of a wounded tendon is often osseous.

III. *Fungus.*—The dura mater, the periosteum, the fascia, &c., are subject to excrescences having a fungoid appearance, which vary in their nature, often consisting of a chronic, indolent growth, whilst at other times they are evidently scrophulous, and occasionally they are malignant.

In the progress of those cases where the disease is situated near the bones, these organs are implicated, and some doubt has consequently arisen concerning the first seat of the disease; it is, however, proved by examination that in the fungus of the dura mater and other fibrous parts, the bones are only secondarily affected. A good illustration of this fact is afforded by a preparation consisting of an extensive fungus arising from the periosteum covering the tibia, in which it is evident, al-

* Leach, Bullet. des Sciences, 1818. P. 14. [Mr. Hunter fully recognised the value of this elastic tissue, and in his Museum he set apart a series for its illustration under two classes—1st, as an antagonist to muscle, and 2d, in aid of muscular action. In the former class he places such examples as that of the oyster alluded to in the text, in the latter the ligamenta nuchæ and the elastic fibrous expansion on the abdomen of the elephant and other larger quadrupeds. See the Descriptive and Illustrated Catalogue of the Hunterian Museum, vol. i.—Ed.]

† Boyer, Traité des Malad. Chir. tom. v. p. 55. This peculiar affection was some years since pointed out by Sir A. Cooper, and has since been more fully described by Baron Dupuytren, (Leçons Orales de Chir. Clin. tom. i. p. 2). The tension and contraction of the palmar fascia, which are usually caused by continued pressure, give rise to a retraction of one or more of the fingers, and may be removed by transversely and freely dividing the aponeurosis opposite to the metacarpo-phalangean joint. I have known one case of similar induration of the fibrous sheath of the corpus cavernosum penis; and I have learnt from Sir A. Cooper that he has seen several such cases, occurring in persons who had freely indulged in sexual intercourse. Boyer has made a similar observation.

though the subjacent bone has been partly absorbed, that the fungoid disease entirely originated from the periosteum.*

Malignant fungus occasionally arises from the periosteum. I have seen one case of this disease connected with the tibia, in which amputation was performed, but with an unfavourable result, the patient sinking rapidly from mortification. In medullary sarcoma that membrane is often involved.

Osteo-sarcoma, according to Howship, Craigie, and Meckel, occasionally has its origin in the periosteum.

(R. D. Grainger.)

FIBULAR ARTERY, *(arteria peronæa; Fr. artère peroniere; Germ. die Wadenbein-arterie).*—This artery is commonly described as a branch of the posterior tibial, or it may be said to be one of the branches resulting from the bifurcation of a short trunk which has its origin immediately from the popliteal, and which has been described under the name of the *tibio-peroneal* artery, the other branch of the bifurcation being what is ordinarily considered as the continued posterior tibial trunk.

The origin of the fibular artery is situated about an inch below the inferior margin of the popliteus muscle, thence the artery extends downwards and with a very gradual inclination outwards, and terminates in the region of the external ankle, just above the os calcis and behind the fibula. It is a vessel of smaller size than the posterior tibial, and about equal to the anterior tibial, and it is interesting to observe that the varieties in its calibre are in the inverse ratio of the calibre of the anterior and posterior tibial, but more especially of the former.

To expose the fibular artery in dissection the gastrocnemius and soleus muscles must be raised, and the deep fascia of the leg dissected away. The artery is then seen resting at first for a very short distance upon the tibialis posticus muscle, and from it getting upon the posterior surface of the fibula near its tibial edge, where the vessel is imbedded in the flexor pollicis proprius and encased between that muscle and the bone. Inferiorly it passes between the flexor pollicis proprius and tibialis posticus, and is applied to the posterior surface of the interosseous ligament.

The fibular artery is sometimes altogether absent, and then its place is supplied by ramifications of the posterior tibial. Sometimes the fibular artery takes its rise higher up than the point we have indicated; but more frequently it has a lower origin, in which case it presents a calibre smaller than that which may be considered as usual; the vessel, indeed, is found to be smaller the lower down its origin is. It is in these cases that the anterior tibial especially and the posterior tibial occur of a larger size than natural, as it were to compensate for the deficiency of the fibular.

Branches.—The first branches the fibular artery gives off are small muscular ones on either side to the soleus, tibialis posticus, flexor pollicis proprius, to which in its whole course it gives a liberal supply; also to the fibula and the peronæi muscles. From its inner side, according to Cruveilhier, it gives an anastomotic branch to the posterior tibial, which passes transversely or obliquely from one artery to the other. This branch sometimes attains a considerable size, and in such cases after its communication with the posterior tibial, that artery also becomes considerably enlarged.

The fibular artery divides into its two terminal arteries in the inferior third of the leg; these are the anterior and posterior peronæal arteries.

Anterior peroneal artery, (arteria peronæa anterior and *perforans peronæa.)* This branch gains the anterior surface of the leg by piercing the interosseous ligament, where it is covered by the peronæus tertius muscle. The situation at which this perforation takes place is stated by Harrison to be about two inches above the external ankle; it then inclines downwards upon the outer side of the tibia, anastomoses by a transverse branch with the anti-tibial, communicates with the external malleolar artery from the anterior tibial, giving off numerous branches both before and after the anastomosis, which pass down to the tarsus and communicate with the tarsal arteries. This artery is generally smaller than the posterior, sometimes so small that the ordinary injection fails to penetrate it. If there be any anomaly in the size of the anterior tibial artery, this branch is generally large in proportion as that artery is small, and in such a case it might exceed the posterior peroneal in calibre. The arteries of the dorsum of the foot spring from the anterior peroneal when the anterior tibial exhibits this deficiency.

Posterior peroneal artery, (A. peronæa posterior; calcanienne externe, Cruveilhier). This branch continues the course of the fibular artery behind the external malleolus to the outer side of the os calcis; it runs parallel to the outer edge of the tendo Achillis, being immediately covered by the continuation of the fascia of the leg. A transverse branch from the inner side of this artery establishes its communication with the posterior tibial, and inferiorly it distributes its terminal branches to the muscles and other parts on the outside of the os calcis to anastomose with the external tarsal and plantar arteries; some small vessels proceed round the tendo Achillis to effect a further communication with the posterior tibial.

This may be considered as the terminal branch of the fibular artery; it is absent only when the fibular artery passes entirely forwards, or when it directly opens into the posterior tibial without having any further communication with the arteries of the ankle.

The fibular artery is evidently a valuable anastomotic trunk to both the tibial arteries, a deficiency in either of which it is prepared to

* The result of dissection induces me to suppose that in many old and intractable ulcers, the fungoid excrescences seen on the surface arise either from the fascia of the leg or from the periosteum, according as they are placed on the outer or inner part of the limb.

supply. Deriving its origin from the same source, and anastomosing freely with both in all parts of their respective courses, it is prepared to take the place of either, one might say, at a moment's warning, and the freedom of this communication affords a sufficient indication to surgeons how ineffectual in cases of wounds a single ligature would be; in short, here as in other places where arterial communications are so free, the rule of practice is so clearly pointed out by the anatomy as almost to render it superfluous to appeal to experience.

The relations of this artery to operations being very similar to those of the posterior tibial, we refer on this head to the article TIBIAL ARTERIES.

(*R. B. Todd.*)

FIFTH PAIR OF NERVES.—This title is derived from the relation which the nerve bears numerically to the other encephalic pairs; it is the fifth nerve met with on the base of the brain counting from before backwards. The fifth is also called the *trigeminal* (Winslow) and the *trifacial* (Chaussier) nerve. It is the nerve upon which the general and tactile sensibility of the face and its cavities, as well as the voluntary power of certain muscles of these parts, depends.

The following account of this nerve is meant to apply especially to the human subject; but as a knowledge of its structure and distribution in other animals must contribute very much to enlighten us in regard to its true character and properties in man, occasion has been taken to mention those particulars by which it is distinguished throughout the animal series.

The fifth nerve is connected at its one extremity with the medulla oblongata, whilst its other end is distributed to the eye and its appendages, to the nostrils, to the palate, the mouth and tongue, to the salivary glands, to the ear, to the integuments and muscles of the face, forehead, and temple, and to the muscles which move the lower jaw in mastication, the temporal, pterygoid, and masseter muscles. The general distribution of the nerve throughout the animal series corresponds to that in man; but, in certain animals and classes, varieties are presented, which claim our attention equally, whether as matters of curiosity or of physiological interest. In some individuals of the class *Mammalia*, the eyes possess a very inferior degree of development; a distinct optic nerve either does not exist or its existence is a matter of doubt, and its place is supplied, in part or altogether, by a branch of the second division of the fifth nerve: thus, in the Mole, according to M. Serres,* the optic is altogether absent, and its place is supplied by a branch of the fifth; but, according to Treviranus,† that animal is provided with an optic nerve, as large as a human hair, and according to Carus‡ it joins an optic branch from the fifth, and the two concur to form the retina. In other animals of the same class the optic seems decidedly absent, and its place is supplied altogether by the fifth. Among Reptiles also instances occur, in which the optic nerve is wanting. According to both Treviranus* and Serres,† the fifth nerve takes the place of the optic in the Proteus Anguinus. A variety in distribution, still more remarkable, is presented in the disposition of the fifth nerve in Fishes. Among the Rays the auditory appears to be, not a distinct nerve, but a branch of the fifth:‡ the special organs, with which they are provided, likewise, in many instances, derive their nerves from the fifth pair; thus, in some the electrical§ organs are supplied by that nerve, and also the albumino-gelatinous organs: lastly, in many the nerve is distributed‖ in a manner and to an extent for which there is no analogy among other animals, the fins being throughout furnished with branches from the fifth. Hence in Fish, in which the distribution of the nerve is so much more extended than in other animals, both the size of it is proportionally greater, and it consists of a greater¶ number of divisions; these, which in the three other classes of vertebrate animals are only three, amounting with them to from three to six. See sketch of nerves in the Ray and Cod. (*Figs.* 144, 145.)

The size of the fifth nerve is very great, it being by far the largest of those proceeding from the medulla oblongata. In this respect it presents much variety according to the animal or its class. M. Serres states that, the nerves being proportioned always to the volume of the organs from whence they proceed, the extent of the face and of the organs of the senses taken together gives the size of this nerve in the different classes of vertebrate animals. Among the Mammalia the extent of the face and of the organs of the senses increases progressively from Man to Apes, the Carnivora, the Ruminantia, and the Rodentia, and, according to him, the size of the fifth nerves follows in a general manner the same progression. Birds are remarkable for the atrophy of the muscles of the face and of several of the organs of the senses, and their fifth nerve is far from presenting the developement to be observed in the inferior Mammalia. Reptiles are still lower than Birds with regard to the dimensions of the nerves of the fifth pair; while in Fish** the size of the nerve is very great, and even surpasses in some the volume it presents in the other classes.†† However just the estimate of the comparative volume of the nerve in different animals, as here stated, may

* Anatomie Comparée du Cerveau, &c.
† Journal Complementaire.
‡ Journal Compl.

* Op. cit.
† Op. cit.
‡ Desmoulins, Journal de Physiologie, t. ii. Serres, op. cit.
§ Desmoulins, Anatomie des Systêmes Nerveux, &c. Carus, Rudolphi.
‖ Desmoulins, op. cit.
¶ Desmoulins, op. cit.
** See Sketches of Nerve in the Ray and Cod, *figs.* 144, 145.
†† Serres, Anatomie Comparée du Cerveau, dans les quatre classes des Animaux Vertébrés.

be, the data, from which it is professedly drawn, may be reasonably objected to. In the first place the volume of the organ cannot be assumed as being alone the measure of that of the nerve supplying it · the degree of nervous endowment, whether general or special, which the organ enjoys, must be also taken into account; and in the second, the extent of the organs of the senses cannot be admitted as a measure of the volume of the fifth nerve, which is not connected with them all; thus the greater part of the organs of touch is independent of that nerve. It appears to me that the extent of distribution and amount of endowment conjointly determine the volume of the nerve, and that the latter cannot be inferred *à priori*.

Each nerve is composed of two portions, which are remarkable for particular characters, and have received distinct names; they differ from each other in size, in anatomical disposition, and in function; one of them, larger than the other, is provided with a ganglion, and differs in its distribution; it also differs in properties, being subservient to sensation; the other is small, has no ganglion, and is destined to volition; they are hence denominated, the former the larger, the ganglionic or the sentient portion, the latter the smaller, the non-ganglionic or the voluntary portion.

The distinction of the nerve into two portions appears to prevail uniformly throughout the animal series. According to M. Serres, it is to be observed in all the classes of the vertebrate animals except the Reptiles; but in them, according to him, the *lateral fasciculi** are wanting. The latter assertion, however, is incorrect, the distinction being to be observed as satisfactorily in that class as in any other.† Again, the distinction is not equally remarkable in all; in some it is still more so than in man; in others it is less; and according to the same authority, it is to be observed among Mammalia the more easily as we pass from Man to the Rodentia. Among the Cetacea it is divided throughout into two separate fasciculi.‡

Each of the two portions of which the nerve consists is a packet containing numerous fasciculi, which are again divisible into filaments. The fasciculi, of which the packets are composed, are differently circumstanced in different stages of the course of the nerve; in one part they are bound up so closely together that they cannot without difficulty be separated from each other and disentangled, while in another they are but loosely connected and are easily separated.

The two packets are associated together more or less intimately throughout their course; but inasmuch as they present remarkable varieties in their disposition and mutual relations at different parts, it may be advantageous to divide the nerve, through its course, into three portions or stages; one from the ganglion to the connexion of the nerve with the brain, which may be denominated its internal or encephalic portion; a second from the ganglion to its ultimate distribution, its external or peripheric portion; and, thirdly, its ganglion. Such a distinction may not be free from objection, but being adopted for the convenience of description, it possesses at least the recommendation that there exist well-defined points of demarcation, whether there exist or not any difference in the properties of those several portions. The nerve, in its encephalic portion, is partly within and partly superficial to the substance of the brain. The superficial part is from one-half to three-fourths of an inch in length, of a flattened form, and of very considerable size. It presents a loose fascicular texture, and is enclosed within a prolongation of the arachnoid membrane sent off upon it from the surface of the brain; this prolongation is, as in the case of all those sent upon the vessels or nerves, in their passage from that organ to the parietes of the cranium, a cylindrical sheath, within which the nerve is enclosed; it is at first remarkably loose, but as the nerve recedes from the brain, the membrane invests it more closely, and is continued upon it as far as the ganglion, from which it is reflected to the surface of the canal in which the nerve is contained. In the last particular the disposition of the membrane is subject to variety, for it is at times continued beneath the ganglion, and partially invests the trunks proceeding from this body before it is reflected to line the canal.

Throughout this part of the nerve the two packets composing it are connected by cellular structure and vessels, and are enclosed within the prolongation of arachnoid membrane just described; but there does not appear to be any interchange of nervous filaments between them, and they are connected so loosely that they can be separated from each other with great facility. They consist each of numerous fasciculi held together, like the packets themselves, so loosely that the latter can be easily opened out and decomposed. The fasciculi of both packets are irregular in size, some large, others small; those of the larger are for the most part somewhat smaller than those of the lesser, but they are much more numerous, amounting, according to J. F. Meckel,* to thirty or forty; while those of the lesser amount, according to the same authority, only to from nine to fourteen. The fasciculi again are composed of numerous and delicate filaments. The number of the filaments is very great, but differently estimated by different authorities; according to Meckel those of the greater packet amount to about one hundred, collected into thirty or forty fasciculi; while, according to Cloquet,† the total number of filaments contained by both packets varies from seventy to one hundred, of which he allots five or six to the smaller, and the remainder to the larger packet. This difference of opinion Meckel explains by supposing that fasciculi have been taken for filaments and not decomposed, and this appears

* The name by which he designates the lesser portion of the nerve.

† See sketch of fifth nerve in the Turtle, *fig.* 143.

‡ Op. cit.

* Manuel d'Anatomie.

† Anatomie Descriptive.

very probable, inasmuch as Cloquet takes no account of fasciculi, and in his description of the smaller packet it is manifest that he has assumed the fasciculi, of which it is composed, to be filaments, for he does not attribute to it a greater number of filaments than it contains of fasciculi. But if Cloquet have underrated the filaments of the larger packet, Meckel junior has certainly overrated the fasciculi of the smaller one. From his account of the latter, it is to be concluded that it contains from three to fourteen fasciculi, but either of those numbers is too great, as will be seen from an examination of the subject, from which it will appear that they do not exceed the number attributed to them by Cloquet. The ultimate number of filaments, however, would seem to be somewhat uncertain, for it appears to depend very much upon the delicacy with which the separation of them may be effected; and after all it is not a matter of any great importance. According to Wrisberg* and Sœmmerring† the number of fibres contained in the greater packet is always less in the fœtus than in the adult. The filaments of the smaller are stated by Cloquet to be larger, softer, and whiter than those of the other; but with regard to the difference of size it is probable that this opinion has arisen also from his having assumed the fasciculi to be filaments, inasmuch as, when the fasciculi have been decomposed, the filaments seem to be equally fine in both packets; and for the other points of supposed difference the author has not been able satisfactorily to observe any in man. In other animals, however,—in some fish at least—a remarkable difference may be observed between the characters of the ganglionic and non-ganglionic portions, the latter of which, in the Cod, is much softer, and of a darker, not whiter, colour than the other.

The fascicular and filamentous disposition which has been described, is not, however, presented by the encephalic portion of the nerve through its entire extent, but only in that part of it which is superficial to the brain; nor is it acquired by it until after it has emerged one or two lines from the substance of the organ, and then it does not assume it throughout at once, but at first superficially and later internally. The appearance of distinct filaments and fasciculi in one part and their absence in the other appears owing to the existence of neurilema in the former, for in one as in the other the nervous matter appears to be arranged in longitudinal tracts, which present in one case the form of expansions, and in the other are divided by the neurilema into separate cords; and again the occurrence of the filamentous disposition earlier upon the surface than internally, is attributed to the superficial substance of the nerve being provided with neurilema sooner than the internal; hence the length of the substance of the nerve without neurilema is greater internally than externally, and when the nerve has been pulled away from its attachment to the brain, the rupture occurring at the point at which the neurilema commences, the part which is left projects in the middle, and presents a conical eminence of white matter: this, as Cloquet justly remarks, is but an incidental appearance, and not entitled to be considered, as it was by Bichat,* a real tubercle, from which the nerve arose. In neither packet are the fasciculi laid simply in apposition; in both, but more remarkably in the larger, they are connected by frequent interchanges of filaments, and that to such a degree that the nerve when opened out appears to form an inextricable plexus, in which it is not improbable that every filament of it is connected directly or indirectly with all the others; this plexiform arrangement diminishes as the nerve approaches the ganglion, before reaching which the fasciculi become more distinct.

The fifth nerve is attached to the surface of the brain on either side of the pons Varolii, at a distance of three-fourths of an inch from its middle line. It is attached to the middle crus of the cerebellum, on its anterior inferior surface, about one-fourth of an inch from its superior, and half an inch from its inferior margin.

The place of the attachment of the nerve to the exterior of the brain varies greatly in different classes of animals; in man, it is, as has been mentioned, the crus cerebelli on either side of the pons; in the other orders of the Mammalia it is either, as in the human subject, the crus cerebelli, or, when the pons is less developed than in man, the nerve is attached behind that part between it and the trapezium of the medulla oblongata; in the other three classes of vertebrate animals, in which the pons and trapezium are both wanting, the nerve is uniformly attached to the lateral parts of the spinal bulb. This contrast is equally curious and important; it affords us a natural analysis, which will throw much light on the next step in our inquiry, viz. the origin of the nerve, or its ultimate connexion with the brain. It furnishes also, as has been suggested by Gall and Spurzheim,† an explanation of the complication which exists in the human being, in whom the great developement and the situation of the pons render it necessary that the nerve should traverse it, in order to reach the surface of the brain.

At the attachment of the nerve to the crus cerebelli in the human subject, the non-ganglionic portion or lesser packet is situate above and to the inner side of the greater. At that place it is separated or separable into two parts, while the greater continues undivided, and hence the nerve is described as having three roots, one for the greater and two for the lesser packet. The existence of two roots for the lesser packet had been announced by Santorini,‡ but they have been more parti-

* Observationes Anatomicæ de quinto pari nervorum, &c.

† In Ludwig, Script. Neurol. Min. Ueber das Organ der Seele.

* Anatomie Descriptive.

† Anatomie et Physiologie du Systême Nerveux.

‡ Observationes Anatomicæ.

cularly and accurately described by Palletta.* They are distinguished by the latter into superior and inferior, being attached to the crus cerebelli, one above and behind the other, and they are frequently separated from each other at their attachment by an interval of one or two lines or more. In such case the superior root is superior and parallel to the inner side of the greater packet, while the inferior is internal to it, and, it may be, on a level with its inferior surface; hence, in such instances, the greater packet corresponds to the interval between the roots of the lesser, and the inferior root of the lesser, in its course from the brain, is placed at first along the inner side of the greater packet, while the superior descends internal to the greater packet, and joins the inferior beneath it to constitute the lesser packet. This is not, however, uniformly the relation of the roots of the nerve at their attachment to the crus, for the distance at which they are placed from each other varies very much; in some instances the roots of the lesser packet are perfectly distinct and separated by the interval mentioned, the inferior being either in immediate contact with the greater packet, and even entering the crus through the same aperture, or being separated from it by an interval varying, according to J. F. Meckel, from a quarter of a line to a line; while in others the roots of the lesser packet are not manifestly distinct, but the fasciculi of which they consist are attached to the crus in an uninterrupted series reaching, from the attachment of the greater packet, to within a line or less of the posterior face of the crus, and separated the one from the other by trifling intervals; in the latter case the lesser packet is, for the most part, altogether superior to the greater at their attachment. But even in this the lesser is still distinguishable into two sets of fasciculi, which take different routes through the substance of the crus, one traversing it nearer to its anterior, the other to its posterior surface. It has been already stated that the lesser packet of the nerve is characterized by the absence of a ganglion; it also has no connexion with the ganglion of the larger packet, but passes it without entering into it, and then becomes attached to one of the trunks proceeding from it; it is further maintained to be distributed ultimately into those branches which are given by the third division of the fifth to the muscles of mastication. Palletta† concluded from these circumstances that it was a nerve distinct from the remainder of the fifth; and observing that the superior root was principally consumed in the temporal muscle, and the inferior in the buccinator, forming the long buccal nerve, he called the former the "crotaphitic," and the latter the "buccinator" nerves. The distribution of the lesser packet to the muscles of mastication has been confirmed by Mayo‡ from the dissection of the nerve in the ass. He differs, however, from Palletta with regard to its distribution to the buccinator, which he denies: this point will come under consideration again. It has been proposed by Eschricht* to denominate it the *masticatory nerve*.

The place at which the nerve is attached to the surface of the brain in the human subject is to be regarded only as the point at which it enters or emerges from the substance of the organ, inasmuch as it can be, without difficulty, followed to a much deeper part, and the fibres of the crus, which are transverse to those of the nerve, manifestly separate from each other, at the entrance of the nerve, to allow it a passage. The larger packet of the nerve is that whose course into the brain can be most easily traced; this circumstance depends partly upon the greater size of the packet, and partly upon the fact that, for the most part, its tracts are not separated from each other by those of the crus, but traverse that part in a body, the fibres of the crus seeming to be simply laid in apposition with it, and connected to it by some delicate medium; while those of the lesser are, in the greater number of instances, separated from each other, or even interlaced with those of the crus; hence the fibres of the crus may be easily raised, without injury to the nerve, from the larger packet, and its course be displayed, while the lesser cannot be followed but with difficulty. The larger is, however, subject to variety in the latter respect; in many instances the fasciculi of the crus do traverse and divide it, and very frequently near its ultimate attachment, and this circumstance, when it occurs, renders the pursuit of its course more difficult; but even here the fasciculus merely traverses it, and its tracts are not permanently separated, but reunite after the fasciculus has passed. The course of the packet may be exposed to a considerable extent even in the recent brain; but for the satisfactory determination of the point, it is necessary that the brain be prepared by some of the methods recommended for that purpose, of which immersion in strong spirit is by far the best, nor does it require much time, for the substance will be found to separate more easily when it has acquired only a certain degree of firmness, than when hardened to the degree which long immersion produces; the plan which the author has found most successful has been to commence the dissection early, to return to it frequently, and at each time to pursue it so far and so far only as it was satisfactory. The course of the larger packet is also beneath and before that of the lesser, and hence, in the usual mode of dissection, in which the brain is reversed, it presents itself first. Its direction is backward, downward, and inward, toward the upper extremity of the spinal bulb; in its course the packet first traverses the middle crus of the cerebellum from its anterior toward its posterior surface, and from its superior toward its inferior margin; it pursues this course until it has reached the back of the crus, and descended so low as its inferior mar-

* Palletta, De Nervis crotaphitico et buccinatorio, an. 1784. Script. Neurol. Min. Select. Ludwig.

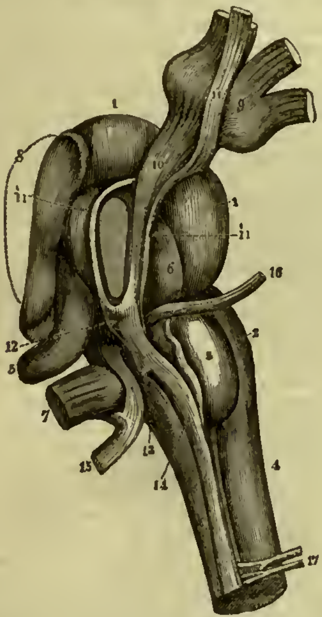
† Op. cit.

‡ Commentaries, and Physiology.

* Journal de Physiologie, t. vi.

gin; it is then situate in the angle formed by the three peduncles of the cerebellum at their junction with the hemisphere; behind the middle, beneath the superior and above the inferior, and before, or in common language, beneath the floor of the fourth ventricle. Thus far the course of the nerve may be ascertained without much difficulty; it is probably the same point to which Santorini had traced it, as described in his 'Observationes Anatomicæ,' in 1724, and from which Sœmmerring has more expressly stated it to be derived, in his work 'De corporis humani fabrica,' published 1798, in which he states "that it appears to arise almost from the very floor of the fourth ventricle."* At the point last described

Fig. 140.



Lateral view of the pons, spinal bulb, and course of the Fifth Nerve in man.

1 Pons Varolii.
2 Spinal bulb.
3 Olivary body.
4 Spinal cord.
5 Superior peduncle of cerebellum.
6 Cut surfaces of middle ditto.
7 Inferior peduncle of cerebellum.
8 Cut surface of crus cerebri.
9 Ganglion of Fifth Nerve reversed.
10 Ganglionic portion of the nerve.
11 Non-ganglionic portion of Fifth Nerve.
11 Roots of non-ganglionic portion.
12 Eminence at the insertion of both portions of the Fifth Nerve.
13 Fasciculus to anterior column of spinal cord.
14 Fasciculus to posterior column.
15 Auditory nerve.
16 Portio dura.
17 Posterior roots of superior cervical nerves.

* Santorini, however, appears to have followed the nerve out into the spinal bulb, though, as will be seen, he did not succeed in determining its real and ultimate connection.

the greater packet is attached to the side of the medulla oblongata. The point of attachment is very close to the interior of the fourth ventricle, being separated from it only by a thin lamina, which is little, if any thing, more than the "epithelium" of Reil: it is situate in the angle formed by the peduncles of the cerebellum, behind the middle one, by the outer margin of the pons, and posterior to it, and above its lower one: it is also superior to the attachment of the auditory nerve, separated from it by au interval of some lines.

We shall, in the next place, direct attention to the course and connection of the lesser packet of the nerve.

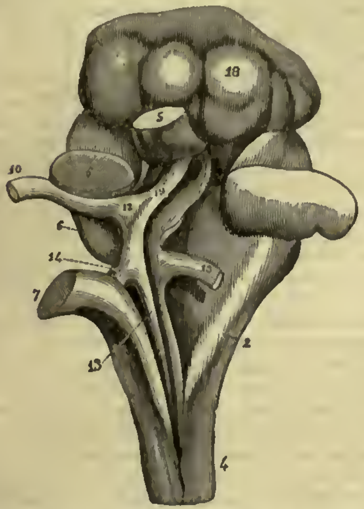
In none of the authorities which the author has had an opportunity of consulting, has he found a particular origin assigned to the lesser packet. By most anatomical writers it is overlooked; J. F. Meckel states that it can be traced a certain way into the crus, but he goes no further; Mayo asserts that the lesser portion arises close upon the greater, and, in a sketch of the origins of the nerves given by him in his Physiology, it is represented traversing the crus cerebelli, as a single fasciculus, above and behind the greater, and attached to some part above that from which the greater is represented to arise: but still the origin is not defined, and it is manifestly intended to be distinct from that of the greater packet.

The author has succeeded, as it appears to him, satisfactorily in tracing both the roots of the lesser packet to a destination for which he was not prepared; at setting out he expected to have found the origin of the lesser different from that of the greater packet, and to have followed it to a prolongation of the anterior columns of the spinal cord, as has been stated by Harrison;* it was therefore with surprise that, after a patient dissection, he succeeded in tracing both its roots to the same point, to which the greater packet is attached, behind the middle crus of the cerebellum (see *fig.* 140, 12); both the roots traverse the crus, as the greater does, the inferior very frequently in company with and internal to the greater packet, or separated from it by a very thin stratum of the substance of the crus, the superior near to the superior surface of that part, and separated from the greater packet by an interposed stratum of two or more lines; the course of the latter is so near to the surface of the crus, that it can frequently be traced for a considerable way by the eye without dissection: they present, in their mode of traversing the crus, two remarkable varieties; in some instances the fasciculi, of which they are composed, are separated from each other and even interlaced with those of the crus, and in such the pursuit of them is intricate and difficult; in others they pass in two distinct packets, and in these they are more easily followed. As they proceed they approach the greater packet, so that the interval between them and it gradually diminishes, and having traversed the crus, they are both attached below and behind it to

* Dublin Dissector.

the same part as the greater packet, and posterior to it. (See *fig.* 140). This view of the connection of the lesser packet, if confirmed, must lead to interesting results with regard to the relations of the two portions of the fifth nerve at least; it will at all events decide the question as yet in dispute, whether they are to be regarded as distinct nerves, or parts of the same; upon this point further light will be thrown by the disposition of the same part in fish, in which the source of the uncertainty prevailing with regard to the nerve in the higher classes does not exist to the same amount; inasmuch as the ganglionic and non-ganglionic divisions of the nerve seem for the greater part associated in their distribution.

Fig. 141.



Back view of pons, bulb, and course of the Fifth Nerve in man.

18 Tubercula quadrigemina.
19 Continuation upward of the tract from which the Fifth Nerve arises.
The other references indicate the same parts as in the preceding figure.

When the adjoining matter has been carefully cleared away from the part to which the packets of the nerve are attached, that part appears to be a longitudinal tract of a yellowish-white colour, composed of fibres running in the same direction, and capable of being followed both upward and downward: upward this tract seems continued beneath the superior peduncle of the cerebellum;* downward it descends from behind the pons into the spinal bulb, and after a short course divides into two cords, one for each column of the spinal marrow (see *figs.* 140, 141). At the entrance of the tract into the bulb it is situate deep, before the floor of the fourth ventricle and behind the superficial attachment of the two portions of the seventh pair, which must be separated from each other and displaced in order that it may be exposed: externally the tract corresponds to the peduncles of the cerebellum, and is united internally to the cineritious matter of the floor of the ventricle. At the point of attachment the tract presents a somewhat prominent enlargement, (*figs.* 140, 141, 12,) which the author will venture to call an eminence, though with hesitation, lest it be considered an exaggeration, from which the nerve may be held to arise.

It is said that the nerve may be held to arise from this tract, because, though it be certainly not its ultimate connection with the brain, and though cords can be traced from it to more remote parts, yet the union of the cords at the point, and the attachment of both portions of the nerve to it, seem to mark it as the origin of the nerve; the change of character too which will be described as occurring at the attachment of the nerve, countenances the opinion that the tract is not simply a continuation of the nerve.

It may be doubted whether the eminence really exist, or whether it be not merely the result of dissection: the author will not insist upon it, but several considerations induce him to consider it real: in the first place, he almost uniformly finds it,* and secondly, it seems to be a common point to the two portions of the nerve and to the other cords, which form part of its encephalic connections; and lastly, this view is corroborated by the disposition of the same part in other animals; for a similar appearance will be found, at the attachment of the nerve behind the pons, in other mammalia as well as in man after the separation of the adjoining matter, e.g. in the horse; and it is even asserted by Desmoulins that an eminence may be observed naturally upon the floor of the fourth ventricle, in some animals, at the attachment of the nerve. His statement is: " on observe même dans les rongeurs, les taupes, et les hérissons, un petit mamelon ou tubercle sur l'extremité antérieure du bord du ventricule; mamelon, dans lequel se continuent les fibres posterieures de la cinquième paire, et de l'acoustique." When the tract has reached the point at which the inferior peduncle of the cerebellum first inclines outward toward the hemisphere, it separates, as has been stated, into two parts or cords, (see *figs.* 140, 141,) destined, one, as is already known, to the posterior, the other, according to the author's belief, to the anterior column of the spinal cord. The course and disposition of these cords are remarkable and

* Of the nature of the structure continued upward from the attachment of the nerve the author is not satisfied: it presents, when cleared, the appearance given to it in fig. 141, 19, but it is very cineritious in character, and he is not prepared to say whether it be a continuation of the tract from which the nerve appears to arise, or a part of the floor of the fourth ventricle at its upper extremity, connected to the attachment of the nerve: the mode in which the nerve arises in the bird and the turtle appears to the author opposed to the opinion that the tract to which the nerve is attached is, in them at least, any thing more than a continuation or root of the nerve, but admitting this, he cannot satisfy himself that it is to be regarded in the same light in the Mammalia.

* The attachment of both the packets must be made out, else the enlargement will not appear.

apparently contrary to analogy; they are distinguishable into anterior and posterior, but they descend, the anterior to the posterior, and the posterior to the anterior columns. The anterior cord is by much the larger, and is prolonged through the inferior peduncle of the cerebellum, until at the inferior extremity of the bulb it is continued into the longitudinal fasciculi of the corresponding posterior column of the spinal marrow; it is situate along the outer side of the olivary body, but separated from it by a slight interval, nor does it seem to have any connection with that body: it is imbedded in the substance of the superior part of the peduncle, situate, however, nearer to its anterior than its posterior surface, and laid obliquely across its fibres as they pass outward toward the hemisphere of the cerebellum; but as it proceeds it becomes gradually more superficial, gains the outer side of the peduncle, and at the lower extremity of the bulb is actually at its surface almost immediately behind the lateral fissure of the cord and the posterior roots of the superior cervical nerves. The existence and course of this cord have been first established and described by Rolando in his "Saggio sopra la vera Struttura del Cervello," and also in a memoir upon the Anatomy of the Medulla oblongata, published in the fourth volume of the Journal of Physiology.

The posterior cord is much smaller than the former; it descends behind the inferior peduncle of the cerebellum, as it passes outward into the hemisphere, and upon the posterior aspect of the spinal bulb; enters the posterior fissure of the bulb, between the posterior pyramids, and can be traced some way downward, in the bottom of the fissure, along the back of the anterior column of the same side, into which it appears to be ultimately continued. (*Figs.* 140, 141, 13.)

The preceding account of the encephalic connections of the fifth nerve differs very much from that adopted by some of the highest modern authorities. It is not necessary to allude to the opinions entertained upon the point, before the course of the nerve had been particularly inquired into; but, according to some of the most recent, the nerve arises from the groove between the restiform and olivary bodies, and from the olivary bodies themselves. Such is the view given of the origin of the nerve by Gall and Spurzheim in their fifth plate of the brain, in which the nerve is represented breaking up, on the outside of the olivary body, into several fasciculi, which plunge obliquely into it. In their account* of the course of the nerve into the brain they state, " on peut aisément suivre son cours entier jusq'au dessous du côté extérieur des corps olivaires;" this might be, perhaps, interpreted to mean *beyond the olivaries*, reference being had to the relations of those bodies in the erect posture; but from the representation given it is obvious that the intended meaning is, that the nerve can be followed to beneath, i. e. underneath, their outer side, the brain being placed in the manner ordinarily adopted for dissection, in which the anterior aspect of the olivaries is rendered superior; indeed their representation is altogether incompatible with the opinion that they had traced the nerve beyond the bodies.

Such also is the opinion of J. F. Meckel,* according to whom the nerve " passes under the posterior peduncle of the cerebellum, along the outer side of the pons, toward the groove between the olivary and restiform bodies, where it arises in part from the groove and in part from the olivary eminences." Cloquet† likewise states the nerve to arise between the olivary and restiform bodies, and has adopted and copied, in his late work,‡ the view given of its origin by Gall and Spurzheim. Further, the discovery of this origin of the nerve has been attributed by Meckel§ and others to Santorini.

It is a hardy thing to contradict such authorities as have been quoted, and the influence which they justly carry with them has made the author hesitate before adopting a contrary opinion; but if reference be made to the work‖ of Santorini on the point, it will be found that he nowhere, in his account of the origin of the nerve, assigns the groove between the restiform and olivary bodies as its situation in the spinal bulb, as will appear from the following extract, the only paragraph of his account in which he particularizes it, and in which he supposes it to be situate between the olivary and pyramidal bodies: " Unde in interiorem medullæ oblongatæ caudicem conjectus, fere inter olivaria et pyramidalia corpora locatus, quo demum pergat, cum tenuium fibrarum implexus, tum earumdem mollitudo, ne consequerer, omnino prohibuere;" from which it is plain, as has been stated, that he supposed the nerve to be between the two latter bodies; and also that he had not been able to trace it to any particular destination, although, in a succeeding paragraph, he conjectures the olivary body to be its source: hence there is reason to conclude that succeeding anatomists have assumed his conjecture to be an established fact, and have modelled their accounts and representations accordingly. Moreover, since the olivary bodies do not exist in the lower classes of animals, it is not likely that they should be points of origin or attachment for nerves; in fine, the author has so uniformly succeeded in tracing the nerve to the destination which has been described, that he is satisfied of the accuracy of it, in which he is confirmed by the fact that the account here given accords with the opinions of Santorini, Sœmmerring, and Rolando, so far as that of the first has been determined to be accurate, or as those of the others extend: the particulars in which it differs from, or rather in which it goes beyond these, rest upon the author's authority and remain to be confirmed,

* Anatomie et Physiologie du Système Nerveux, tom. i. p. 107.

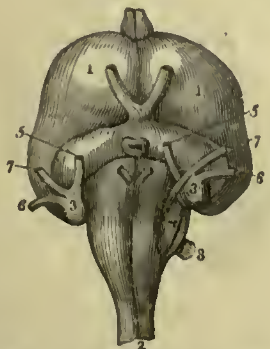
* Manuel d'Anatomie, French edit.
† Traité d'Anatomie descriptive.
‡ Anatomie de l'Homme.
§ See note 5, p. 82, op. cit. vol. ii.
‖ Observationes Anatomicæ.

viz. the attachment of the two packets to the same point, the existence of the eminence at the insertion, and that of a cord of communication with the anterior column of the spinal marrow.

The encephalic connections of the nerve, as detailed, are corroborated by those to be observed in inferior animals. In those Mammalia in which the pons is but little developed, the nerve is attached between that part and the trapezium; in those instances in which the pons is more so, the nerve is attached, superficially, not actually behind that part, but near to its posterior margin; with little trouble it can be followed to the back of the pons, where it is attached, as in Man, to the medulla oblongata, the point of attachment presenting here also, after the separation of the adjoining matter, the appearance of an eminence or tubercle, from whence a cord descends beneath the trapezium into the lateral column of the spinal bulb. This cord is of great size in many animals; and in some can be seen distinctly, without dissection, upon the surface of the spinal bulb, in consequence of the degree to which it projects: it is well expressed in the delineation of the brain of the calf in the third plate of Gall and Spurzheim, and in that of the brain of the horse in fig. 275 of M. Serres' Illustrations of the Comparative Anatomy of the Brain.

In Birds, Reptiles, and Fish, neither pons, trapezium, nor olivary bodies exist, and the nerve is attached to the lateral part of the spinal bulb at its superior or anterior extremity, and to its lateral column—the prolongation of the superior column of the spinal cord. In all three the point of attachment is situate a little way from the back of the bulb and beneath the floor of the ventricle, the cineritious stratum, of which the latter consists, being directly connected to the back of the nerve. In Birds (*fig.* 142) the continuation of the nerve

Fig. 142.



Brain and Fifth Nerves of the Goose.

1 Inferior surface of cerebrum.
2 Spinal bulb. 3 Ganglia of fifth nerves.
4 Root of nerve from lateral column of the bulb exposed by turning aside the superficial stratum of that part.
5 First division of the fifth. 6 Second do.
7 Third do. 8 Auditory nerve.
On one side (the reader's right) the non-ganglionic fasciculus has been traced beneath the ganglion into the third division of the nerve.

can be traced downward along the side of the bulb toward the spinal cord, and without difficulty, inasmuch as it is superficial and is not crossed by a trapezium, as in the Mammalia.

In the Turtle the nerve can be traced in like manner from the point of attachment downward into the lateral column; and in Fish the

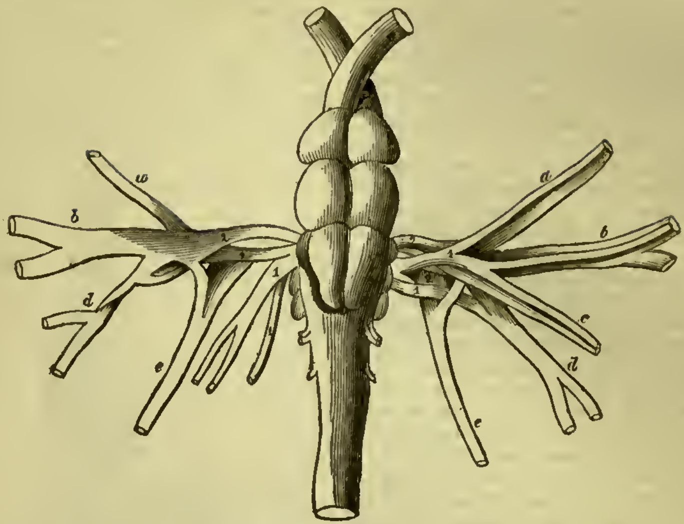
Fig. 143.

Origin of nerve in Turtle.

1 Spinal bulb.
2 Fifth nerves.
The pin is passed between the ganglionic and non-ganglionic fasciculi, the latter being continued into the third division.
3 Ganglion.
4 First division of the nerve.
5 Second do.
6 Third do.

attachment is in all essentials similar: the comparative smallness of the bulb and the direction which the nerve takes in its course outward, make it resemble the spinal nerves more than in the other classes; but its encephalic connection is strictly the same, namely, to the lateral column of the bulb beneath the floor of the ventricle. In the Cod, after the removal of the floor of the ventricle from the back of the nerve, the latter may be followed for some way into the column, though neither to the same extent nor so satisfactorily as in the bird or the Turtle; and in the Ray, while the two inferior fasciculi of the nerve—for in this fish it consists originally of three—are connected in the usual mode to the lateral column, the superior is attached to a convolution formed by the floor, in consequence of a greater developement of its margin. In the Cod the convolution adverted to does not exist, but the floor of the ventricle cannot be raised from the nerve without destroying a connection of some kind between them. In the latter fish the fifth nerve is attached before and rather superior to the auditory nerve, and the two nerves are quite distinct as far as the point of attachment, but there they are in

Fig. 144.



Brain and Fifth Nerves of the Cod.

1 Non-ganglionic portions (on the reader's left side) separated from the ganglionic and thrown back.
2 Ganglionic portion.
a First branches of both portions.
b Second do.
c Third do.
d Fourth branch derived from both.
e Fifth branch derived only from the ganglionic.
The third division has been removed on the left side.

immediate apposition and appear to have the same source. In the Ray it is different; in it the auditory seems merely a branch of the fifth (*fig*. 145, 7) given off from its posterior ganglionic fasciculus about three lines from its attachment to the spinal bulb, and before the formation of its ganglion.

After the preceding details it must seem

Fig. 145.

Brain and Fifth Nerves of the Ray.

a Anterior ganglionic portion of the fifth nerve.
b Posterior do.
c Non-ganglionic portion. On the reader's left it is laid back to display its connexion with the posterior ganglionic; on the right it is in situ.
e First branches of the two portions.
f Second do.
7 Auditory nerves.

extraordinary if the nerve in the higher animals differed, in its ultimate connection with the brain, so very much from that in the inferior, as it is represented by some to do.

Yet it is asserted by M. Serres,* who has founded his opinion upon the observations which he has made upon the successive developement of the brain and nerves in the embryo of vertebrate animals, that in the Mammalia the nerve is implanted upon the trapezium. Such is the form of expression by which he intends, as the author understands, the ultimate connection of the nerve with the brain. Now, in the first place, we have already seen where that connection is in those animals in which the trapezium does not exist, and it appears to the author reasonable to conclude that similar nerves have similar or analogous attachments in the several classes of animals, however the parts with which they are connected may be complicated or obscured by superadded structures. In the second place the trapezium can be regarded only as a superadded structure, and is not among those parts from which nerves are likely to arise, being itself but a commissure: and, thirdly, the situation and connections of the part to which the nerve is attached, are altogether incompatible with the opinion that it is the trapezium, inasmuch as the latter is situate before the cords, which ascend from the anterior columns of the spinal cord to the crura cerebri, while the structure with which the nerve is connected is posterior to them. For these reasons the author concludes that M. Serres has mistaken the place of the nerve's attachment in the Mammalia.

In conclusion, the representation of the origin of the nerve, which appears to the writer to be the most remote of all from the real one, is that given by Swan, in his plates of the nerves lately published, in which the fifth is reflected into the auditory nerve: such a connection is merely artificial and does not really exist; it can be produced only by stopping short in the pursuit of the fifth nerve, and moulding it into the anterior root of the auditory, which is in contact with it.

This view of its encephalic attachment has probably originated in the intimate connection known to exist between the two nerves in inferior animals. The complication of the cerebral connection of the nerve in the higher animals may be now better understood. In those, in which the pons and trapezium do not exist, the nerve emerges directly from the spinal bulb, in a manner similar to the adjoining nerves; but in those, in which the bodies alluded to are present, inasmuch as the attachment of the nerve is behind them, it can reach the surface only by either passing between them, or traversing their substance. Hence, if the nerve simply traverse them, it ought not to receive any accession of fibres from them, and such, according to the writer's experience, is the case. As it emerges from the pons, the lesser packet receives an epithelium from its surface; but he has not been able to detect any fibres originating within the substance of that part.

The structural arrangement, which the encephalic portion of the nerve presents within the brain, is different from that, for which it is remarkable, while superficial to it. Externally it is, as has been stated, of a fascicular texture; but, within, that appearance is not to be observed: there the larger portion is a white, soft, homogeneous, flattened cord, the delicacy of which, in the natural state, forbids the separation of it into distinct parts; but when sufficiently hardened, it may be divided into numerous thin strata, and these again into delicate fibrils. That such an arrangement is a natural, and not an artificial appearance, is manifest from the circumstance, that the separation into fibrils can be effected only in one direction, the length of the nerve, and that they break off when it is attempted in the other. The nerve retains those characters as far as its attachment behind the crus, but there they cease; the pure white colour suddenly disappears; the point of attachment and the cords descending from it present a cineritious tint; and they are not absolutely distinct from the surrounding substance, as the nerve had previously been, but immersed in it; they are, however, still manifestly composed of filaments, which may be rent either toward or from the point of attachment; and after immersion in spirit they become nearly white. The course of the nerve, from its attachment to the surface of the brain, is forward and outward toward the internal anterior extremity of the petrous portion of the temporal bone; it next passes over the superior margin of that portion, and descends upon its anterior surface into the middle fossa of the base of the cranium, where it reaches the Gasserian ganglion. During its short course, from its attachment to the brain, to the ganglion, it is at first contained within the proper cerebral cavity, by the side of the pons Varolii, and beneath the internal anterior angle of the tentorium cerebelli; in the second place, in the middle fossa, it is not within the cerebral cavity of the cranium, but beneath it, separated from it by a lamina of dura mater; it is there contained in a canal or chamber, formed by a separation of the dura mater into two layers, between which the nerve and its ganglion are inclosed, one beneath them attached to the bone, another above separating them from the brain. This chamber is situate immediately external to, and lower than the cavernous sinus, but separated from it by the inferior lamina of the dura mater just described, which ascends from the bone to join the superior, and in so doing forms a septum between the two chambers; it is about three-fourths of an inch long, reaching from the superior margin of the petrous bone to the anterior margin of the depression upon its anterior surface, in which the ganglion rests. In front this chamber is wide, containing at that part the ganglion, and sends fibrous offsets upon the nervous trunks proceeding from it; posteriorly it is narrow, and presents an oval aperture, about one-third of an inch long, situate external and inferior to the posterior clinoid process of the sphenoid bone beneath the attachment of the tentorium cerebelli to that process,

* Op. cit.

and also beneath the superior petrous sinus: by this aperture the chamber communicates with the cerebral cavity and the nerve enters. The chamber is lined by the arachnoid membrane, as far as the posterior margin of the ganglion, but along this the membrane is reflected from the interior of the chamber to the nerve, and returns upon it into the cranium: hence the nerve is free within the chamber, while the dura mater is attached to the surfaces of the ganglion, and so closely that it requires care to separate it from them. The chamber presents a remarkable variety in its construction in some animals: in the horse, for instance, its parietes are not simply fibrous, as in man, but, frequently at least, in great part osseous, being at the same time lined by the membrane.

The passage of the nerve over the margin of the petrous bone is marked by an interruption in the sharp edge, which the bone presents external to that point, and its site upon its anterior surface, as also that of the ganglion by a corresponding shallow depression.

Throughout the course of this portion of the nerve, the relation of the two packets to each other varies; at the attachment of the nerve to the crus cerebelli, the smaller packet, allowance being made for those varieties presented by it in its mode of attachment, is superior and internal to the larger; in the interval between the crus and the margin of the petrous bone, the smaller packet gradually descends along the inner side of the larger, until it has reached the same level, so that the two packets are placed immediately side by side upon the margin of the bone, the lesser internal to the greater; but as the nerve proceeds into the middle fossa, the smaller, at the same time, passes from within outward beneath the larger, and also beneath the ganglion, toward its outer and posterior extremity; during this course it has no communication with the ganglion, but is quite distinct from it, though inclosed in common in the chamber formed by the dura mater, and connected with it by a dense cellular or fibrous structure; but having thus passed the ganglion, the lesser packet is united to the third trunk proceeding from that body, and with it constitutes the third division of the nerve.

The larger packet, on the contrary, is attached to the ganglion. It has been before stated that the plexiform arrangement, which it presents, becomes less, as it approaches that body; its fasciculi become more distinct; they separate from each other, so that the width of the packet is greatly increased, and having reached the posterior margin of the ganglion they are received into the channel which it presents; in which they are ranged, in series, from one extremity of the body to the other, overlapped by its edges, and enter abruptly into the substance of the ganglion.

External portion of the nerve.—The external or peripheric portion of the nerve consists of three large trunks or divisions, which are connected, on the one hand by their ramifications, with the organs to which the nerve is distributed, and on the other, with the ganglion and the brain. They are distributed, generally speaking, to three different regions of the head and face, one to the uppermost, another to the middle or superior maxillary, and the third to the lowest or inferior maxillary regions, and they are denominated, either numerically, first, second, and third, as by the first Meckel; or, according to the parts to which they are distributed, the first the ophthalmic, by Willis; the second the superior maxillary, and the third the inferior maxillary, by Winslow. These methods of distinction have their several advantages. Could we select names which would give adequate ideas of the distribution of the trunks, the latter would certainly be preferable; but inasmuch as those which have been selected do not at all adequately express that distribution, and are attended, therefore, with the inconvenience of not giving a sufficiently enlarged idea thereof, it would probably have been better, had the former been from the first adopted and adhered to, for such names could not create any incorrect impression with regard to the distribution of the several divisions of the nerve; in fact, the epithets *ophthalmic*, *superior*, and *inferior maxillaries* ought to be altogether discarded, for, beside the objection to their use already stated, it will be found, upon reference to the anatomy of other animals, that they are by no means distinctly appropriate, and that the circumstances upon which they are founded are purely incidental, associated with the peculiarities of the animal; for the proof of which, see the comparative disposition of the fifth nerve in the several classes.

The three trunks differ from each other in size. The first, the ophthalmic, is the smallest; the second, the superior maxillary, is intermediate in size; and the third, the inferior maxillary, is by much the largest. They are connected to the anterior convex margin of the ganglion,—the first to its superior internal extremity, the second to its middle, and the third to its inferior external extremity. At their attachment they are wide, flattened, and of a cineritious tint; but as they proceed they become contracted in width, cylindrical or oval in form, and of a white colour. Their texture is fascicular and compact, the fasciculi of which they are composed being bound up closely together, and they differ remarkably in composition, the two first, the ophthalmic and superior maxillary, being derived altogether from the ganglion, and thus being, in anatomical constitution, simple; whereas the third is composed of two parts, one derived from the ganglion, and another formed by the lesser packet of the nerve, which does not join that body, and hence that division is compound.

The trunks rest partly against the outer side of the cavernous sinus and in part upon the base of the cranium in its middle fossa, and they are enclosed in offsets from the fibrous chamber, in which the ganglion is contained. Their relative position corresponds to the position of the ganglion; the first is superior and internal to the other two, the second is inferior and external to the first, and the third is external, posterior, and inferior to both the others. They go off from the ganglion at different inclinations, the first forward and slightly upward, the second directly forward, and the third almost directly downward; hence the first and second form a very acute angle with each other, while that between the second and third is much greater.

First or ophthalmic division.—This division is distributed to the eye and its appendages, to the nostril, and to the forehead. It is the smallest of the three trunks proceeding from the ganglion, and is situate superior and internal to the other two. It is about three-fourths of an inch long from the ganglion to its division into branches, and is contained thus far within the cranium. Its course is forward, upward, and slightly outward toward the upper part of the foramen lacerum of the orbit. It is laid against the outer side of the cavernous sinus, in company with the third and fourth nerves, and is contained in the external wall of the sinus, being separated from the interior of that chamber by a thin septum, which is a prolongation of the inferior internal wall of the canal in which the nerve and ganglion are contained. The septum is dense, but at the same time so thin and transparent that the nerve can be seen through it from the side of the sinus, while the lamina of the dura mater, by which it is separated from the interior of the cranium, is so thick and opaque, that the course of the nerve is altogether concealed from that side. At its outset the nerve is beneath, and external to the third and fourth nerves, and external and somewhat superior to the sixth, which is within the sinus; but ascending as it proceeds, it gains, about the middle of the sinus, the same level with the third, placed still at its outer side, and inferior to the fourth, and then terminates by dividing into branches.

Presently after its origin from the ganglion the nerve is joined by one or more very fine filaments from the sympathetic: this is expressly denied by the first Meckel, but he was certainly mistaken; they are very faithfully represented by Arnold. In order to display them the sixth nerve may be separated carefully from the carotid artery in the cavernous sinus, after which it will be found that branches of the sympathetic ascend upon the artery internal to that nerve, and distinct from those which are connected with it. Having surmounted it they branch off, some upon the artery as it passes to the brain, others to other destinations, and of the latter some incline outward above the sixth nerve and are connected to the first division of the fifth: they are short and very delicate.

The first division of the fifth gives off no branch from its outset to its final division, except an extraordinary filament described by Arnold, and denominated by him *the recurrent branch of the first division of the fifth.* It arises from the upper side of the trunk immediately after it leaves the ganglion, runs backward above this body at a very acute angle, enters the structure of the tentorium cerebelli, and divides between its laminæ into several very delicate filaments.

The branches into which the first division of the fifth ultimately divides are either two or three; according to the elder Meckel and the greater number of authorities they are three; according to others they are sometimes three, but are more frequently only two. The three branches are the frontal, the nasal, and the lachrymal. When the branches are but two, they are, according to J. F. Meckel, the nasal and the frontal, the latter in such case giving off that, which in the other mode of distribution is the third, the lachrymal. The elder Meckel attributes the difference of opinion which prevails with regard to this point to the fact that the lachrymal nerve frequently has a second root derived from the frontal, which in such cases has been assumed to be the origin of the nerve. The names which have been applied to those branches have been taken either from their destination or from their relative course; thus the frontal, so called from its distribution to the forehead, is also called the superior or middle branch; the nasal, so called because finally distributed to the nostril, the internal or inferior, and the lachrymal, which derives its name from the lachrymal gland, the external. The three branches differ in size; the frontal is considerably larger than either of the others, the nasal is second, and the lachrymal is much the smallest. They all three traverse the orbit, but they pursue different routes, and have, at entering, very different relations.

1. *The frontal nerve* appears in the human subject, both from its size and its direction, to be the continuation of the original trunk. In other animals, however, it is otherwise: in them the predominance of the frontal nerve diminishes along with that of the superior region of the face, until in some it ceases to exist as a primary branch of the first division of the fifth, and its place is supplied by a secondary branch of another, while the nasal branch increases in the same proportion, and seems ultimately to constitute itself the first division of the fifth.* The frontal nerve passes upward and forward toward the highest part of the foramen lacerum of the orbit, and enters that region through it. It then continues its course through the orbit to the superciliary foramen and escapes through it to the forehead. During this course it is placed, before it has entered the orbit, at the outer side of the third nerve; it then rises above the third and crosses over it to its inner side. In doing so it is accompanied by the fourth nerve, to which it is external and inferior; it enters the orbit in company with the fourth and nearly on the same level, but still external to and somewhat beneath it. In entering, it passes above the origin of the superior rectus muscle, and all the other parts transmitted through the foramen lacerum, with the exception of the fourth nerve. At the entrance of the frontal nerve into the orbit and during its course from its origin thereto it is

* See comparative distribution of the fifth nerve.

closely attached to the fourth nerve, but presently after separates from it, the fourth inclining inward, is continued forward to the superciliary foramen, lying upon the superior surface of the superior rectus and levator palpebræ muscles, being through its whole course within the orbit immediately beneath its roof. Having reached the foramen it passes through it, and changing its direction, ascends round the superciliary arch, upon the forehead, beneath the orbicularis palpebrarum and frontalis muscles, and is thenceforth called by some the external frontal nerve in contradistinction to a branch from itself, the supra-trochlear, or internal frontal. In its mode of escape from the orbit the frontal nerve is subject to some variety, consequent in part upon the mode in which the superciliary foramen is formed, that being in some instances altogether osseous, in others osseous only at its superior part and completed by ligament below; in this case the nerve escapes through an osseous notch, and not a foramen. In other instances, again, when the nerve divides previous to its escape it is sometimes transmitted through two apertures.

The distribution of the frontal nerve, as well as that of most of the secondary branches, is subject to varieties, which the author has endeavoured to embrace in the following account. In the first place the frontal, at its entrance into the orbit, anastomoses with the fourth nerve. Next it gives off, some time after its entrance and previous to its division, a long and slender branch, which runs forward and inward toward the trochlea of the superior oblique. Then it divides into two branches, a larger one, the continuation of the nerve, which escapes through the superciliary foramen, and a smaller, *the supra-trochlear* or *internal frontal.* The latter passes forward and at the same time inward toward the trochlea of the oblique muscle, escapes from the orbit internal to the continued trunk of the frontal nerve, and ascending upon the forehead beneath the corrugator supercilii, orbicularis, and frontalis muscles, it has received the name of *internal frontal*, in contradistinction to the continued trunk, which is at the same time called *external frontal.* The point at which the frontal divides is variable; for the most part the division takes place about midway in the orbit. In some instances it occurs before the nerve has reached that point, and in others, again, not until it has approached nearer to the anterior margin of the orbit. The distance of the division from the margin of the orbit appears to modify the course of the internal branch: when it is far back, the nerve escapes from the orbit above the trochlea, and hence the name supra-trochlear, given to it by Meckel; and when near the margin it escapes external to the trochlea, between it and the superciliary foramen; while in the latter case a branch of the nerve is transmitted above the trochlea, in the usual course of the nerve itself. Nor is the size of the two branches into which the frontal divides equal or uniform; for the most part the external branch is the larger, but in some instances the two are of equal size. In its course forward the supra-trochlear nerve gives off first, occasionally a delicate branch, which frequently arises from the frontal itself prior to its division, the course and destination of which have been already described. Next it gives off, in some instances before, in others not till after it has escaped from the orbit, a branch which passes inward toward the internal canthus, and, uniting with either the infra-trochlear itself or a branch of it, concurs in forming a small plexus, from which filaments are distributed to the structures of the upper eyelid, toward its internal part, and to the eyebrow. Having escaped from the orbit, the supra-trochlear nerve divides into two sets of branches, denominated *palpebral* and *frontal;* the first descend into the superior eyelid, and are distributed to the structures of that part; the filaments communicating externally with those of the frontal, and internally with those of the infra-trochlear. The frontal branches ascend round the superciliary arch, beneath the orbicularis palpebrarum and the corrugator supercilii muscles, upon the forehead, and these are disposed of in a manner similar to that in which the branches of the proper or external frontal are. Some are distributed to the orbicularis, corrugator, and frontalis muscles; other, long branches, ascend beneath the frontalis, traverse it, and become subcutaneous, and are distributed to the integuments of the scalp upon the forehead. Of these the external unites with the internal branch of the external frontal, and forms with it a common branch, which has the same destination as the others.

The external larger branch of the frontal, called, in contrast with the last, the external frontal nerve, also divides into two sets of branches, *palpebral* and *frontal.*

The nerve in some instances emerges from the orbit a single trunk, in others it divides before it escapes from that region, for the most part into two branches, which are transmitted sometimes through the same, at others through distinct apertures, and from which the several ramifications arise, they themselves becoming ultimately the long frontal branches.

Immediately after their escape the frontal branches give off externally slender filaments, which run outward toward the external canthus, one beneath the eyebrow, through the upper eyelid, and one or more through the brow itself; these ramify as they proceed, supply the lid and brow at their outer part, and anastomose with filaments of the portio dura, and of the superficial temporal nerve.

The frontal branches are arranged into *superficial* and *deep;* those epithets have been differently applied by different writers; thus those which the elder Meckel terms the *superficial,* Boyer and Cloquet denominate the *deep branches;* nor is this to be wondered at, inasmuch as both sets become ultimately superficial; it were better, perhaps, to arrange them into *short* and *long* branches. The short branches are distributed to the orbicularis muscle, the corrugator, and the frontalis, and having supplied those muscles, they or others of them become subcutaneous, and terminate in the integuments of the eyebrow and forehead: one of these branches, as described by Meckel, runs outward, through the orbicularis, toward the external canthus, and establishes anastomoses with filaments of the facial portio dura nerve. The long branches are two, an external and an internal; of those the external is, for the most part, the larger; they ascend beneath the frontalis and the frontal aponeurosis, the former inclining outward, the latter inward, as they ascend; they distribute in their course ramifications to the muscle, and to the deeper structures of the scalp, as well as sometimes, according to Meckel, to the pericranium, and traversing the frontal aponeurosis, they become subcutaneous, and terminate in the structure and integument of the scalp. The external communicates with the superficial temporal nerves; the internal with the internal frontal, the supra-trochlear. They are said both to anastomose with the branches of the sub-occipital nerve; but Meckel states that he has pursued them until they have escaped his sight, and yet he could not discover any anastomoses between them and the branches of that nerve.

2. *The nasal nerve* is in size the second branch of the first division of the fifth, and arises always separately from the original trunk. Its course is inferior and internal to those of the other two, and hence the nerve is called by some the inferior, by others the internal branch. It is distributed partly to the eye and its appendages and partly to the nostril, and hence it is also called *naso-ocular* by Sœmmerring. The direction of its course is forward and very much inward; it passes through the foramen lacerum into the orbit; then traverses that region from without inward toward its internal wall, and having reached it at the foramen orbitarium internum anterius, it escapes from the orbit through that foramen, and passes into the cranium; it emerges into the cranium from beneath the margin of the orbitar process of the frontal bone, and crosses the cribriform plate of the ethmoid obliquely forward and inward, contained in a channel in the bone, and invested by the dura mater, until it reaches the crista galli; it then descends from the cranium into the nostril, through the cleft, which exists at either side of the crista galli at the anterior part of the cribriform plate, and having reached the roof of the nostril, it divides into its final branches.*

The nasal branch is concealed at its origin by the frontal, which is situate external and superior to it. Before its entrance into the orbit it is placed by the outer side of and closely applied to the third nerve. In entering the orbit it passes between the two posterior attachments of the external rectus muscle, in company with the third and sixth nerves, external to the former and between its two divisions, and internal and somewhat superior to the latter. In its course across the orbit the nasal nerve passes above the optic nerve, immersed in fat, and accompanied by the ophthalmic artery, being at the same time beneath the levator palpebræ, the superior oblique, and superior rectus muscles, and in crossing the optic nerve, it is placed between it and the last mentioned muscle. Through the foramen orbitarium the nerve is accompanied by the anterior ethmoidal artery, and within the cranium is situate beneath but not in contact with the olfactory bulb, being separated from it by the dura mater. The course of the nerve from the orbit to the nostril is liable to be modified by the developement of the frontal sinuses; when they are very large, and extend, as they not unfrequently do, into the orbitar processes of the frontal bone and the horizontal plate of the ethmoid, the nerve may cross to the side of the crista galli without entering the cranium, being contained in a lamella of the ethmoidal bone. The nasal branch, before entering the orbit, receives, according to Bock, J. F. Meckel, and Cloquet, a filament from the sympathetic. The branches which the nasal gives off, are the *lenticular*, the *ciliary*, the *infra-trochlear*, and the *nasal*.

The lenticular branch is given off as the nasal enters the orbit, and on the outer side of the optic nerve; it is a delicate branch, about half an inch long; it first anastomoses with the superior division of the third nerve; then runs forward along the outer side of the optic nerve, and terminates by joining the superior and posterior part of the lenticular ganglion. According to Bock and Meckel junior, it occasionally gives off a ciliary nerve, and according to Meckel senior it is, in rare instances, derived from the third nerve. To the latter statement, however, the author hesitates to assent: it appears to him, that it should rather be said in such cases to be wanting.

The ophthalmic, lenticular or ciliary ganglion, according to Cloquet, is of an oblong form—its greater length from behind forward; it is one of the smallest ganglia of the body, being, however, variable in size; its colour is reddish, at times white; it exists constantly in the human subject: it is situate between the external rectus muscle and the optic nerve, laid against the outer side of the nerve, at a little distance from its entrance into the orbit; its external surface convex, corresponding to the muscle; its internal, concave, to the nerve; to its superior posterior angle is attached the lenticular twig of the nasal branch of the first division of the fifth; this filament constituting its *long root;* to its inferior posterior angle a filament from the inferior division of the third nerve is attached, constituting its *short root*. To the posterior part of the ganglion are also attached two filaments derived, one from the cavernous ganglion or the carotid plexus; the other, the constant existence of which has not

* The nasal is usually described as terminating by dividing within the orbit into two branches, the *ethmoidal* or *internal nasal*, and the *infra-trochlear* or *external nasal:* the author has preferred considering the former as the continuation of the nerve, because in inferior animals both the nasal is the principal portion of the first division of the fifth, or alone constitutes it, and it is manifestly prolonged, as such, into the nostril and the beak. See Comparative Distribution.

been yet established, from the spheno-palatine ganglion.

The ganglion gives off from its anterior extremity a considerable number of very delicate filaments, denominated from their distribution *ciliary:* they amount to from twelve to sixteen; are reddish and tortuous; and run forward along the optic nerve to the back of the eye, which they enter at a short distance from the nerve. They are distinguished into two fasciculi, *superior* and *inferior;* which are attached, one to the superior anterior, the other to the inferior anterior angles of the ganglion: the former is the smaller; contains at first but three filaments, which, as they proceed, divide so as to produce six, and run parallel to each other above the optic nerve: the second fasciculus is situate on the outside of and beneath the optic nerve, and contains from six to ten filaments collected at their origin into six branches: they pass beneath the nerve and incline inward, so as to gain, some of them, its inner side: one of them runs outward and joins one of the ciliary branches of the nasal nerve. The ciliary nerves all penetrate the sclerotic coat of the eye separately and obliquely; then run forward between the sclerotic and choroid coats, without giving filaments to either, lodged in channels upon the inner surface of the former: as they approach the ciliary circle they divide, each into two or three filaments, which enter the circle and are lost in it: some of them pierce the choroid at the anterior part of the eye, and go to the ciliary processes.

The *ciliary branches* are two or three in number; they are very delicate, and are given off, while the nasal is crossing the optic nerve; they run forward along the optic, imbedded in fat, penetrate the sclerotic coat of the eye posteriorly, and then continue forward between the sclerotic and choroid coats, in like manner as the other ciliary nerves, to the ciliary circle.

The *infra-trochlear branch,* so called by the elder Meckel, because it escapes from the orbit beneath the trochlea of the oblique muscle, is also called *external nasal.* It is given off when the nasal has reached the inner wall of the orbit, and as it is about to enter the foramen orbitarium; it is a branch comparatively considerable, at times longer, at others smaller decidedly than the continuation of the nasal; it runs directly forward along the inner wall, beneath the superior oblique muscle, toward its trochlea, and having reached that, escapes from the orbit beneath it. It then divides, in the internal canthus of the eye, into two branches, a superior and an inferior.

The infra-trochlear, while within the orbit, gives off occasionally, soon after its origin, a small branch, which returns and joins the nasal before it enters the foramen orbitarium;* also a delicate branch, which joins a corresponding branch given off either by the supra-trochlear or the frontal. The distribution of the nerve resulting from their junction has been already described under the frontal nerve. Of its ultimate branches, the superior joins and forms a plexus with a branch of the supra-trochlear nerve, already described, given off either immediately before or after that nerve has escaped from the orbit. From the junction of the two, numerous delicate ramifications are distributed to the upper eyelid and to the eyebrow. The inferior gives off several ramifications, which are distributed to the origin of the corrugator, the orbicularis, and the pyramidalis nasi muscles; to the conjunctiva, at the internal canthus; the caruncula lachrymalis and the lachrymal sac. Of those ramifications, one descends before the tendon of the orbicularis, and communicates with a branch of the portio dura: another communicates with a branch of the infra-orbital; but the latter anastomosis is uncertain.*

The nasal nerve having entered the nostril divides at the roof of the cavity into two branches, an external and an internal: of these the former descends behind the nasal process of the frontal and the corresponding nasal bones, contained in the groove or canal observable upon their posterior surface. It escapes from beneath them at their inferior margin, emerging between it and the lateral cartilage of the nose, and then descends along the corresponding ala, superficial to the cartilage, and covered by the muscles of the ala, toward the tip: as it approaches the tip, it divides into two filaments, one of which is distributed to that part, and the other to the ala. During its descent along the side of the nose it also gives off some delicate filaments, and anastomoses with the ramifications of the nasal branches of the infra-orbital nerve and with the portio dura. It is called by Chaussier the *naso-lobar:* it is also generally known as the nerve of Cotunnius. The second branch, as it proceeds, divides presently into two, of which one attaches itself to the septum, and descends, between the pituitary membrane and the periosteum, parallel and near to its anterior margin, as the *naso-palatine* of Scarpa does to its posterior: as it proceeds, it furnishes ramifications to the membrane of the septum. The second attaches itself to the outer wall of the nostril, and descends, in like manner between the mucous membrane and the periosteum, along its anterior part, in front of the middle turbinate bone, until it reaches the anterior extremity of the inferior one: it then breaks up into branches, of which some are distributed to the convex surface of the latter bone in front, and others beneath it to the anterior part of the inferior meatus. The distribution of the branch is very happily represented in Arnold's Icones.

The nasal nerve is described as giving also, in some instances, but not uniformly, a branch to the membrane of the superior turbinate bone, at the superior part of the nostril.

3. The third branch of the first division of the fifth is the *lachrymal:* it has been so called by Winslow from its distribution to the lachrymal gland: it is the smallest of the three branches: its course is external to that of the others, and hence it is also called the external branch. It

* J. F. Meckel.

* The elder Meckel.

arises, for the most part, from the ophthalmic at the same time with its other branches; J. F. Meckel asserts that it arises more frequently from a trunk common to it and the frontal; but the contrary is maintained by the elder Meckel; he, however, states that it arises frequently by two roots, one from the ophthalmic, and a second from the frontal, and once he has seen it derive a root from the temporo-malar branch of the superior maxillary nerve.* When it arises from the ophthalmic, it is at its origin, inferior to the frontal, and external to the nasal. Its course is forward and outward at a very acute angle with the frontal; it enters the orbit through the foramen lacerum, and from its origin until its entrance it is contained in the dura mater lining the inner side of the middle fossa of the base of the cranium, beneath the lesser wing of the sphenoid bone: in entering it passes above the origins of the external rectus muscle, between it and the periosteum, and pursues its course along the outer wall of the orbit, external to the superior rectus and superior to the external, until it reaches the lachrymal gland: it then passes between the gland and the eyeball, and then divides into branches. It is accompanied through its course by the lachrymal artery. The branches into which it divides are, for the most part, three; they enter the gland on its ocular surface, traverse it and again escape from it on its external aspect; in their course through the gland they divide and communicate with each other, and thus form within it a plexus, from which numerous ramifications are distributed to its substance. After having supplied the gland the branches of the lachrymal emerge from it, and pursue two destinations: one of them, which is for the most part the first branch of the nerve, and is frequently given off before it has reached the gland, descends backward toward the spheno-maxillary cleft, and joins the temporal branch of the temporo-malar branch of the second division of the fifth. In its course this branch passes first between the external rectus muscle and the outer wall of the orbit, then becomes attached to the wall, and is either simply inclosed in the periosteum, or contained in a groove or canal in the orbitar process of the malar, or sometimes of the sphenoid bone; in this canal it meets the branch of the temporo-malar, and from the junction of the two results a filament, the destination of which will be described under that of the temporo-malar. This branch of the lachrymal nerve is called *the posterior* or *spheno-maxillary*: it might from its destination be appropriately termed *temporal*: it frequently gives off in its descent a filament, which passes forward, escapes from the orbit beneath the external canthus, and is distributed as the other branches of the lachrymal are. The remaining branches of the lachrymal escape from the orbit into the upper eyelid, beneath the external part of the superciliary arch. They give off numerous filaments, which are distributed to the structures of the lid, the conjunctiva, the orbicular muscle, and the integument: the external of them, which are the largest, not only supply branches to the upper, but descend behind the external commissure of the lids into the lower one, which they supply at its outer part; they are also distributed to the superficial parts on the malar region. They anastomose with the frontal nerve, the superficial temporal, the facial, the temporo-malar, and the infra-orbital nerves.

The second division of the fifth.—This has been called also by Winslow, in consequence of its distribution, *the superior maxillary nerve*. It is the second trunk connected with the Gasserian ganglion, and is intermediate to the others, both in size and situation; larger than the first, and placed beneath and external to it; smaller than the third, and situate internal, superior and anterior to it; it is attached to the middle of the anterior convex margin of the ganglion; at first it is flattened, wide, and of a cineritious tint; but, as it proceeds, it becomes contracted in width, of a cylindrical form, and presents a white colour. At leaving the ganglion it is joined by a filament of the sympathetic. This has been seen by Munniks* and Laumonier,† and is stated by Meckel junior, on the authority of the latter. The communication between the sympathetic and the second and third divisions is called in question by Arnold.‡ That with the third the author has not yet made out, but that with the second he has found satisfactorily established by a filament from the branch of the sympathetic which joins the sixth nerve: this filament connects the sixth to the second division of the fifth, and is short, but grosser than those which join the first: in consequence of the irregularity which prevails in the arrangement of the sympathetic system, the description here given may not apply in other instances.

The course of the second division of the fifth within the cranium is short; it is directed forward, slightly outward and downward, toward the superior maxillary or the foramen rotundum of the sphenoid bone; having reached that foramen it enters the canal, of which it is the aperture, and escapes through it from the cranium. While within the latter the nerve is contained in a sheath of dura mater, and rests in a shallow channel on the body of the sphenoid bone, at its junction with the great ala. From the cranium it enters the spheno-maxillary fossa, and crosses that fossa at its superior extremity, from behind forward, inclining still downward and outward, though but slightly; its course across the fossa is also very short, extended between the root of the pterygoid process behind and the highest part of the posterior wall of the maxillary antrum before; having traversed the superior part of the fossa it enters the infra-orbital canal, through

* [According to Cruveilhier the lachrymal nerve very often arises by two filaments, one from the ophthalmic, the other from the fourth nerve, and Swan describes this as the normal condition.—Cruveilhier, Anat. Descr. t. iv. p. 911.—ED.]

* De Origine nervi intercostalis.
† Roux, Journ. de Méd. t. xciii.
‡ Journ. Comp. t. xxiv.

which it is transmitted, in company with the infra-orbital artery, to the face. In the canal it is situate in the floor of the orbit or the roof of the antrum, separated from each cavity, more or less perfectly, by a thin lamina of bone; its course within the canal is by much its longest stage; as the nerve approaches the anterior extremity of the canal, it inclines inward, and thus its course is rendered a curve, convex outward. In this respect, however, it presents varieties, dependant upon the transverse dimensions of the face, which being great, the course of the nerve is more curved and vice versa, it being sometimes nearly straight. From the time that the nerve enters the canal, it has been called *infra-orbitol;* but, inasmuch as that part of it is manifestly but the continuation of the trunk, and names are already rather too numerous than otherwise, it would be better if that one were discarded. From the infra-orbital canal the nerve escapes through its anterior aperture into the face; that aperture corresponds, for the most part, to the point of junction of the two external with the internal third of the inferior margin of the orbit, and is from a quarter to half an inch below it; its situation, however, is not uniform; in some skeletons it will be found to correspond nearly to the middle of the margin, and this circumstance is worthy of attention, in consequence of its relation to the operation for the division of the nerve.

At its escape from the canal the nerve is concealed by the lower margin of the orbicularis palpebrarum and by the levator labii superioris muscle, beneath which it is placed, and it is above the upper extremity of the origin of the levator anguli oris: immediately after its escape it separates into a number of branches, which go off in different directions to their several destinations, but principally downward.

The branches which the second division gives off are the *temporo-molor*, the *spheno-palatine*, the *posterior superior dental*, the *anterior superior dentol*, and the *facial* branches. While within the cranium the nerve gives off no branch.

1. The first branch given off by the second division, the temporo-malar, has been called *cutaneous malar* by the elder Meckel; it has been also called orbitar, but without good reason; the name *temporo-malar* fully expresses its distribution. This branch is given off by the nerve, either while yet within the canal, through which it escapes from the cranium, or after it has entered the spheno-maxillary fossa; it is one of its smallest branches; it passes forward through the fossa, toward the spheno-maxillary cleft, enters the orbit through the cleft, and then pursues its course forward and outward, along the floor of that region, beneath the inferior rectus muscle, and about the middle of it divides into two branches; an external, the temporal, and an anterior, the malar.

Before entering the orbit it sometimes gives off a small branch, which enters that cavity through the periosteum of the posterior part of the orbitar process of the sphenoid bone, and joins the lachrymal branch of the first division, presenting one of the instances of a second root to that branch, as described by the elder Meckel.

The *external temporal branch* passes toward the outer wall of the orbit, ascends between it and the external rectus muscle; then becomes attached to the wall, and continues its course either through the periosteum, or in a groove, or at times through a canal in the orbitar process of the malar, or occasionally of the sphenoid bone; here it is joined by the posterior temporal branch of the lachrymal nerve, the third branch of the first division: the conjoined branch is then transmitted into the temporal fossa, through an aperture on the temporal surface of the orbitar process of the malar bone; there it is joined by a small branch of the anterior deep temporal branch ot the inferior maxillary or third division of the fifth, and plunging among the fibres of the temporal muscle, it is distributed to them in common with the filaments of the deep temporal; a filament or filaments of it gain the superficial surface of the muscle, perforate its aponeurosis, become subcutaneous, and are distributed superficially upon the temple, communicating with filaments of the portio dura, and of the superficial temporal branch of the third division. The temporal branch of the temporo-malar is sometimes double, or divides into two, one communicating with the branch of the lachrymal, the other transmitted to the temple.

The *malar branch* pursues the course of the original nerve, until it has reached nearly to the anterior margin of the orbit, at its inferior external angle; then it enters, either single or divided into two, the corresponding canal or canals, by which the malar bone is perforated, and through them is transmitted outward and forward to the malar region of the face. Its ramifications are distributed to the inferior external part of the orbicularis palpebrarum, and to the integuments of the malar region; they communicate with those of the portio dura, of the superficial temporal and lachrymal nerves, and of the palpebral branches of the second division. Before reaching the malar canals, the malar branch frequently gives off one or more filaments, which ascend to the lachrymal gland, unite with those of the lachrymal nerve, and follow a similar distribution.

2. The branches, which are given off next by the second division of the fifth, are those by which the nerve is connected to the spheno-palatine ganglion; they are hence denominated *the spheno-palatine;* the ramifications derived from them, or from the ganglion with which they are connected, are distributed to the nostril and the palate, and they may hence with more propriety be termed the naso-palatine, an appellation which is the more appropriate, since it is already applied to the corresponding branch of the second division of the fifth in other animals. It is at the same time to be borne in mind that a difficulty has been created in this matter by the application of the epithet in question to certain secondary branches, to be mentioned by and-by; but the latter use of the term ought to be discarded. They are irregular in number, there being sometimes but one, at

others two or three: they are short and of considerable size, and arise from the inferior side of the nerve, immediately after it has entered the spheno-maxillary fossa; they descend from it, almost perpendicularly, into the fossa, posterior to the internal maxillary artery, and immersed in fat, and after a very short course they are connected to the ganglion, from which they may seem to ascend to the nerve. They are thus described by Cloquet, but this view is not sanctioned either by comparative anatomy, or by the result of experiments, both which prove that they are to be considered branches of the nerve, with which the ganglion is connected.

The ganglion has been first described by the elder Meckel,* and hence has also received the title of *Meckel's ganglion;* it is very small, of a grey colour, and firm consistence; its shape is triangular or cordiform, one surface directed outward, the other inward; it is situate immediately external to the spheno-palatine foramen, its internal surface, which is flat, corresponding to the foramen, its external, which is convex, to the zygomatic fossa. It is subject to variety; in some instances it is wanting, and then the spheno-palatine nerve gives off those branches which otherwise arise from the ganglion: in other rare cases, according to Meckel, the two principal branches, which arise from the ganglion when present, or from the spheno-palatine when single, viz. the Vidian and the palatine, proceed separately from the trunk of the second division of the fifth; in others again the author has observed a cineritious soft enlargement upon the Vidian nerve at its junction with the spheno-palatine, but not involving that nerve or the branches proceeding from it; and this, it is worth remarking, is precisely the disposition of the ganglion in the dog and some other animals. Different views have been taken of the nature and relations of this ganglion: the Meckels, by the elder of whom it was discovered, Bichat, Boyer, and others, have regarded it as belonging properly to the fifth nerve, and formed by the branches which have been mentioned: Cloquet, on the other hand, considers and describes it as a part of the ganglionic or sympathetic system, and all the nerves connected with it, as well the original spheno-palatine branches as the others, to be branches from it: Cruveilhier again, while he admits the existence of ganglionic structure, yet leaves it uncertain whether he regards it as a sympathetic or a cerebro-spinal ganglion, but he differs from Cloquet in maintaining that "the nerves," which seem to arise from it, "are not detached from the ganglion itself, and come directly from the superior maxillary." The opinions of Cloquet and Cruveilhier appear to the author to be both, to a certain degree, well-founded. The ganglion would seem not to be properly a part of the fifth nerve, because, 1. it is not, as he believes, present in animals below the mammalia; 2. it is not always present even in them, and in neither case is the general distribution of the part of the fifth nerve, with which it is connected, influenced by its absence; 3. it is manifestly different in its characters from the fifth nerve and from the branches of the nerve to which it is attached, nor does it resemble the cerebro-spinal ganglia, the peculiar appearance of these bodies, viz. white filaments entering and emerging, their continuity being apparently interrupted by an interposed mass of cineritious matter, not being observable; while, on the other hand, it resembles the ganglia of the sympathetic, and is actually connected with that nerve by a branch having precisely the same qualities with those which proceed from it, viz. by the inferior branch of the Vidian nerve: for those reasons the author would adopt the opinion of Cloquet, that the ganglion is properly a part of the ganglionic system, and that it is only accessory to the fifth nerve. On the other hand, it appears to him that Cloquet is mistaken in considering the ganglion as the source of all the nervous filaments connected with it, and more particularly of the spheno-palatine branches of the second division of the fifth, to which in man the ganglion is attached, for, as has been already stated, the general distribution and existence of these branches are not at all influenced by the absence of the ganglion, and when present it allows in general, as Cruveilhier has observed, the nerves to be followed up and down from the swelling, and lastly, any obscurity existing with regard to this point in the human subject will be at once removed by reference to the disposition of the ganglion in other animals, in none of which that the author has examined does it involve the nerve, but is merely connected to it either by filaments or by one extremity, the continuity of the nerve being altogether uninterrupted, and a marked contrast being to be observed between the characters of the two parts: thus in the dog, the ganglion is an oblong dark-grey swelling, with the posterior extremity of which the Vidian nerve is united, while its anterior is attached to the naso-palatine nerve. The author, therefore, concurs in the opinion of Cruveilhier, so far as to regard the nerves connected with the ganglion, for the greater part, as branches of the fifth nerve and not of the ganglion; but he would exclude from this view the Vidian nerve, or at least its carotidean branch, which appears to him to belong to the sympathetic system. (See posterior branch of ganglion.)

The disposition of this ganglion throughout the animal series is an object of interest. The author cannot assert its existence in the mammalia universally, but from indirect considerations it appears to him likely that it does exist, generally at least, in animals of that class. It is asserted in the work* of Desmoulins and Majendie on the Anatomy of the Nervous System in vertebrate Animals, that "there does not exist any trace of it in cats, dogs, the ruminantia, the rodentia, the horse, &c.;" and it is reasonable to infer that they had found it in others. Now their statement with regard to

* Mém. de l'Acad. de Berlin, 1794.

* Tom. ii. p. 396.

its absence is, in the majority of the instances which they have selected, positively incorrect, for the author has ascertained its existence most satisfactorily in the dog, the horse, the cat, the cow, and the rabbit. Nor is any exception to its existence mentioned by Cuvier, and hence he thinks it likely that it does exist generally, if not universally, throughout the class. It is not however similarly disposed in all; in some it is connected with the primitive naso-palatine nerve; in others with its nasal; and in others again with its palatine division: in some it gives off few filaments; in others, the horse, e. g. they are numerous beyond description. The ganglion does not appear to exist in the inferior classes.

From the spheno-palatine ganglion or nerve, according to the view of their source adopted, there is given off a considerable number of branches, which run in different directions and have different destinations: they have been distinguished into four sets, viz. superior, inferior, internal, and posterior. The superior branches are very delicate and, in some instances at least, numerous. Among them are described and represented by Arnold two long slender filaments, which join the optic: another is also mentioned by him to be sometimes found connected with the ophthalmic ganglion. The discovery of this connection between the two ganglia is due to Tiedemann, who found, upon the left side of a man, an anastomosis between them, established by a filament, of tolerable size, which, arising from the inner face of the spheno-palatine, entered the orbit and passing above the inferior branch of the motor-oculi nerve, where it gives off the short root, went in company with the last to gain the inferior and posterior part of the ophthalmic ganglion;* and beside those there may be found, in favourable subjects, others, which seem destined to the posterior ethmoidal cells. The inferior branch is the largest given off by the ganglion; it is distributed principally to the palate, and hence is called "the palatine;" but it supplies the nostril also in part, and hence it has been suggested by J. F. Meckel, that it might be appropriately called the "naso-palatine:" this appellation has, however, been applied by Scarpa to one of the internal branches, and it has been already explained that it belongs more properly to the original branch before its junction with the ganglion. The palatine nerve descends from the ganglion into the spheno-maxillary fossa, posterior to the internal maxillary artery and toward the pterygo-palatine canals, and after a short course divides into three branches; an anterior, larger one, denominated "the great palatine," and two posterior smaller branches, "the lesser palatine nerves."

These branches continue to descend in company until they reach the superior apertures of the canals; they then enter the canals and are transmitted downward through them to the palate and fauces. The great palatine descends through the anterior pterygo-palatine canal, in company with a branch of the palatine artery, at the same time inclining forward: during its descent it gives off, in some instances before, in others after it has entered the canal, either one or two filaments, which descend inward, pass through the nasal process of the palate bone, and enter the nostril at the back part of the middle meatus, between the posterior extremities of the middle and inferior turbinate bones: one of them is distributed to the membrane of the middle bone and of the middle meatus; the other to that of the convex surface of the inferior bone: when a single branch arises from the palatine it divides into two, which follow a similar distribution; these branches are denominated by the elder Meckel inferior nasal nerves in contradistinction to the superior nasal, to be described, given off by the ganglion and by the Vidian nerve. Another filament is described by Cloquet arising from the palatine shortly before it escapes from the canal, entering the nostril through the perpendicular plate of the palate bone, running along the margin of the inferior turbinate bone, and lost upon the ascending process of the superior maxillary bone, often also contained in an osseous canal.

The great palatine nerve, then, for the most part divides into three branches, of which one, the smallest, descends through an accessory canal, in the pterygoid process of the palate-bone, leading from the anterior, and escapes from it inferiorly into the soft palate in which it is consumed.

The other two escape from the pterygo-palatine canal, through the posterior palatine foramen, into the palate: at emerging from the foramen they are situate very far back, in the posterior angle of the hard palate on either side, and behind the last molar tooth of the upper jaw; they are immediately superficial to the periosteum, and above the other structures of the palate; they are lodged, along with the branches of the accompanying artery, in channels upon the inferior surface of the palatine processes of the palate and the superior maxillary bones; they pass forward, one along the alveolar arch, the other toward the middle line of the palate, and subdivide, each, into several branches, which are distributed to the structures of the hard palate, the mucous glands and membrane, and to the gums, and communicate in front with branches of the naso-palatine ganglion.

In some instances the palatine nerve does not divide into those ultimate branches until after it has escaped from the palatine canal; but their disposition in such cases is in other respects the same.

The lesser palatine nerves are posterior to the greater; they are transmitted also through the pterygo-palatine canals, the first through the posterior, the second through the external.

The first, the larger of the two, and called *middle palatine nerve*, escapes from the canal inferiorly in front of the hamular process of the sphenoid bone, and divides into filaments, which are distributed to the soft palate and its muscles.

* Journal Compl. vol. xxiv. Arnold.

The second, the posterior, little palatine nerve, descends at first between the external pterygoid muscle and the posterior wall of the antrum, then enters the canal, and escapes inferiorly external to the former; it divides into two filaments, one of which is distributed to the soft palate, the other to the tonsils and arches of the palate.

Those branches are accompanied by minute branches of the palatine artery.

The internal branches vary in number from three to five; they arise from the inner surface of the ganglion, run directly inward, posterior to the nasal branch of the internal maxillary artery, toward the spheno-palatine foramen, which they immediately reach; pass through the foramen, perforating the structure by which it is closed, and enter the nostril, and thus attach the ganglion closely to the foramen: at their entrance into the nostril they are situate before and beneath the anterior wall of the sphenoidal sinus, at the back part of the superior meatus, and immediately above the posterior extremity of the middle turbinate bone.

They are distinguishable, according to the majority of descriptions, into two sets; one destined to the outer wall of the nostril and denominated by Meckel *anterior superior nasal*, in contradistinction to branches of the Vidian nerve, which he has designated "posterior superior nasal," and another connected with the septum. A third destination has been assigned to them by Arnold, according to whom a branch derived either from one of the nerves of the septum, or originally from the ganglion itself, is distributed to the superior part of the pharynx, corresponding to the pharyngeal branch of Bock.

The anterior superior nasal branches are either one or two in number; when but one, it divides into branches corresponding to the two; it is so expressed in Arnold's fifth plate; one of the two divides into filaments, which are distributed to the posterior ethmoidal cells, to the posterior part of the superior turbinate bone, and to the superior meatus, to the membrane of those parts. The second distributes its filaments to the convex surface of the middle turbinate bone; according to Cloquet they in part perforate the bone, and thus gain its concave surface: they all run between the periosteum and the mucous membrane, and are distributed finally to the latter.

The branches connected with the septum are two, a short and a long one; they both pass across the anterior wall of the sphenoidal sinus from without inward, and thus reach the posterior part of the septum nasi, become attached to it, and changing their direction descend forward along it, between the periosteum and mucous membrane.

The short, lesser, branch is situate very near to the posterior margin of the septum, to which it is parallel in its course, and distributes its filaments to the membrane of the posterior part of it: one of them is represented by Arnold as constituting the phar geal branch.

The long branch descends to the superior aperture of the anterior palatine canal, enters the canal, and in it the nerves of the two sides are united to a small ganglion denominated *the naso-palatine;* from it filaments descend to the anterior part of the palate, in which they are distributed and communicate with filaments of the palatine nerves. Each nerve, during its course along the septum, is situate nearer to its position inferior than to its superior anterior margins: it is said not to give any filaments during its descent, but this is incorrect, as is well represented by Arnold; those, which it gives off, are distributed to the membrane of the septum about its middle; at times also it divides into two filaments, which are afterwards reunited. Each nerve is received inferiorly in a separate canal, which inclining inward is soon united to the other in the palatine, and in it the nerve or the naso-palatine ganglion receives a filament of communication from the anterior superior dental branch of the second division of the fifth, as described by Cloquet.

This branch has been particularly described, first by Scarpa,* and by him denominated *the naso-palatine;* it has been also described by J. Hunter,† between whom and Scarpa appears to lie the merit of having first observed it; it is also known as "the nerve of the septum," but the latter appellation is manifestly incorrect; nor is the former free from objection, inasmuch as the same title has been applied, and with reason, in the inferior Mammalia, to the original branch given off by the second division of the fifth for the supply of the nostril and palate, with which the spheno-palatine ganglion is connected, and which in man has received the name of *spheno-palatine branch.* The branch of the ganglion in question is called by some the nerve of Cotunnius, but incorrectly; having been first described by Scarpa, it cannot with justice be attributed to the former.

The posterior branch of the ganglion is described and represented by the majority of authorities as arising single and in its course dividing into two filaments; but Bock, J. F. Meckel, and Hirzel state that the two filaments at times are throughout distinct and connected separately to the ganglion; and Arnold represents, in like manner, two filaments arising from the ganglion, corresponding to the two into which the single nerve divides. The posterior branch arises from the back of the ganglion, passes directly backward from it, and is received immediately into the pterygoid or Vidian canal, along with the corresponding branch of the internal maxillary artery: it is transmitted through the canal backward and slightly outward, beneath the course of the second division of the fifth itself, and external to, or in many instances beneath the sphenoidal sinus; having traversed the canal,

* Annotationes Academicæ, in which is also contained a good representation of the nerve as a single branch.

† Animal Œconomy.

it escapes from its posterior aperture into the foramen lacerum anterius basis cranii: in this it is contained in the fibrous structure by which the foramen is closed, and is situate at the outer side of and beneath the internal carotid artery, as that vessel ascends, from the aperture of its canal in the petrous bone, into the cavernous sinus. Here also, or even before it has escaped from the Vidian canal, it receives, when single, a filament of communication from the superior cervical ganglion of the sympathetic: this filament had been long regarded as arising from the posterior branch itself, and—though at present generally* considered a branch from the sympathetic—it has been for the most part described, in systematic works, as such under the name of the *inferior*, *deep*, *sympathic*, or *carotidean branch* of the Vidian nerve. In its direction it certainly resembles a branch of that nerve; but in that particular it is equally entitled to be regarded one from the sympathetic to the spheno-palatine ganglion, it being either from before backward and from above downward, or from behind forward and from below upward. Further, in sensible qualities it strictly resembles other branches of the latter nerve; it is, as has been stated, at times separate from the proper Vidian, and connected directly with the spheno-palatine ganglion; and it is, in fact, but one of the branches which ascend into the cranium from the superior cervical ganglion along the internal carotid artery, so that it would be equally correct to describe that filament which is connected with the sixth nerve as a branch of that nerve, as to style the filament in question a branch of the Vidian nerve.

The view of the nature of this filament here advanced is, however, not universally admitted. Cruveilhier objects to it because the cranial branch of the Vidian nerve appears to him to resemble in all respects the carotidean: this, however, cannot be considered a valid objection, it can only prove that one branch may be as much allied to the ganglionic system as the other, but the validity of the assertion may be questioned; however it may be in man, the characters of the two branches in the larger quadrupeds, the horse e. g. are sufficiently distinct, the cranial branch being of a pure white colour, and the carotidean having a ganglionic enlargement upon it at its junction with the cranial.

While traversing the pterygoid canal, soon after it has entered that canal, and in some cases even before, the posterior branch of the ganglion gives off from its inner side two or three filaments, denominated by the elder Meckel *posterior superior nasal*: these enter the posterior superior part of the nostril, in one case by passing through the spheno-palatine foramen, in the other by perforating the inner wall of the pterygoid canal, and are distributed to the posterior part of the lateral wall of the nostril, to the root of the septum, to the sphenoidal sinus and to the lateral wall of the pharynx in the vicinity of the orifice of the Eustachian tube. These branches frequently arise from the ganglion itself by a single filament, denominated by Bock the *pharyngeal* nerve, and represented by Arnold among the internal branches of the ganglion: it divides into filaments distributed to the several parts mentioned.

After the junction of the sympathetic filament, the posterior branch is continued through the fibrous structure already mentioned, external to the internal carotid artery, and thus enters the cranium. It then passes outward, backward, and upward, upon the anterior surface of the petrous bone, beneath the third division of the fifth, very near its attachment to the Gasserian ganglion, and enclosed in the dura mater: it is at the same time lodged in a channel upon the surface of the bone. It is stated by Cloquet that it here sends into the cavity of the tympanum by two canals, the orifices of which are to be seen in the channel one above the other, two filaments of extreme delicacy, which go to anastomose together upon the promontory, and to communicate with a filament of the superior cervical ganglion, and with the glosso-pharyngeal nerve. According to Hirzel,* this connection between the superficial branch of the Vidian and the tympanic branch of the glosso-pharyngeal nerve on the nerve of Jacobson, takes place in the vicinity of the junction of the former with the facial nerve. According to Arnold,† the superficial branch of the Vidian nerve is, as proved by the researches of others and his own, not simple, but composed of two or of several filaments, and is accompanied by one or more very delicate filaments from the carotid plexus. In one instance he found the petrous nerve composed of four filaments on the right, and three on the left. The existence of several distinct filaments in the Vidian nerve may be easily observed in the larger animals. It pursues the course mentioned, until it has reached the hiatus Fallopii, through which it is transmitted to the aqueduct of Fallopius, where it meets and becomes intimately connected with the facial portio dura nerve. At their junction the facial nerve presents a gangliform swelling, from which two very delicate filaments proceed to the auditory nerve.‡

From the time that the posterior branch of the ganglion enters the cranium until it has joined the facial nerve, it is called the *cranial* or *superficial petrous* branch of the Vidian nerve; by Arnold *petrosus superficialis major* in contradistinction to another nervous filament, which connects his 'otic' ganglion to the tympanic branch of the glosso-pharyngeal nerve; but the application of either of these epithets would be rendered unnecessary by ceasing to consider the filament by which the posterior branch of the ganglion is connected to the sympathetic, a branch of the former.

The posterior branch is also known by other

* Bock, Cloquet, Hirzel, J. F. Meckel.

* Journ. Compl. t. xxii.

† Journ. Compl. t. xxiv.

‡ Arnold. See lingual brauch of third division and chorda tympani.

names, viz. the *recurrent*, the *pterygoid*, the *Vidian*, the *anastomotic*, or *sympathic*.

3. The next branch or branches of the superior maxillary nerve are the *posterior superior dental*. These arise from the nerve in front of the internal maxillary artery, between it and the back of the antrum, and are separated from the artery by the spheno-palatine; they are very irregular as to their number and precise place of origin; at times there is but one branch, at others there are two or three: they are distributed to the buccinator muscle and the mucous membrane of the posterior lateral part of the mouth, to the roots of the posterior teeth, the membrane of the maxillary antrum, and the gum of the upper jaw. When but one branch is present, its subdivisions supply the place of the others. It descends into the fossa, behind the superior maxillary bone, and before the internal maxillary artery, and after a certain way divides into two branches or sets of branches, posterior and anterior.

The posterior consists of several long slender filaments, which continue to descend immersed in the fat of the zygomatic fossa, until they reach the surface of the buccinator muscle; they then in part are distributed to it, but in greater number pass between the fibres of the muscle and are lost in the mucous membrane of the mouth.

The anterior branch descends for some time, until it reaches the back of the maxilla; it then enters a canal in the bone, within which it is transmitted forward through the wall of the antrum; after a short way it escapes from the canal and continues its course forward within the wall, between it and the lining membrane, describing a curve convex downward; having reached the front of the antrum it ascends and terminates by joining either the anterior superior dental or a branch of that nerve.

During its course around the antrum the anterior branch of the nerve gives off downward numerous delicate filaments, which descend toward the teeth, traverse the structure of the alveolar arch, and in part are distributed to the roots of the posterior superior teeth in a manner analogous to that of the inferior dental nerves: in part they escape inferiorly from the alveolar arch between the sockets of the teeth, and are consumed in the gums. The nerve is also stated to give filaments to the membrane of the maxillary antrum.

4. Shortly before its escape from the infraorbital canal, but at a distance somewhat variable from it, the second division of the fifth gives off its next regular branch, *the anterior superior dental*: this descends, from the infraorbital canal, through one of its own name in the anterior wall of the antrum toward the canine tooth; it next runs inward above the root of that tooth, and then again descends through the perpendicular process of the maxillary bone, until it reaches the floor of the nostril, and is continued inward through the horizontal process of the bone above the roots of the incisor teeth.

While descending through the wall of the antrum the anterior superior dental nerve either is joined by the termination of the anterior branch of the posterior dental, or it divides into two, one of which inclines outward and joins that branch, the other pursues the course of the nerve. It supplies the anterior teeth of the upper jaw in the same manner as the posterior nerve does the posterior teeth; it also gives at its termination filaments to the membrane of the nostril, and one to the naso-palatine ganglion or nerve.

Besides the regular dental nerves, others at times arise from the second division of the fifth within the infraorbital canal, and take the place of branches of the regular nerves.

5. *The facial branches* of the second division of the fifth are from five to seven in number; they differ from each other in size, and branch off in different directions; they are distinguished, according to the direction in which they run and their destination, into three sets; a superior or palpebral, an inferior or labial, and an internal or nasal.

For the most part there is but one superior or palpebral branch, though sometimes there are two. This branch is destined to supply the lower eyelid, and is denominated the *inferior palpebral nerve*; it presents some variety in its mode of origin and its course; most frequently it does not separate from the trunk till after the latter has escaped from the infraorbital foramen; but in some instances it does so within the infraorbital canal, is transmitted through a distinct canal, and escapes into the face through a separate foramen, situate internal to the infraorbital; it ascends inward toward the lower lid, in front of the inferior margin of the orbit; in its ascent it is situate beneath the orbicularis palpebrarum, to which it gives filaments, which after supplying the muscle become cutaneous, and it is frequently contained in a superficial groove on the superior maxilla; having reached the lid it divides into two branches, an external and an internal. The external runs outward, through the lid, toward the external angle, supplies its structures on that side, and anastomoses with filaments of the portio dura, and of the inferior palpebral branches of the lachrymal nerve. The internal ascends in the course of the original nerve toward the internal canthus of the eye, gives a filament to the side of the nose, which communicates with the naso-lobar branch of the nasal nerve, supplies the lower lid at its internal part, is also distributed to the caruncula and lachrymal sac, and anastomoses with a filament of the inferior branch of the infratrochlear nerve described in the account of that nerve. It sometimes anastomoses also with the portio dura.

When there is a second palpebral branch, it takes the place of the external branch of the former, which in such case is denominated the *internal inferior palpebral*, and the second the *external*. It perforates the levator labii superioris muscle; ascends toward the external angle of the eye, beneath the orbicularis palpebrarum; and, like the external branch of the inferior palpebral, already described, supplies the structure of the lid, and anastomoses with the portio dura, lachrymal, and malar nerves, as also with the internal palpebral.

The descending or *labial* branches are the largest and the most numerous; for the most part they are three, at times four. They descend to the upper lip, one toward its middle, the second toward its intermediate, and the third toward its outer part, the commissure of the lips, and are denominated internal, middle, and external; they are situate, all at first, beneath the levator labii superioris, between it and the levator anguli oris or canine muscle; as they descend, they give filaments to these muscles and to the parts superficial to them; and they pass to their several destinations, the internal between the levator labii and the depressor alæ nasi; the middle between the same muscles; and the external superficial to the levator anguli, and uncovered by the levator labii; as they approach the lip they divide each into branches, which are distributed to the structures of the part at their several situations; to the orbicularis oris, and the insertions of the other muscles of the lip, to the integument of the lip, internal and external, and also to the labial glands; they all communicate together, and with branches of the portio dura; the external more particularly with the latter, as also with the neighbouring branches of the fifth; the internal with the inferior nasal; the external with the inferior labial and buccal nerves. In the infraorbital region, the branches of the superior maxillary are crossed by and interlaced with those of the portio dura; the latter running from without inward, and for the most part superficial to the former; but also beneath and among them, and even forming loops about them; while the former run from above downward, and are principally deeply seated. In consequence of this diversity in their directions and the numerous anastomoses which they hold with each other, the branches of the two nerves form a very intricate mesh in that region.

In some Carnivora filaments of the facial branches of the fifth nerve have been traced into the bulbs of the hairs of the whiskers and the tufts with which they are furnished; this is remarkably so in the seal, as described by Andral: they are strongly expressed by Rapp.*

The internal or nasal branches are, for the most part, two; they are termed superficial nasal by the elder Meckel, and distinguished into superior and inferior; they pass, both, inward toward the nose, beneath the levator labii superioris, the inferior at the same time descending, and having reached the side of the nostril they subdivide.

The superior is the smaller of the two, and arises frequently from a branch common to it and the internal inferior palpebral; it divides into three, of which the first, the uppermost, is distributed to the origin of the levator labii alæque nasi, to the compressor naris, and to the integuments on the dorsum of the nose; the second, the middle, to the compressor naris and also to the integuments of the nostril, and the third, the inferior, to the compressor naris, to the depressor alæ nasi, and to the integuments of the ala.

The inferior superficial nasal, the larger of the two, first gives occasionally a branch, which ascends to the eyelid; then communicates with the superior, and having reached the ala of the nose, it gives off numerous ramifications which are distributed to the levator and depressor alæ, to the integuments of the inferior part of the ala, of the tip, and of the septum, and also to the upper lip; it communicates with the ramifications of the naso-lobar branch of the nasal nerve, of the internal labial, and of the portio dura.

The third division of the fifth.—This trunk has been denominated by Winslow, on account of its general distribution, the inferior maxillary nerve, and it is generally known by that appellation; yet it appears to the writer that it would have been much better had that title been applied only to that portion of the nerve which enters the lower jaw. Such is the opinion of the elder Meckel, who observes that this use of the epithet leads to the inconvenience that the branch alluded to and the trunk of the nerve may be easily confounded. It is much the largest of the three divisions, and differs remarkably from the other two in its composition; they are both single, and derived altogether from the Gasserian ganglion; it on the contrary is composed and made up of two portions, one derived from the ganglion, the other not connected with it; the former is the largest of the three trunks connected with the ganglion; it is attached to its posterior external extremity; at its attachment it is cineritious and very wide, but as it proceeds it loses that tint, and acquires a compressed cylindrical form. It is situate external, posterior, and inferior to the others, and its course within the cranium is very short or none, for from the ganglion it enters at once the inferior maxillary or foramen ovale of the sphenoid bone, and escapes from the cavity, passing downward, forward, and outward, nearly at right angles with the second division of the fifth. Before leaving the cranium it is joined, as the first and second divisions are, by a filament from the sympathetic, according to Munniks, Laumonier, and Bock.*

The second portion, of which the third division is composed, is the lesser packet of the fifth itself; this, it has been already stated, does not join the ganglion, but passing outward, beneath that body, is united to the former portion posteriorly, in the foramen ovale; it forms, however, but a small proportion of the nerve, that part which is attached to the ganglion exceeding it very much in size. At its junction, it is placed posterior to the other, but it immediately spreads out, and increases very much in width, and at the same time is lapped round the inner side of the ganglionic portion so as to get before it, and to form the

* Die Verrichtungen des fünften Hirnnervenpaars.

* Op. cit. and Journ. Compl.

anterior part of the nerve by the time it has escaped from the cranium.

The third division of the fifth nerve, after its escape from the cranium, is situate in the superior, posterior, and internal part of the zygomatic fossa; it is placed immediately behind the external pterygoid muscle, before and somewhat internal to the styloid process of the sphenoid bone, internal to and on a line with the anterior margin of the temporo-maxillary articulation, and external to the Eustachian tube. So soon as the inferior maxillary nerve has entered the fossa, it gives off, immediately beneath the superior wall of that fossa, a set of branches remarkable for their source and destination; they proceed from the front of the nerve; their regular number is five, but they present variety in this respect, being in some instances not so many at their origin, in others amounting to six; they vary also in the mode in which they arise; for the most part they are given off separately and branch off, as rays, from the nerve, but at times the nerve divides into two branches, a smaller anterior one, and a larger posterior; in such case the anterior divides immediately into the branches, which otherwise arise from the nerve itself. These branches are *the masseteric*, *the deep temporals*, *the buccal*, and *the pterygoid nerves*, and they are ranged in succession from behind forward, and from without inward; the first is external and posterior; to it succeed the temporals, then the buccal, and lastly the pterygoid.

1. *The masseteric branch* proceeds from the anterior and outer part of the nerve; it passes outward, nearly transversely, beneath the superior wall of the temporal fossa, and in front of the articular surface of the temporal bone; it crosses obliquely over the external pterygoid muscle, at its outer extremity, between the muscle and the wall of the fossa, and then inclines downward through the sigmoid notch of the lower jaw, in front of its neck, and of the insertion of the external pterygoid muscle, and posterior to the coronoid process and the tendon of the temporal muscle. Having traversed the notch it descends forward, external to the ramus of the jaw, and passing between the two portions of the masseter, divides into numerous ramifications, which are distributed altogether to that muscle: while between the portions of the masseter, it inclines from its posterior toward its anterior margin, and its terminating filament can be traced to the latter at the inferior part of the muscle. This branch gives off, during its course, some minor branches; while in front of the articulation of the jaw it gives one or more filaments to the articulation; in the next place it gives a small branch to the posterior part of the temporal muscle, and lastly it frequently gives off the external or posterior deep temporal nerve.

2. *The deep temporal branches* are two; they are distinguished into posterior and anterior or external and internal. The anterior is the larger. They present varieties in their number and mode of origin; at times there is but one, at others there are three; in some instances they arise by a common origin; in others, and for the most part, separately, and in others again the posterior or lesser branch is given off either by the masseteric or the buccal nerve. They both pass outward, in front of the temporo-maxillary articulation, between the external pterygoid muscle and the superior wall of the zygomatic fossa; they then change their direction and ascend in the temporal fossa, between the muscle and the surface of the fossa, and divide into branches, which attach themselves to the temporal muscle, on its deep surface, and are distributed, those of the posterior to its posterior, and those of the anterior to its middle and anterior parts. The two branches frequently anastomose with each other as they leave the zygomatic fossa. The anterior also frequently communicates with or receives a branch from the buccal nerve, and by one of its anterior filaments it anastomoses with the nerve resulting from the junction of the temporal branches of the lachrymal nerve and the temporo-malar branch of the second division of the fifth. This communication between the three divisions of the fifth is however, according to the elder Meckel, subject to variety; he states that he has seen the communicating branch of the anterior deep temporal at times enter the orbit either through the malar bone, or through the spheno-maxillary fissure, and there unite with the conjoined branch of the other two.

3. *The buccal nerve* is the largest and the principal of these branches; it arises from the front of the inferior maxillary nerve, next in order after the anterior deep temporal, for the most part a distinct and single branch; but it is not unusual to find the buccal nerve give off one or both of the deep temporals, or in rare cases all the three former branches: in some instances also it arises double, the two filaments, of which it is then composed, being separated by a portion of the external pterygoid muscle. It runs downward and forward, passing at first either and for the most part through the external or between the two pterygoid muscles, beneath the external and external to the internal; having traversed the pterygoid it descends in front of its inferior part, internal to the coronoid process of the lower jaw, and the inferior part of the temporal muscle, next between the tendon of the temporal and the buccinator, then between the anterior margin of the masseter and the latter muscle, and finally emerging from between them it inclines toward the angle of the mouth, superficial to the buccinator and beneath the dense expansion by which that muscle is covered. During its descent it is immersed in the fat which occupies the lower part of the zygomatic fossa. The ramifications which it gives off are numerous; first while traversing and immediately after escaping from the pterygoid it gives branches to the muscle; at the same time it gives off a fasciculus of branches which pass outward, in front of the external pterygoid to the internal surface of the temporal muscle, at its inferior part; some of these descend with the muscle

toward its insertion, and are distributed to it at that point, others ascend in the temporal fossa, between the muscle and the bone, penetrate the muscle, and are distributed, along with the branches of the anterior deep temporal, with which they anastomose freely, to the muscle at its inferior anterior part. In the next place, while between the masseter and the buccinator, the nerve gives off backward several branches, three or four, which are distributed to the buccinator at its origin, to the buccal glands, and to the membrane of the mouth; as it lies upon the last-named muscle, between the ramus of the jaw and the angle of the mouth, it gives filaments to it at its middle and anterior part, which, like the former, both supply the muscle, pass through its fibres, and are distributed also to the buccal glands and membrane. Finally, as the nerve approaches the angle of the mouth, it divides into two, occasionally three, branches; these two branches pursue the direction of the nerve toward the angle, passing beneath the facial vein and inclining, one upward, the other downward; after a short course they are united both to branches of the portio dura, the inferior to a branch of the inferior or cervico-facial division, the superior to one of the superior or temporo-facial division of that nerve. By their union they form conjoined branches or loops, from each of which are given off several filaments to the muscles of the mouth at their insertion into the angle; from the superior, more particularly, to the buccinator, the zygomatic, and levator anguli; and from the inferior to the buccinator and depressor anguli oris.

4. The fifth and last of these branches is the *pterygoid;* it is the smallest of them, and arises from the anterior internal part of the trunk; it passes inward and downward, behind the external pterygoid, and then between the internal pterygoid and circumflexus palati muscles; it gives a filament of some size to the latter muscle, and then entering into the internal pterygoid at its upper extremity, it is consumed altogether in that muscle.

The external pterygoid also, at times, but not uniformly, receives a distinct filament from the trunk; when present it arises from the front of the nerve, beneath the buccal branch, and passes forward directly to the muscle, in which it is consumed. The constitution of these branches is peculiar, and is a matter of much interest: involving physiological questions, this subject is deferred to another occasion.

In consequence of its connection with the third division of the fifth, and more particularly with the lesser packet of the nerve, this seems a fit place to advert to the ganglion discovered by Arnold, and by him denominated *Otic or auricular*, of which the following sketch has been taken from his own account. It is situate at the inner side of the third branch of the fifth, some lines beneath the foramen ovale, at the part where the deep temporal, the masseteric, and the buccal nerves are detached from the same side, and a little above the origin of the superficial temporal nerve: its posterior part touches the middle meningeal artery, and the internal the internal pterygoid muscle: an abundant adipose tissue surrounds it: its form is not altogether regular, however it approaches to an oval, flattened internally and externally. It is united to the trunk of the third division not merely by cellular tissue, but by many filaments, which enter into the formation of the ganglion; these filaments, which come solely from the lesser portion of the nerve, are mostly extremely short, and can only be observed when we try to separate the ganglion from the trunk; but in cases where the ganglion is situate rather distant from the nerve, the filaments are of course longer and can be more easily observed. With regard to the branches of the third division, the pterygoid nerve especially is in very intimate connection with the otic ganglion, so that in a superficial examination it appears as if it arose from it; but, in a more accurate investigation, it is clear that this nerve soon after its origin penetrates through a part of the substance of the ganglion and takes up some of it: the slender branch, which ramifies in the tensor palati, is likewise in very intimate relation with this ganglion, and distinguishes itself from the other branches by its reddish appearance. The ganglion thus communicates with the lesser packet of the fifth: it also communicates with the glosso-pharyngeal and with the facial and auditory nerves by means of the nervus tympanicus. But, the ganglion being a body which is to be regarded as distinct from the fifth nerve, and not part of it, a further pursuit of its connections and properties would be here out of place. See Sympathetic Nerve.

The third division of the fifth descends from the foramen ovale, outward into the zygomatic fossa, posterior to the external pterygoid muscle, before the superior part of the levator palati, and internal and parallel to the middle meningeal artery. After a course of half an inch from the foramen, it divides for the most part into two large branches, an anterior internal one destined to the tongue, denominated the *lingual branch*, and an external posterior one, which is transmitted through the inferior maxillary canal, and, escaping from this, through the mental foramen, is distributed finally to the muscles and integuments of the chin; this second branch is called *inferior dental*, or *inferior maxillary* nerve; the latter, as has been already intimated, appears much the more appropriate appellation.

The first branch bears, very generally, the name of *gustatory* nerve from its presumed connection with the sense of taste; but, since the opinion that it is the nerve in which the sense of taste resides has been brought into question, and since, as will appear by-and-bye, it is at least certainly not the sole nerve of that sense, it is obvious that that name should be discontinued.

The manner in which the third division finally divides is not always such as has been described: in some instances it separates fairly into three branches, viz. the lingual, the inferior maxillary, and the superficial temporal, and such is the mode of division mentioned by the elder Meckel. The writer has before him an instance of another mode; the inferior maxillary arises by two roots, and the original trunk divides into two parts; one common to the lingual, and one root of the maxillary; the other to the superficial temporal and the other root: the superficial temporal is thus, in this instance, equally an original branch as the others, and is connected to the maxillary by a filament, which it gives off soon after its origin, while the maxillary is also connected in the usual mode to the lingual: the maxillary artery, however, passes through the loop formed by the two roots of the former nerve.

The length of the third division from the ganglion to its bifurcation is about three fourths of an inch, one fourth contained within the bone during its escape from the cranium, and the other two between the aperture externally and the division. When it divides into two, the branches are, at times, of the same size, but for the most part the inferior maxillary is the larger; they descend at first in close apposition with each other, but as they proceed they gradually separate, the lingual branch inclining inward and forward, the inferior maxillary outward, in the course of the original nerve, in order to gain the aperture of the dental canal; they thus leave between them an angular interval, acute above, through which the internal maxillary artery for the most part passes. In their descent they cross, at right angles, the artery internal to the origin of the middle meningeal branch: in doing so either they pass both behind the vessel, or the lingual branch passes before, and the inferior maxillary behind it. The two nerves are most frequently connected, soon after their origin, by a short and delicate branch, which passes from the inferior maxillary to the lingual, and forms, with the nerves, a triangle, through which the artery passes in those instances in which the lingual descends before it.

The nerves are situate internal to the neck and ramus of the jaw, between the pterygoid muscles, posterior and inferior to the external, external and anterior to the internal; and they are contained in a triangular space included between the two muscles and the jaw, bounded superiorly by the external, beneath and internally by the internal pterygoid, and externally by the jaw; through this space they pass from above downward, the lingual from behind forward, and from without inward, the maxillary from within outward, toward the aperture of the dental canal, and holding the mutual relation already indicated,—the lingual anterior and internal, the maxillary posterior and external.

Before pursuing these branches of the third division further, it will be well to describe *the superficial temporal nerve*. This branch has been viewed differently by different authorities; by some it is accounted one of the former set, the superior anterior branches of the third division; by Meckel it is described as one of three, into which the continuation of the nerve divides. It arises for the most part by two, and in some instances by three, roots; a larger one from the inferior dental nerve, and a smaller from the trunk of the third division itself, given off at the same time with its superior branches, and derived from the same source; the two roots forming together a loop, through which the middle meningeal artery ascends: in consequence of this mode of origin it appears better to describe it thus separately, and not to refer it to either of the sets described. It has, however, been already explained that in some cases it appears to be an original branch of the third division, one of three into which it finally divides.

The nerve runs outward, backward, and somewhat upward, behind the external pterygoid muscle, toward the back of the neck of the lower jaw; it then passes behind it and the condyle, between them and the auditory canal, traversing the posterior part of the glenoidal cavity of the temporal bone, and imbedded in the process of the parotid gland, which occupies it.

The superficial temporal nerve, while within the ramus of the jaw, pursues a course nearly the reverse of that of the trunk of the internal maxillary artery in the first part of its course. At first it is situate before the tensor palati muscle, between it and the external pterygoid; then it passes between the internal lateral ligament of the maxillary articulation and the neck of the jaw, situate at the same time above and in contact with the artery; and lastly, it is situate behind the condyle of the jaw, between it and the meatus auditorius, and involved in the parotid.

The nerve gives off numerous branches; when it has reached the situation last described, it breaks up at once into a leash of branches, which pass off in different directions: of these two, at times only one, are destined for the interior of the meatus auditorius; they ascend toward the canal, become attached to its exterior, and pass through the fibrous structure of the tube, close to its connection with the osseous portion: having thus gained its interior, they are distributed to its lining membrane, its sebaceous follicles, and the membrane of the tympanum. Before entering the tube they give some delicate filaments to its exterior; these branches may be called the *internal auricular*.

Others, the smallest which the nerve gives off, descend along the external carotid artery, are in part distributed to the parotid gland, and establish upon the artery a manifest communication with branches of the sympathetic. Its next branches, two in number, pass outward through the substance of the parotid, behind the neck of the jaw; one external or superficial, the other internal to the temporal artery; and turning forward round the posterior margin of the jaw, either they both, having given some fine ramifications to the gland, join the temporo-facial branch of the portio dura, immediately before its division, or one of them joins the facial branch of the temporo-facial, while the other continues forward, upon the face, below the zygoma, and deeper than the branches of the temporo-facial: it divides into numerous long filaments, of which some join both branches of the temporo-facial; others are distributed superficially upon the side of the face beneath the zygoma and upon the malar region, and, ascending over the former part, to the inferior anterior part of the temple, as far forward as the margin of the orbit. These may be called the *communicating* branches, in consequence of the remarkable and important communication which they establish with the portio dura.

The next may be called *external auricular;* they ascend to the anterior part of the cartilaginous tube of the ear, concealed by the temporal artery, attach themselves to the tube in front, and are distributed to the integuments of the concha.

Lastly, the superficial temporal nerve emerges from the parotid gland, beneath the root of the zygoma, between the condyle of the jaw and the cartilaginous tube of the ear, in company with the temporal artery, and concealed by it: it then changes its course and ascends with the artery behind the zygoma and in front of the ear, upon the temple: there it emerges from beneath the artery, posterior to it, and divides into branches, which become subcutaneous, run superficial to the fascia and the artery beneath the subcutaneous cellular structure, and are ultimately distributed to the integument of the temple: their number is two or three; they may be distinguished into anterior, middle, and posterior, and they are destined to the corresponding parts of the temple: they correspond in their course, but by no means regularly or strictly so, to the branches of the temporal artery, from which they are separated by the fascia.

Of the two terminal branches of the third division, the larger one, the *inferior maxillary or dental,* descends outward to the upper orifice of the inferior maxillary canal. In its course it passes always behind the internal maxillary artery, and soon glides between the internal lateral ligament of the temporo-maxillary articulation, and the ramus of the jaw, descending in front of the anterior margin of the ligament, which thus becomes interposed between it and the lingual branch, and also between it and the internal pterygoid muscle, from the pressure of which the ligament is considered to protect it. In that situation it is joined by the inferior dental artery, a branch of the internal maxillary given off between the ligament and the jaw, which accompanies it through its further course. It next enters the canal, and is transmitted through it downward, forward, and inward toward the chin, beneath the sockets of the teeth; having reached the termination of the canal, it is reflected upward and outward through the mental foramen, and escapes from the canal upon the lateral and superficial surface of the jaw, at either side of the chin; at its exit it is beneath the second bicuspid tooth of the lower jaw, and covered by the muscles of the lip: it then terminates by dividing into two branches, called *inferior labial nerves,* external and internal. The branches of the inferior maxillary are as follow:—presently after its origin it gives off the branch by which the lingual branch and the inferior maxillary are connected, and which completes the loop through which the internal maxillary artery passes; also the branch which forms a root of the superficial temporal nerve. Next, immediately before entering the dental canal, it gives off a long slender branch, denominated *mylo-hyoid nerve;* this branch descends forward and inward along the inside of the ramus of the jaw, between it and the internal pterygoid muscle, and lodged in a groove upon the surface of the bone, which leads in the same direction, and is occasionally in part a bony canal; it is covered in the groove by a prolongation of the internal lateral ligament, and escapes from it inferiorly in front of the insertion of the internal pterygoid muscle and beneath the lingual branch; it then passes beneath or external to the mylohyoid muscle, between the submaxillary gland and the internal surface of the jaw, gains the surface of the muscle itself and runs forward and inward above the superficial portion of the gland, between it and the muscle, and accompanied by the submental artery; finally, it divides into a leash of branches. Of these one is sometimes destined to the submaxillary gland; two or three are distributed to the mylohyoid muscle; another to the anterior belly of the digastric, and the last passes first between the anterior belly of the digastric and the mylohyoid, gives filaments to the muscles in its passage, then ascends upon the chin internal to the belly of the digastric, and is consumed in the depressor labii muscle.

The next branches of the nerve are those which are given off by it while within the inferior maxillary canal: they have two destinations, viz. the roots and periosteum of the teeth and the gum of the lower jaw. During its course through the canal the nerve gives off several long, slender branches, which run for some distance within the canal, ascend thence through the bone beneath and on either side of the roots of the teeth, ramify as they proceed, and distribute their ramifications to the destinations which have been mentioned. The author has never found these branches as they are for the most part represented, viz. short single filaments ascending almost directly into the several fangs of the teeth: they are decidedly less remarkable and less numerous in the old subject after the fall of the teeth than in the young. Again, at the mental foramen, and immediately before its escape from the canal, the nerve gives off a more considerable branch, denominated by Cruveilhier *dentaire incisif,* which is continued through the jaw toward the symphysis beneath the canine and incisor teeth, and distributed to them. The former set supplies the posterior molar teeth. According to the general opinion the nerves of the teeth enter the fangs through the apertures in their extremities, and are transmitted through them into the bodies of the teeth, to be consumed in the pulp and the structure of the teeth themselves. J. Hunter, however, has stated in his work on the teeth, that he has never succeeded in tracing nerves into the fangs, and the experience of the writer, so far as it extends, tends to confirm the doubt thus expressed; he has frequently traced the filaments to the structure at the root of the fang, but never into the fang, and in the jaw of the fœtal calf they may be found distributed in number upon the membrane of the pulp, but he has not been able to follow them into the pulp itself.

The filaments sent into the gums from the dental nerves, superior as well as inferior, traverse the alveolar arch, escape from the bone upon its gingival aspect, and at once enter the gum: they are well represented by Arnold.

The final branches of the inferior maxillary nerve are the *inferior labial*, internal and external. Of these the internal is the larger; it ascends toward the mouth, inclining inward, and breaks up into a great number of ramifications, which are distributed to the depressor labii inferioris, the depressor anguli oris, the orbicularis, and the levator menti, also to the integument and internal membrane of the lip, and to the labial glands; they anastomose with branches of the inferior division of the portio dura. The external inclines toward the angle of the mouth; it also gives off a great number of ramifications, distributed to the depressor anguli, the orbicularis, and the insertion of the muscles at the angle, the integument, and internal membrane of the lip, and the labial glands; it also anastomoses with branches of the portio dura.

The lingual branch of the third division.— The situation and relative size and position of the lingual and inferior maxillary branches in the first part of their course, have been already described. Having crossed the internal maxillary artery, the lingual branch pursues its course downward, forward, and inward, passing first between the pterygoid muscles in the manner described, and then between the internal pterygoid and the ramus of the jaw, until it has reached the anterior margin of that muscle; during this part of its course it is at first separated from the inferior maxillary nerve by the internal lateral ligament, which is placed between them, the lingual branch internal, the maxillary external to it, and afterward it is situate anterior and superior to the mylohyoid branch of the maxillary. Having reached the margin of the pterygoid it emerges from between the muscle and the jaw, immediately behind the posterior extremity of the mylohyoid ridge, and enters into the digastric or submaxillary space, in which it is among the parts most deeply situate; within this space it continues to run forward and inward, until, at the anterior extremity, it attaches itself to the under surface of the tongue, and is prolonged by one of its branches to the extremity of that organ. During its course through the digastric space, it is at first left uncovered by the muscles inferiorly, and in the interval between the margin of the pterygoid and that of the mylohyoid, where it is situate between the mucous membrane of the mouth and the posterior extremity of the submaxillary gland; it then passes internal to the mylohyoid muscle, between it and the stylo-glossus, hyo-glossus, and genio-glossus, and is at the same time contained in a triangular or wedge-shaped space, the base of which is above and the apex below; this space is bounded above by the mucous membrane of the mouth, externally by the mylohyoid muscle, and internally by the hyo-glossus, stylo-glossus, and genio-glossus muscles. In it are contained the sublingual gland, the deep process of the submaxillary and the duct of that gland with the lingual branch of the fifth and the ninth nerves; in the anterior part and superiorly, immediately beneath the mucous membrane, is situate the sublingual gland; at the posterior and rather inferiorly the deep process of the submaxillary; while the nerves and the duct are placed at the posterior or external part of the lingual branch of the fifth above, immediately beneath the mucous membrane; the ninth below, along, and above the cornu of the os hyoides, and the duct between the nerves; but as the three parts pass forward, the duct and lingual branch cross each other, the nerve descending, the duct ascending between the nerve and the hyo-glossus, and in consequence of this circumstance, at the anterior part of the space, the duct is superior, the lingual branch is intermediate, and the ninth nerve is below. At first the lingual branch is above the deep process of the submaxillary gland, then it is situate internal and superior to it, external and inferior to the duct; as it proceeds, it is beneath the sublingual gland, and, lastly, it ascends internal to that gland, between it and the genio-glossus, in order to reach the tongue.

At the posterior part of the space, the nerve is immediately beneath the mucous membrane; as it proceeds it descends from, but toward the anterior part again ascends, and is in contact with the membrane as it becomes attached to the tongue.

Having reached the anterior margin of the hyo-glossus the nerve breaks up into three branches, posterior, middle, and anterior. Of these the posterior is the shortest, and ascends almost directly; the middle runs upward and forward, and the anterior, which is much longer than, and at the same time inferior to the others, almost directly forward, along the under surface of the tongue, between the genio-glossus and the stylo-glossus; the former muscle internal, the latter external to it. In its course beneath the tongue it is accompanied by the ranine artery, which joins it at the anterior margin of the hyo-glossus, and is situate inferior to it, immediately above the mucous membrane.

The lingual nerve does not give off many branches in the first part of its course: soon after its origin it receives the branch of communication, by which the inferior dental nerve is connected to it. About the same point or presently after it is also joined by the chorda tympani. The uncertainty which has prevailed with regard to the source of this nerve renders a more particular account of it necessary than would otherwise be required. The chorda tympani—a delicate filament—is given off from the portio dura shortly before that nerve escapes from the aqueduct of Fallopius, behind and below the tympanum: it passes upward and forward toward the tympanum, contained in a special canal of the bone, and having reached the back of the chamber it emerges from its posterior wall through a small aperture beneath the base of the pyramid; it then attaches itself to the outer wall of the tympanum and crosses it toward the anterior, having first received* a delicate filament from the sympathetic, and running forward, upward, and outward. During its course from the posterior to the anterior wall it is situate at first beneath the short crus of the incus, then between the long crus of the incus and the superior part of the handle of the malleus, to which it is connected by the lining membrane of the tympanum. Having ascended above the internal muscle of the malleus it changes its direction and runs downward, forward, and inward along the superior anterior part of the circumference of the membrana tympani, until it has reached the anterior wall of the chamber, from which it goes out through the Glaserian fissure, along the tendon of the anterior muscle of the malleus. It is throughout excluded from the interior of the tympanum by the lining membrane, which is connected to it upon that side; it is therefore incorrect to say that it crosses the chamber. After its escape from the tympanum the nerve continues to descend forward and inward in front of the levator palati muscle, and after a course from three-fourths of an inch to an inch long it is attached at a very acute angle to the back of the lingual branch, becomes inclosed in the same sheath with the nerve, and continues connected with it altogether until the nerve has reached the posterior extremity of the submaxillary gland: at that point the chorda tympani divides into two parts, one of which is despatched to the submaxillary ganglion, and the other continued along with the lingual branch. By some† it is stated that it separates from the nerve at the ganglion, and is altogether ununited to it; this, however, is incorrect. During its descent in company with the lingual branch there may be observed, upon particular examination of the conjoined trunk, a communication and identification between the nervous matter of the two nerves.

Originally the chorda tympani was regarded as either a recurrent filament of the lingual branch of the fifth or a branch of the portio dura: afterwards the opinion was adopted that it was not a branch of the portio dura, but the cranial superficial petrous branch of the Vidian nerve, which, instead of uniting and being identified with the portio dura, descended through the aqueduct merely in apposition with it or within the same sheath, separated from it again before the nerve escaped from the aqueduct, and constituted the chorda tympani. This view

* Bock, Meckel junior, Cloquet.

† Cloquet.

of the nature of the chord, suggested first, as it would appear, by J. Hunter, has been advocated also by Cloquet and Hirzel, and is at present entertained by many in this country at least; it has been objected to by Arnold, and another has been advanced by him from observations made upon the calf and the human subject. Hunter's account of the connection of the nerves is as follows: "This nerve composed of portio dura and the branch of the fifth pair sends off, in the adult, the chorda tympani before its exit from the skull, and in the fœtus, immediately after. The termination of the branch called *chorda tympani* I shall not describe, yet I am almost certain it is not a branch of the seventh pair of nerves, but the last-described branch from the fifth pair," i.e. the Vidian, "for I think I have been able to separate this branch from the portio dura, and have found it lead to the chorda tympani; perhaps is continued into it; but this is a point very difficult to determine, as the portio dura is a compact nerve, and not so fasciculated as some others are."* According to Arnold, neither of the previous opinions is correct; but the petrous nerve anastomoses with filaments of the facial nerve, principally the external, with which it forms a gangliform swelling at the place at which the nerve receives it; and the branch which forms the corda tympani arises from the gangliform swelling of the facial nerve, and holds in an intimate manner to the petrous nerve; however it is not to be considered a continuation of the latter: it is united, during its course, to the facial nerve by several filaments, and consequently the chorda tympani ought to be regarded neither as a branch of the facial nerve nor as a continuation of the petrous nerve, but as one composed of both.† Cruveilhier‡ maintains that the chorda tympani is not a prolongation of the Vidian nerve, but he assigns no reason for his opinion. The question at issue probably cannot be decided from the human subject: the impediment opposed to its satisfactory determination by the density of the facial nerve, as admitted by Hunter, and by the manner in which the facial and the Vidian nerves are in it blended together at their junction, will hardly permit the point being accurately ascertained; but the same difficulty does not exist in other animals, and if the disposition of the Vidian nerve at its junction with the facial be examined, in the horse *e.g.*, no doubt will remain that, 1. the Vidian nerve certainly does not run simply in apposition with the facial nerve, and, 2. the chorda tympani is certainly not a mere continuation of the Vidian nerve. In the horse the facial nerve is much less dense, and more easily analyzed than in man, and at the point of junction with the Vidian its filaments are so free and so loosely connected, that little more is required than to open the packet without violence in order to display satisfactorily the disposition of the Vidian at its junction with the facial: the

* Animal Œconomy, p. 267.

† Journ. Compl. t. xxiv. p. 339, 341.

‡ Anatomie Descriptive.

Vidian passes into the interior of the packet, crossing its fasciculi nearly at right angles, but rather in a reflex direction, and then spreads out and breaks up into a number of very delicate filaments with which cineritious matter is intermixed, and thus a ganglionic structure is produced, which is in some instances more manifest than in others, and is at the same time connected with fasciculi of the facial nerve. The filaments into which the Vidian separates can be followed in both directions, some retrograde, and some along with the facial: the former appear to pass partly to the auditory nerve, as stated by Arnold, and partly to the facial between the point at which the Vidian joins it and the brain: they can be rent from the one into the other, and indeed look more like filaments from the facial to the Vidian than from the latter to the former. The latter filaments of the Vidian are dispersed among the fasciculi of the facial, with which they become united, and can be followed by means of a careful dissection for some distance: their number the writer is not prepared to state: the fasciculus of the facial from which the chorda tympani more particularly arises, appears decidedly to receive one or it may be more. Further, the chorda tympani does not arise by a single root, but is formed by two or three derived from different parts of the facial. The opinion that the chorda tympani is a continuation of the Vidian nerve appears, therefore, to the writer altogether unfounded, and while he admits that the conclusion of Arnold may probably be well-founded, with regard to its compound nature, he yet must dissent from the opinion that the branch which forms it arises immediately from the gangliform swelling of the facial · the fasciculus, from which its principal root proceeds, existing distinctly upon both sides of, and consequently not arising from the swelling, however it may receive an accession from, or be affected by its connection with this part. The author cannot refrain from regarding the chord as a branch of the facial nerve in the same sense with any other branch arising within the limits of the influence of the Vidian nerve. Magendie maintains that the chord is a continuation of the Vidian, because the section of the fifth nerve itself deprives the ear of all sensibility, but whatever part the chord may play in the sensibility of the ear, and it is doubtful that it plays any, the result of the experiment will be easily explained by the doctrine of Eschricht, that the facial nerve owes its sensibility to the fifth nerve, the division of which must in such case influence through the Vidian nerve any branch of the facial arising within the range of its influence.

After the junction of the chorda tympani with the lingual branch, the latter gives at times a small branch to the internal pterygoid muscle: during its descent along the ramus of the jaw, it also gives filaments to the arches of the palate, to the mucous membrane of the cheek, and to the gum of the lower jaw. While the nerve is situate between the mucous membrane of the mouth and the submaxillary gland, it is connected by means of two, three, or four filaments with the *submaxillary ganglion*. This ganglion is a small reddish body resembling the spheno-palatine ganglion in size, colour, and consistence, situate above the posterior extremity of the submaxillary gland, and connected superiorly with the lingual branch by the filaments mentioned; inferiorly there arises from it a considerable number of very delicate nerves, which descend through the divisions of the gland, anastomose with each other, and are distributed for the most part to the substance of the gland; one of them descends upon the hyoglossus, anastomoses with a filament from the ninth, and enters into the genioglossus muscle, and another long one accompanies the duct of the gland. A filament of communication also from the superior cervical ganglion of the sympathetic reaches the submaxillary ganglion by following the course of the facial artery, and is represented by Arnold.

The filaments by which the ganglion is connected to the lingual branch, are, as has been stated, two, three, or four; they are not attached to the nerve all together, but one or two some lines before the others, and they are remarkable for the circumstance, that the posterior descend forward, while the anterior descend backward; on attentive examination it is found that the posterior are derived one from the chorda tympani, and the other from the lingual branch itself; it also appears that the filament derived from the former source is but a part of the cord, the remainder being continued on with the trunk of the lingual, and again that the anterior filament or filaments, which descend backward to the ganglion, are continuations of the posterior, which, after having been connected to the ganglion, ascend forward from it again to the trunk of the nerve. The course of those filaments of connection is well described and represented by the elder Meckel, and a very accurate delineation of them is given by Treviranus and Arnold. To this connection probably it is, that we are to attribute the influence which impressions on the organs of taste, or even sounds exert upon the salivary apparatus; let us, when hungry, only hear a sound associated in our minds, in any way, with the gratification of our appetite, and at once that apparatus is roused into activity.

Next, while lying between the mylohyoid and the hyoglossus muscles, the lingual nerve sends off from its inferior side some branches, which descend upon the hyoglossus, and anastomose with filaments ascending from the ninth nerve. At the same time, from its superior side, it gives filaments; some of which, the posterior, are distributed to the mucous membrane and to the gum of the lower jaw; others, the anterior, to the sublingual gland, and by some of their ramifications to the membrane and the gum. Lastly, the nerve divides at the anterior margin of the hyoglossus into its lingual branches; these are, at first, three, posterior, middle, and anterior; they pass upward and forward, and divide, each into two or three branches, which altogether diverge from the nerve, and are ranged in succession from behind forward, along the line of separation between the stylo-glossus and the genio-glossus; they traverse the substance of the tongue toward its superior surface and margin, and run along its inferior surface, above the mucous membrane, toward its extremity; as they proceed they subdivide, and thus results a great number of filaments, the course of which through the tongue is remarkable; they appear not to terminate, any of them, in the substance of it, but they traverse it as long, slender, single filaments, unconnected with its structure until they approach its superior surface, when they break up into pencils (to adopt the phrase used) of still more delicate filaments, which may be followed into the mucous membrane; the posterior filaments of the posterior branch insinuate themselves internal to the hyoglossus, and reach as far back as the foramen cœcum; the filaments of the anterior are distributed to the extremity of the tongue, and are continued between the under surface of it and the mucous membrane very near to the tip, the substance of which they then traverse in order to reach its superior aspect and margin: they thus supply the mucous membrane of the organ upon its superior and lateral parts, from the foramen cœcum to its point.

Ganglion of the fifth nerve (Ganglion semilunare Gasseri). See *fig.* 140, 9.— The ganglion of the fifth nerve is a body of crescentic form, a cineritious colour, and firm consistence. It presents two surfaces, two margins, and two extremities: its surfaces are both slightly prominent, and are directed one upward, outward, and forward, the other downward, inward, and backward; they are also, the former concave and the latter convex longitudinally, the ganglion being somewhat curved upon itself in the same direction: they are both for the most part adherent to the laminæ of dura mater, which form the chamber in which the ganglion is contained; but it is not uncommon to find the arachnoid membrane prolonged beneath it, so that its inferior surface in such instances is free; the superior corresponds to the cranial cavity in its middle fossa, being excluded from it only by the dura mater; the inferior rests, with the intervention of dura mater also, upon the petrous portion of the temporal bone, the great ala of the sphenoid, and against the outer side of the cavernous sinus. The margins of the ganglion are directed one forward and downward, the other backward and upward; the anterior is convex, and to it are attached the three great trunks, which compose the ganglionic portion of the nerve in its third stage; the posterior is concave and presents through its entire length a deep groove, into which the fasciculi of the ganglionic packet of the nerve are received. The extremities are obtuse, and project beyond the packet at either side; they are situate relatively, one superior, internal, and anterior to the other. When the ganglion is in situ, the chord of the arch which it forms is six or seven lines long; Niemeyer has sometimes found it amount to from nine to ten:* its width is about two lines, and its thickness, according to the part, from half a line to a line. Its colour and appearance vary much according to the subject: the former is always of a cineritious tint of different degrees of intensity; when the subject is wasted, flabby, or anasarcous, it is pale or grey, while, if the subject have been robust and corpulent, it is of a deep brown colour: in the former case also a plexiform arrangement is more perceptible, whereas in the latter the ganglion seems composed of two concentric arcs, an anterior of lighter colour and manifestly plexiform character, and a posterior of very deep colour and apparently homogeneous indeterminate texture, devoid altogether of the plexiform appearance.

A particular inquiry into the structure and probable function of the ganglion of the fifth nerve would involve that of the cerebro-spinal ganglia in general, and will be better postponed to another occasion: it will suffice for the present to state that according to both Monro and Scarpa, they are composed in part of nervous chords, and in part by a soft grey or brown substance, which fills the intervals between the nervous filaments, and which according to the former resembles the cortical matter of the brain, while in the opinion of the latter it is a cellular texture filled by a matter, which varies in character according to the subject; thus he states that he has found it fatty in fat and watery in anasarcous subjects. 2. That nervous filaments can be traced through them without interruption from the nerves situate above to those situate below the ganglion, which opinion is objected to by Niemeyer, who compares the connection of the former with the ganglion to that of the fœtal and maternal portions of the placenta; but inspection suffices to satisfy one that this idea of Niemeyer is incorrect; for whether additional filaments be furnished or not by the ganglion, the continuity of filaments above and below it is evident even in the human subject, and is still more manifest in other animals: in the horse it is easily seen, particularly after a section of the ganglion.

The question whether the ganglion receives filaments from the sympathetic system has been a subject of dispute among anatomists. The elder Meckel* denies the existence of any filaments of connection between the sympathetic and the fifth nerve, while within the fibrous chamber or while situate by the cavernous sinus; and others also, among whom are Eustachius, Haller, Albinus, and Morgagni, are of the same opinion; but later investigations have put it beyond doubt that such a communication does exist. Bock† has described filaments of the sympathetic united to the trunk of the fifth, before the formation of the Gasserian ganglion, and which join chiefly the fasciculi of the trunk, from which the ophthalmic nerve originates. And Arnold

* De origine paris quinti nervorum cerebri monographia, Halæ, 1812.

* Scriptores Neurologici Minores, tom. i.

† Beschreibung des funften Nervenpaares und seiner Verbindung mit andern Nerven, vorzüglich mit dem Gangliensystem, 1817.

states "that several very delicate filaments go from the carotid plexus to the semilunar ganglion, particularly to the first and third branches of the nerve, and upon those points the ganglionic matter is accumulated in greater abundance."* Besides this connection between the sympathetic and the ganglion, others exist between it and the branches of the ganglion.

The ganglion appears to constitute an essential part of the fifth nerve throughout vertebrate animals, and to be uniformly present. It also presents in all the common character of being composed both of white and cineritious matter, though the comparative amount of the two constituents varies according to the class, the order, or even the individual. The presence of the two structures the author would regard as essential to the constitution of cerebro-spinal ganglia, and he would exclude from such those enlargements presented by nerves in certain situations, but from which cineritious matter appears to be absent. In Mammalia, Birds, and Reptiles, the fifth nerve is provided with a single ganglion, but in Fish and in both orders of that class it possesses for the most part two ganglia and two ganglionic fasciculi; this however is not uniformly so, for in some, e.g. the lophius piscatorius, the ganglion is single.

Vital Properties of the Fifth Pair of Nerves.—The discussion of the vital properties of the fifth nerve the writer proposes may be fitly arranged under the following heads: 1. its sensibility; 2. its influence upon the faculties of sensation and volition, as also upon the ordinary sensibility of the parts to which it is distributed; 3. its relation to the special senses and connection with the function of nutrition.

1. *Sensibility.*—Numerous experiments performed and repeated by different physiologists have established the fact, that the fifth nerve enjoys exquisite sensibility. Bell appears to have been the first who directed attention particularly to this point: in his paper, published in the Philosophical Transactions for the year 1821, it is stated that, touching the superior maxillary branch of the fifth nerve, when exposed in an ass, "gave acute pain." In the first of Mayo's experiments upon the fifth nerve, published in his Commentaries in 1822, it was also found that "on pinching the opposite extremities" (those connected with the brain) "of the infraorbital and inferior maxillary nerves in an ass, the animal struggled violently as at the moment of dividing the nerves: these latter results uniformly attend the division of the nerves above-mentioned, and of that branch of the fifth which joins the portio dura."† Similar results were obtained by the writer last quoted from experiments of the same description upon the dog and the rabbit, and upon the pigeon, in regard to the first division of the fifth. He also found "that on pinching the gustatory nerves in living rabbits pain was evinced." Magendie carried the inquiry farther, and in the fourth volume* of the Journal of Physiology, has related an experiment in which he exposed the fifth nerve within the cranium in the rabbit and dog, and found that the slightest touch produced signs of acute sensibility. From the preceding facts we infer that the ganglionic portion of the nerve at least is exquisitely sensitive, and that it is endowed with sensibility through its entire extent: further, the experiment of Magendie indicates that the sensibility of the nerve is proper and independent of the influence of other nerves, he having experimented upon it at a point prior to its junction with any other.

With regard to the non-ganglionic portion of the nerve, our data are at present altogether analogical: it is so situated that satisfactory experiments upon it separately are hardly to be accomplished, so that we are left to infer of it as probable what has been ascertained of other non-ganglionic nervous cords, viz. the anterior roots of the spinal nerves. The question in regard to the functions of the different portions of the spinal nerves has been inquired into by Magendie, by whom the endowments of both sets of roots have been tested in various modes, and who has inferred that the anterior roots are not devoid of sensibility, and if they be sensitive it is probable that the lesser packet of the fifth is sensitive also.†

2. *Influence of the fifth nerve upon sensation and volition.*—It is hardly necessary to remark that this point has been the subject of much dispute, as well with regard to the fact itself as to the relative claims of the several inquirers to whom we are indebted for the investigation of the matter: however, physiologists now seem to be generally agreed that the nerve is one of compound function, being subservient to both the faculties of sensation and volition, and that the faculty of sensation is dependent upon its ganglionic, that of voluntary motion upon its non-ganglionic portion, and that it thus resembles the spinal nerves. That the nerve is one of compound function, and subservient to the two faculties, was announced by Bell in the paper already alluded to. He there distinguishes the nerves into two classes; one original and symmetrical, the other superadded and irregular. To the former class he refers the spinal nerves, the suboccipital, and the fifth nerve, and assigns to them the following characters, namely, they have all double origins; they have all ganglia on one of their roots; they go out laterally to certain divisions of the body; they do not interfere to unite the divisions of the frame; *they are all muscular nerves, ordering the voluntary motions of the frame; they are all exquisitely sensible, and the source of the common sensibility of the surfaces of the body*: to it he refers the nerves of the spine, the suboccipital, and *the fifth nerve.*‡ It has been already stated that

* Journ. Compl. tom. xxiv.
† Commentaries, No. 1, p. 110.

* P. 314.
† Journal de Physiologie, t. ii. p. 368.
‡ Philosophical Transactions, 1821, p. 404.

he had ascertained by experiment that the fifth nerve was exquisitely sensitive; that it is the source of the sensibility of the parts to which it is distributed, he has also determined, for in allusion to the fifth he says, "if the nerve of this original class be divided, the skin and common substance is deprived of sensibility;"* and "by an experiment made on the 16th of March, it was found that, on cutting the infra-orbitary branch of the fifth on the left side, the sensibility of that side was completely destroyed."† The experiments of Bell were repeated by Magendie, and a similar result, so far as regards the sentient properties of the fifth, obtained, as mentioned in the Journal de Physiologie, Octobre 1821. A similar result has been obtained also by Mayo in his experiments upon the fifth nerve, as detailed in his Commentaries for August 1822, more than a year after the publication of Bell's paper. In his first experiment the infra-orbital and inferior maxillary branches were divided on either side in an ass, where they emerge from their canals, and the sensibility of the lips seemed to be destroyed: and, in a second experiment, the frontal nerve was divided on one side of the forehead of an ass, when the neighbouring surface appeared to lose its sensibility: the same effect was produced by the division of that branch of the fifth which joins the portio dura, inasmuch as the cheek loses sensation upon its division. From these experiments Mayo concluded that the facial branches of the fifth are nerves of sensation. The experiments upon the influence of the nerve on sensation have been carried still further by Magendie; he divided the nerves within the cranium, where they lie against the cavernous sinus, and also between the pons Varolii and the petrous portion of the temporal bone, and in both instances he obtained the same result with regard to the sensibility of the parts to which the nerves are distributed, viz. total loss of sensibility on one or both sides of the face, according as one or both nerves were divided; this extended not only to the integuments as in the former trials, but also to the lining membrane of the nostrils, to the conjunctiva, to the tongue and the interior of the mouth. The effect upon the nostril was so remarkable that the most active effluvia, even those of ammonia and acetic acid, produced no impression upon it: in like manner neither piercing instruments nor ammonia excited any sensation when applied to the conjunctiva, and the tongue was insensible to the action of sapid bodies at its anterior part.

From such accumulated evidence but one conclusion can be drawn, viz. that the fifth is the nerve of general and tactile sensation to the face and its cavities, or to the parts upon which it is distributed.

With regard to the influence of the fifth nerve upon volition, it has been already stated that Bell had announced it, as one of his regular or symmetrical nerves, to be "a muscular nerve ordering the voluntary motions." This conclusion with regard to the fifth nerve he adopted in consequence of the following experiment, and of the result, which, as he conceived, he obtained from it. "An ass being tied and thrown, the superior maxillary branch of the fifth nerve was exposed. Touching this nerve gave acute pain. It was divided, but no change took place in the motion of the nostril; the cartilages continued to expand regularly in time with the other parts which combine in the act of respiration; but the side of the lip was observed to hang low, and it was dragged to the other side. The same branch of the fifth was divided on the opposite side, and the animal let loose. He could no longer pick up his corn; the power of elevating and projecting the lip, as in gathering food, was lost. To open the lips the animal pressed the mouth against the ground, and at length licked the oats from the ground with his tongue. The loss of motion of the lips in eating was so obvious, that it was thought a useless cruelty to cut the other branches of the fifth." The inference here indicated is obvious, viz. that the motion of the lips in eating depends upon the *superior maxillary* branches of the fifth pair, so far at least as the distribution of those branches extends; and what he conceived he had thus established with regard to one branch he inferred analogically of the rest. The opinion that the fifth is a muscular nerve as well as one of sensibility Bell also maintains in later writings, and supports by additional experiments: thus, in his *Exposition of the Natural System of the Nerves*, published in 1824, he says, "to confirm this opinion by experiment, the nerve of the fifth pair was exposed at its root, in an ass, the moment the animal was killed; and on irritating the nerve the muscles of the jaw acted, and the jaw was closed with a snap. On dividing the root of the nerve in a living animal, the jaw fell relaxed." That the fifth is to a certain extent a nerve of voluntary motion is universally admitted, but then a question arises of equal interest and delicacy; of interest for its own nature, and of delicacy because of the personal claims and feelings involved in it. The question is,—it being admitted that the nerve is one of double function,—is such function enjoyed equally by all its branches and by both its portions; and if otherwise, upon which do they severally depend? From the extracts quoted it is evident that no distinction in function between the different branches of the nerve was contemplated by Bell at the time the first was written, in 1821, and that he regarded them as being all alike nerves of compound function,—nerves both of voluntary motion and sensation; and, such being the case, either that he had not recognised a difference between the properties of the ganglionic and the non-ganglionic portions of the nerve, or that he was then not aware of the peculiar distribution of the latter; nor is any express information afforded us upon the subject in his earlier writings, or antecedent to 1823. The conclusion to which he had arrived with

* Philosophical Transactions, 1821, p. 405.
† Ibid. p. 417.

regard to the nerve generally and its superior maxillary branch in particular, in the year 1821, has been stated; in his communication to the Royal Society in 1823, he adds, "all the nerves, without a single exception, which bestow sensibility from the top of the head to the toe have ganglia on their roots; and those which have no ganglia are not nerves of sensation, but are for the purpose of ordering the muscular frame:" from this, when applied to the fifth nerve, it might be inferred that sensation depended upon its ganglionic, and muscular action upon its non-ganglionic portion. But between the years 1821 and 1823 additions had been made by others to the knowledge of the functions of the fifth nerve which require notice. It is to be borne in mind that Bell inferred from his first experiment, published in 1821, that the *superior maxillary nerve* is one both of sensation and voluntary motion to the lips (see the preceding page): to this conclusion Magendie was the first to object, for in the Journal of Physiology for October of the same year (1821), he says, "we have repeated these experiments along with Messrs. Shaw and Dupuy, and the result which we have obtained agrees perfectly with that which we have just related, *with the exception always of the influence of the section of the infra-orbital upon mastication, an influence which I have never been able to perceive.*" In August 1822 Mayo published, in his Commentaries, his "experiments to determine the influence of the portio dura of the seventh, and of the facial branches of the fifth pair of nerves." Those relating to the latter point, which have been already alluded to, are as follow. 1. The infra-orbital and inferior maxillary branches of the fifth were divided on either side, where they emerge from their respective canals; the lips did not lose their tone or customary apposition to each other and to the teeth; but their sensibility seemed destroyed: when oats were offered it, the animal pressed its lips against the vessel which contained the food, and finally raised the latter with its tongue and teeth. On pinching with a forceps the extremities nearest the lips of the divided nerves, no movement whatever of the lips ensued: on pinching the opposite extremities of the nerves, the animal struggled violently, as at the moment of dividing the nerves. Some days afterwards, though the animal did not raise its food with its lips, the latter seemed to be moved during mastication by their own muscles."

2. "Some days after, the frontal nerve was divided on one side of the forehead of the same ass, when the neighbouring surface appeared to have lost sensation, but its muscles were not paralysed." 4, 5, and 6. The branch of the fifth, that joins the portio dura, was divided on either side: in the fourth experiment, the under lip at first appeared to fall away from the teeth; at times the lips were just closed: in the fifth and sixth, the under lip did not hang down, and no difference was observed between the action of the muscles of either side; but, he observes in a later publication, "the cheek loses sensation upon its division." The results of these experiments, while they confirm fully the inference drawn by Bell with regard to the influence of the nerve over sensation, are altogether at variance with that of his experiment relating to the control of the superior maxillary nerve over muscular motion, and are equally incompatible with the doctrine that the branches of the nerve, which were the subjects of experiment, have any direct connexion with muscular contraction; for while, on the one hand, the division of the nerves was followed by total loss of sensibility in the lips, on the other, the latter did not fall away either from each other or from the teeth, nor did irritation of the portions of the nerves connected with the lips excite any movement whatever of those parts, but they seemed afterwards to be moved during mastication by their own muscles. Mayo inferred accordingly from his experiments, "that the frontal, infra-orbital, and inferior maxillary are nerves of sensation only, to which office that branch of the fifth which joins the portio dura probably contributes." A circumstance in the first experiment doubtless seems at variance with the conclusion which Mayo has drawn, and demands consideration here, because, unless unexplained, the fact is inconsistent with the inference. It has been stated that both in Bell's and Mayo's experiment, the animal ceased to take up its food with its lips after the division of the facial branches of the fifth, and from that circumstance chiefly the former appears to have inferred that the motions of the lips in eating depended on these nerves; but the inference is objected to by Mayo as "a theoretical account of the fact that the animal did not elevate and project its lip; this fact," he says, "was noticed in my own experiments, but appeared to me from the first equally consistent with the hypothesis, that the lip had merely lost its sensibility, as with Mr. Bell's explanation," that it had lost its muscular power. The fact may be obviously explained by either of the two suppositions, and it is very remarkable that it should occur equally in one case as in the other. In the one, the muscles of the lips having been deprived of their power of voluntary contraction, the lips themselves cannot, of course, be made use of to take hold of an object; and in the other, the animal not being made aware of the contact of the food in consequence of the loss of sensation, volition is not exerted, nor are the muscles called into action in order to take hold of it. To the latter cause it is attributed by Mayo, after the division of the branches of the fifth, and he confirms this view of its production by reference to the effect of anæsthesia in the human subject: "in that disease the sensation of the extremities is wholly lost, while their muscular power remains. Now it is remarkable that in persons thus affected the muscles of the insensible part can only be exerted efficiently when another sense is employed to guide them, and to supply the place of that which has been lost: a person afflicted with anæsthesia is described in a case quoted

by Dr. Yelloly, as liable on turning her eyes aside to drop glasses, plates, &c. which she held in safety so long as she looked at them;" but that the absence of motion in the lips on the division of the fifth is due to the loss of sensation merely, and not of voluntary power, is positively proved by the effect of the division of the portio dura on the two sides, an experiment performed for the first time by Mayo: in it the voluntary motion of the lips is altogether lost, while sensation continues unaffected,* and hence the division of the fifth cannot deprive them of voluntary power, but only of sensation. The explanation of Mayo has been admitted and adopted by Bell himself in his "Exposition," 1824, in which he has added to the detail of his experiment, as already related, the following note: "what I attributed to the effect of the loss of motion by the division of the fifth, was in fact produced by loss of sensation;" and he corroborates this by the case of a gentleman in whom loss of sensation in the lip had been produced by extraction of a tooth. "On putting a tumbler of water to his lips, he said, 'Why, you have given me a broken glass:' he thought that he put half a glass to his lips, because the lip had been deprived of sensation in one half of its extent; he retained the power of moving the lip, but not of feeling with the lip." The last particular noted is of great value, as demonstrating satisfactorily the separation of the two faculties, and, taken in connexion with anatomical considerations, renders it necessary to refer them to separate sources. It is manifest, then, that the circumstance of the animal not taking up the food by means of the lips, after the division of the fifth nerve, is not proof that it had lost the voluntary muscular power of them, but only that it did exert it, not having been, as it were, apprised of the necessity of doing so. It is also stated by Bell, that on the division of the nerve upon one side, "the side of the lip was observed to hang low, and it was dragged to the other side." This result also is objected to by Mayo, first, as contrary to his observation, for in his first experiment, after the division of the infra-orbital and inferior maxillary nerves, "the lips did not lose their tone or customary apposition to each other and to the teeth;" and secondly, as being the effect of an extensive division of the muscular fibres, a cause quite adequate certainly to explain the fall of the lip, independent of the influence of the nerves. The difficulty, therefore, which these circumstances appear at first to present is removed, and we are left to determine the question by other means, and they are abundantly furnished from other sources. In the first place, the division of the nerves completely destroys the sensation of the parts to which they are distributed, without producing any effect upon the tone or contractile power of those parts, nor does irritation of the divided nerves excite muscular contractions. Secondly, were these nerves the source of the voluntary powers of the parts they supply, the division of every other nerve must fail to affect that power while the former remain entire; but Mayo, in several instances, divided the portio dura alone on both sides, and the result was, that "the lips immediately fell away from the teeth, and hung flaccid," and could not be used by the animal to take hold of food, and consequently had lost all voluntary power; while, "when the extremity, nearest the lips, of either divided nerve was pinched, the muscles of the lips and nostrils on that side were convulsed." Bell doubtless asserts that after the division of the portio dura nerve on one side, the animal "ate without the slightest impediment;" to this Mayo objects that "the experiment is inconclusive, because the nerve was not divided on both sides;" but in truth the experiment is quite conclusive, for though the animal can eat, and without impediment, his eating is far from perfect, and the imperfection is not the less obvious because confined to one side.

When an animal which has had the portio dura divided upon one side only takes food, the lips remain motionless upon that side; and when it masticates, the lips continue in the same state, while on the other side they actively co-operate, the food and saliva escaping on the side at which the nerve has been cut, and on the other being confined within the mouth. Now, if any action of the lips be voluntary, it is assuredly that by which they co-operate in the prehension and mastication of food; and since no action of their muscles can be excited by irritation of the branches of the fifth nerve, while such action can be excited by that of the portio dura, and all voluntary action is destroyed by the division of that nerve, but one inference remains, that of Mayo already adverted to, viz.—that those branches of the fifth in question possess no influence upon the voluntary faculty of the muscles; that they are exclusively sentient; and that the contractile power of the muscles of the face, whether voluntary or involuntary, is to be attributed to another source.

After what has been stated, we must admit that Mayo has been the first expressly to announce that the function of these nerves is restricted to sensation. Beyond that, however, he has not gone, in reference to the question of sensation, in the publication alluded to, though it must be admitted that little remained to be added in order to complete the conclusion, that the ganglionic portion of the nerve is exclusively sentient. At the same time he inferred, "from the preceding anatomical details,"—viz. their exclusive distribution to muscles,—"that other branches of the third

* It will be satisfactory to those interested in this question to know, that the result of Mayo's experiment has received full confirmation from those of others; and first from Shaw, who has bestowed so much labour to establish the respiratory connexion of the portio dura. In the Medical and Physical Journal for December, 1822, he writes, "immediately on cutting the nerve (the portio dura) on both sides, the lips became so paralyzed that the animal could no longer use them in raising its food." The same result has been obtained by Mr. Broughton in experiments upon the horse, as detailed in the same Journal, June, 1823.

division of the fifth are voluntary nerves to the pterygoid, the masseter, the temporal, and buccinator muscles." Here again he has not reached the conclusion, though he has fallen but little short of it, and though, as in the former instance with regard to sensation, he has been the first to announce a restriction of the motor properties of the nerve to particular branches. The opinion expressed by Bell, in June 1823, has been already quoted, and from it we are bound to admit, that then at least he recognised the distinction at present acknowledged with reference to the appropriate function of the ganglionic and non-ganglionic portions. But in Mayo's Commentaries for July 1823, the conclusion is for the first time expressly stated thus:—"In the last paper of the preceding number, I mentioned that the division of the supra-orbital, infra-orbital, and inferior maxillary nerves, at the points where they emerge from their canals upon the face, produces loss of sensation, and *of that alone*, in the corresponding parts or the face. I have since, after the division of the fourth branch which emerges on the face,—namely, that which joins the portio dura,—ascertained that this branch likewise is a nerve of sensation, inasmuch as the cheek loses sensation upon its division. I mentioned in addition that I concluded that other branches of the fifth nerve, from their distribution, are voluntary nerves. Now it is well known that the fifth nerve at its origin consists of two portions; a larger part, which alone enters the Gasserian ganglion, and another smaller, which does not enter, but passes below the ganglion to join itself with the third division of the fifth. Towards the close of last summer I endeavoured to trace the final distribution of this small portion in the ass, and succeeded in making out that it furnishes those branches, which are distributed exclusively to muscles: I have since ascertained that in the human body precisely the same distribution exists. But the remaining branches of the fifth are proved to be nerves of sensation; thus it appears that the fifth nerve consists of two portions, one of which has no ganglion, and is a nerve of voluntary motion (and probably of muscular sensation); and another, which passes through a ganglion, and furnishes branches, which are exclusively nerves of the special senses."

We return now to the question of the properties of the non-ganglionic portion of the fifth nerve. It has been stated that Mayo was the first to announce the restriction of the voluntary influence of the fifth to certain branches, and that he was led to this conclusion from the observation of the fact that certain branches of the nerve are distributed exclusively to muscles. These muscles he has stated, in the first part of his Commentaries, to be the pterygoid, the masseter, the temporal, and buccinator; to which he has added, in his second part, the circumflexus palati; by dissection he ascertained that as well in man as in the ass, the lesser portion of the nerve "furnishes those branches which are distributed exclusively to muscles;" and having already determined that the ganglionic portions of the nerve are destined exclusively to sensation, he came to the conclusion that the non-ganglionic portion is a nerve of voluntary motion. His first conclusion upon this point he himself states to have "involved a trifling error: the pterygoid, masseter, and temporal muscles are indeed exclusively supplied by the fifth, and therefore, without doubt, the branches so distributed are voluntary nerves, but the buccinator receives branches from the portio dura as well, and I have found subsequently, that pinching the branch of the fifth that perforates the muscle, produces no action in it: and in accordance with this view he writes in his Physiology,* "I was led to observe that there were muscles which received no branches from any nerve but the fifth; these muscles are the masseter, the temporal, the two pterygoids, and the circumflexus palati. After some careful dissection, I made out that the smaller fasciculus of the fifth is entirely consumed upon the supply of the muscles I have named." The determination of the constitution and function of the buccal branch of the inferior maxillary nerve has become a matter of greater importance since the publication of Bell's work on the Nervous System in 1830. In it he says, "I am particular in re-stating this, because from time to time it has been reported that I had abandoned my original opinions, whereas every thing has tended to confirm them." Now, it will be remembered that Bell's original opinion is, that the muscles of the face are endowed with two powers, a voluntary one, dependent on the fifth nerve, and an involuntary respiratory one, dependent on the portio dura; also, that in the first instance he attributed the voluntary power of these muscles to the facial branches of the fifth, but that he had abandoned that idea, and acknowledged that what he had attributed to loss of motion was in fact due to loss of sensation. In the work adverted to he has taken new ground, and at the same time reiterates his first opinion with regard to the existence of the two distinct contractile powers in the muscles of the face, and attributes to the buccal nerve that influence over their voluntary motion which he had before referred to the infra-orbital, &c. Thus, "but finding that the connexion between the motor root and the superior maxillary nerve proved to be only by cellular texture, and considering the affirmation of M. Magendie and those who followed him, that the infra-orbitary branch had no influence upon the lips, I prosecuted with more interest the ramus buccinalis labialis,"—the buccal nerve,—"and nobody, I presume, will doubt that the distribution of this division confirms the notions drawn from the anatomy of the trunk, not only that the fifth nerve is the manducatory nerve as it belongs to the muscles of the jaws, but also that it is distributed to the muscles of the cheek and lips to bring them into correspondence with the motions of the jaws." To the point at issue the writer has directed particular atten-

* 1833, p. 261.

tion: he has made repeated dissections of the distribution of the lesser packet of the nerve both in the horse and in man, and after a careful examination, it appears to him that Mayo is essentially right, though the view given by him does not exactly agree with the arrangement of the nerve as found by the author either in the horse or in man. In the former the masseteric branch arises from the lesser packet by two fasciculi, one of which runs round the ganglionic portion of the third division of the nerve, and joins the other and larger fasciculus before it: the facial portion of the buccal nerve appears to the author to be purely ganglionic, but the root of the nerve in part *appears* to be derived from the non-ganglionic portion and is not; and in part may or may not be considered to proceed from it. It is entangled at its origin with fasciculi of that portion, more or fewer of the filaments which it derives from the ganglionic packet passing between and even interlacing with fasciculi of the non-ganglionic; but by a patient proceeding these may be traced to their proper source, and the nerve be extricated from this connexion. It is, however, difficult to accomplish it at times, at others it is sufficiently easy. Again, one or more branches of the non-ganglionic portion accompany the buccal nerve for some distance, connected to it more or less intimately, but apparently not enclosed within the same sheath, though communicating with the nerve by filaments from a ganglionic fasciculus and separable without injury to either. These branches, however, separate from the nerve again for distribution before it leaves the zygomatic fossa; they may be considered, or not, to belong to the nerve, but they do not affect the question with regard to its facial portion; and the author believes that the arrangement described is not uniform, the branches adverted to not always accompanying the buccal nerve.

Again, on the one hand it has been already shewn that division of the portio dura on both sides deprives the facial muscles of all independent* contractile power, whether voluntary or involuntary; and on the other, Mayo has found that irritation of the buccal nerve does not excite contraction in those muscles: the author has taken occasion several times to repeat the experiment of Mayo upon the latter nerve after it had emerged upon the face, and he has not succeeded in obtaining contraction of the facial muscles thereby, while the struggles of the animal, excited by the irritation of the nerve, proved it to be one of exquisite sensibility. It appears then to the author impossible to admit that the facial muscles either possess two contractile powers dependent on distinct nerves, or that they derive any voluntary power from the fifth.

It is extraordinary that Magendie, who was the first to detect the error into which Bell had fallen with regard to the influence of the infra-orbital nerve over the motions of the muscles of the face, and has, according to his own report, divided the portio dura on animals, should, notwithstanding all that has been written upon the subject, have adopted the opinion that the muscles of the face are endowed with the two distinct faculties of motion, one of which is derived from the fifth. His view will be found at page 703-4, Anatomie des Systemes Nerveux, &c., and the opinion there expressed is implied in a note at page 191, Journal de Physiologie, t. x. In the former he says, " Now Mr. Charles Bell in England and M. Magendie in France by cutting the facial nerve have paralyzed the respiratory motions of all the side of the face corresponding to the nerve cut. But the muscles which receive at once filaments from the facial nerve and from the fifth pair were paralyzed only in their action relative to respiration and to the expression of the physiognomy."

The influence of the fifth nerve upon the tactile sensibility of the parts with which it is connected has been discussed: its influence upon their ordinary sensibility also requires notice. From the preceding details it appears established that it is to the same nerve that this property also of the parts in general is due; but there is reason to believe that the nerve exerts a more extended control over this faculty than was at first supposed. At the commencement of the inquiries into the functions of the nerves of the face, the opinion generally held was that the facial nerve—portio dura of the seventh pair—was devoid of sensibility. Further observations, however, showed that this conclusion was erroneous, and that the insensibility to any injury done to the nerve in question manifested by the subjects of experiment, and from which the inference had been drawn, was only apparent, and to be referred to the constitution of the individual animal or of its species. The sensibility of the facial nerve having been established, a question arose, whether that property was independent and proper to it, or whether it was conferred by another? Those who first observed the sensibility of the nerve adopted the former opinion; but considerations entitled certainly to much weight led Eschricht to suspect that the facial nerve is not endowed with independent sensibility, and that the sensibility which is manifested when it is injured is conferred on it by the fifth nerve. In order to determine the question he performed a series of experiments in which he divided the fifth nerve within the cranium upon one side after having opened the cavity and removed so much of the corresponding hemisphere of the brain as was necessary for the accomplishment of his purpose: the facial nerve of the same side was then exposed, and its properties tested. The faculties of the animal are so little affected by the removal of the brain, that the result of the experiment seems free from objection, while all influence of the fifth nerve upon the sensibility of the facial or other parts must be destroyed. In his first successful experiment irritation of the facial excited spasms of the lips, and also indications of suffering so decided that a doubt

* This expression has been used because the muscles may be still excited to contraction by irritation of the portion of the nerve connected with them.

could not be entertained: the fifth nerve had also been fairly divided: thus far, therefore, his conjecture was disproved. Pursuing his inquiry still further, he found in his next experiment that no indication whatever of pain was manifested by the animal on irritation of the facial on the side on which the fifth nerve had been cut; but in two succeeding experiments he ascertained that while irritation of the nerve anterior to the meatus auditorius produced no other effect but spasms of the nasal and labial muscles, when exerted posterior to that point it excited manifest evidence of suffering: this latter circumstance he accounts for by the communications of the posterior part of the facial with other sentient nerves besides the fifth, and he has come to the conclusion that the former nerve is not endowed with independent sensibility, but that it derives the property from the fifth and other sentient nerves: this question, however, requires further investigation.*

Relation of the fifth pair of nerves to the special senses.—The organs of the special senses are in the higher classes and in the case of smell, sight, and hearing, each supplied with nerves from at least two sources. Besides the particular nerves, which are generally considered to be the source or medium of the special sense, they are furnished with branches from the fifth pair; and a question must, at the outset, be asked in regard to the two nerves derived from these different sources, as to which is to be considered the proper nerve of the peculiar sense enjoyed? In connexion with the two separate nervous supplies, it is also to be observed that each organ enjoys two kinds of sensibility, viz. the special sensibility, through which sensations of the particular sense are received, and the general sensibility, in which the several organs of the body participate, and which is the medium through which impressions of contact are conveyed. The existence of the special sense, the coincidence of the particular nerve, the impairment or loss of the special function uniformly consequent upon the injury or destruction, whether by disease or otherwise, of that nerve; and the community both of function and distribution, displayed by the nerve from which the organs of the senses are in common supplied, have led physiologists generally to the conclusion that in each case the particular nerve is the medium of the special sense, and that the fifth nerve confers upon the organs of the special senses general sensibility only. The conclusion thus commonly adopted has been at different times called in question: thus Mery and Brunet, in 1697, denied to the nerves of the first pair the function of smell, and attributed this sense to the fifth nerve.* The question of the connexion between the fifth nerve and the special senses is one of much difficulty, and probably we are not as yet in possession of sufficient data from which to draw a positive conclusion upon it when viewed in all its bearings. It resolves itself into three: 1. how far the nerve may be concerned in the perception of special sensations in those cases in which nerves, considered to be specially intended for their perception, exist: 2. how far its cooperation or influence may be necessary to enable the special nerves to fulfil their functions: 3. how far it may be capable of taking the place of those special nerves, and of becoming, under certain conditions, media of perception to sensations, for which, in other cases, peculiar nerves are conferred. We shall review the relation of the nerve to the several senses in succession, bearing in mind the three points to which our attention is to be directed. That it is a medium of perception in the case of two senses, viz. touch and taste, is already so universally acknowledged that it is unnecessary to dwell upon the point.

The importance of the fifth nerve in the three other senses of smell, sight, and hearing, has been advocated by several physiologists, and more particularly by Magendie, who appears disposed to view the fifth nerve as the source or medium of all the three. His application of this doctrine, however, has reference more particularly to the sense of smelling, upon which he has performed a series of experiments, of which the following is a summary: he destroyed entirely the olfactory nerves within the cranium, and he found the animal still sensible to strong odours, such as ammonia, acetic acid, essential oil of lavender. The sensibility of the interior of the nasal cavity had lost nothing of its energy; the introduction of a stylet had the same effect as upon a dog which had not been touched. This experiment he performed several times, and always with the same results. He next divided the fifth nerves within the cranium, of course before they had given branches to the nostrils, and found all trace of the action of strong odours to disappear. He hence concluded that smell, in so far as pungent smells are concerned, is exercised by the branches of the fifth pair, and that the first is not concerned in the function. To this conclusion he himself starts the objection that the agents used are not odours, properly speaking, but chemical, pungent, irritating vapours, and that by the section of the fifth we destroy not the sense of smell, but only the sensibility of the membrane of the nose to these irritating vapours, and he admits the force of the objection with respect to some of the vapours alluded to; but he denies that it will apply to the oil of lavender or that of Dippel, the effect of which in the experiments is the same. In order to remove the difficulty he destroyed the olfactory nerves of a dog of particularly fine nose, and then enclosing portions of food of various kinds in paper, he

* Eschricht, de functionibus nervorum faciei et olfactus organi, Hafn. 1825. [The superficial temporal nerve doubtless contributes mainly to supply sensibility to the posterior twigs of the facial: but so much difficulty do some see in satisfactorily accounting for the sensibility of the portio dura, that they find it convenient to discover two roots of origin, and a ganglion on one, thus reducing it to the class of compound nerves. See Arnold, Icones capitis nervorum; also Gaedechens, nervi facialis physiologia et pathologia.—Ed.]

* See Journal Complementaire, v. 20.

presented them to the animal, and it always undid the paper and possessed itself of the food; but, he adds, "I do not regard this experiment as satisfactory, because in other circumstances it appeared to me to want smell to discover food which I put near him without his knowledge" *(à son insu)*. However, the latter circumstance is overlooked by Magendie, and his conclusion is, "une fois le nerf trifacial coupé, toute trace de sensibilité disparait, aucun corps odorant à distance ou en contact, les corrosifs mêmes n'affectent plus en aucune façon la pituitaire."* Doubtless this conclusion is qualified by another immediately succeeding, "that does not prove that the seat of smell is in the branches of the fifth pair; but it proves at least that the olfactory nerve has an indispensable need of the branches of the fifth pair to be able to enter into action; that it is devoid of general sensibility, and that it can have only a special sensibility relative to odorous bodies."† The latter must be admitted to come, if not quite, at least very near to the general opinion, but it is altogether at variance with the former, and one is rather at fault for the author's precise meaning. Reference to later writings, however, leaves no doubt upon that point. In the conjoint work of Desmoulins and Magendie (1825) upon the nervous system of the vertebrata, besides other similar passages, will be found the following: "La cinquième paire, par ses branches nasales dans les mammifères, et par ses branches propres à la cavité pre-oculaire des trigonocéphales et des serpents à sonnettes, est donc l'organe de l'odorat."‡ Notwithstanding the weight of Magendie's authority, a careful review of the matter will not permit us to assent to this conclusion, and compels us to avow not only that it is not proved, but that the premises justify a contrary one. In the first place it is not warrantable to call the effluvia of ammonia or acetic acid odours: they are no more odours than the fumes of muriatic or nitric acid; and, though aware of the objection, he still calls them *odeurs fortes*, and bases his inference upon their operation. But he says the objection does not apply to oil of lavender or the animal oil of Dippel: this, however, is but an assumption at variance with fact; in the human subject these agents may act feebly upon the sensibility of the membrane of the nostrils, and may not appear to possess irritating properties; but this will not prove that they act similarly upon animals, whose organ of smell is more sensitive than that of man, and accordingly Dr. Eschricht,§ who combats the opinion of Magendie, has found that, on application to the nostrils of those animals upon which the experiments of Magendie have been performed, they produce all the same effects which ammonia or nitric acid does. In the second place his experiment of presenting food to a dog, whose olfactories had been destroyed, enclosed in paper, and in which the animal undid the paper, upon his own showing not only does not justify his inference, but, so far as it reaches, proves the contrary. To establish his position the animal must have discovered the food by smell, without knowing that it was in the paper; but it is manifest, from Magendie's own relation, that when the animal undid the paper, it knew, or was led by some circumstance to expect the food to be in it; but that when it was not already aware or in expectation that the food was near it, it did not discover it. To the writer it seems that the natural inference from the experiment, as related, is that the animal's proper sense of smell depended upon the olfactory nerves, inasmuch as it did not display fair evidence of its presence after their destruction, and that the sensibility displayed by the membrane of the nostrils after the destruction of these nerves, and dependent upon the fifth, has reference only to those impressions which are objects of tactile or general sensation, but not of the special sense.

At the same time, however, that we express our dissent from Magendie with regard to the nervous connexion of the proper sense of smell, it must be admitted that his researches positively indicate a distinction between the media of perception in the case of different agents operating on the olfactory organ, which it has been too much the habit to regard as producing their impressions all through the olfactory nerves: they have gone a considerable way in demonstrating the separation of those media; a result which is made complete by the continuance of the simple sense after the loss of the influence of the fifth nerve consequent upon disease: further, they indicate that sensations derived through the organ of smell are less simple than they are usually accounted; that they may be, and probably are for the most part, compound, resulting from the combination of impressions made upon the two senses thus shewn to be enjoyed by the organ.

Magendie's view has been adopted, and an endeavour made to corroborate and establish it by Desmoulins in 'Reflexions' upon a case communicated by Beclard, and published in the fifth volume of the Journal of Physiology. The case is that of a patient, in whom the olfactory nerves and their bulbs were destroyed by the growth of a tubercular disease from the anterior lobes of the brain; "yet he took snuff with pleasure, appeared to distinguish its different qualities, and was affected disagreeably by the smell of the suppuration of an abscess with which one of his neighbours was afflicted." From this case, from that of Serres, related elsewhere, and the experiments of Magendie viewed in connexion, Desmoulins has adopted the opinion that "the nerves and lobes called olfactory are alien to the sense of smell, or at all events co-operate so little in it, that the sense continues to be exerted without them; that, on the contrary, this sense resides essentially in the branches of the fifth pair, which are distributed to the nostrils." Serres' case has been discussed elsewhere; that of Beclard appears at first unanswerable; but

* Journal de Physiologie, t. iv. p. 306.
† Ibid.
‡ T. ii. p. 712.
§ Journal de Physiologie, t. vi. p. 350.

how will it appear after the qualification by which it is followed has been perused? "I owe it to truth," he says, "to add that these last statements were not collected till after the dissection, and that they were gathered from the patients of the ward." Such an admission manifestly destroys the value of the case: evidence obtained only after the individual's death, so little marked as during his lifetime to have been overlooked, and relating to a question at once so obscure and delicate, can hardly fail to be imperfect; but admitting that the patient did relish and distinguish between different kinds of snuff, and that he was disagreeably affected by his neighbour's ailment, what then? The chief property of common, if not of every snuff, is pungency and not odour, and the perception of pungency is not the function of the olfactory nerve; and one may be as disagreeably affected by a disgusting sight as by a disgusting smell, and the patients of the ward not make any distinction between the senses affected, until taught by the inquiries made that it must have been that of smell. And if the case just quoted prove the existence in the organ of smell of a sensibility to the impression of volatile agents independent of the olfactory, and conferred by the fifth nerve, the existence of another equally independent of the latter is satisfactorily established by the continuance of smell in those cases in which the faculty conferred by the fifth nerve has been lost through disease. This may be seen from reference to the case furnished by Beclard, and advanced by the very advocates of Magendie's doctrine in support of it; but the fact is still more strongly established by the case some time since published by Mr. Bishop, in which, though the fifth nerve was completely destroyed by the pressure of a tumour within the cranium, and both the ordinary and tactile sensibility of the same side of the face and its cavities was in consequence altogether lost, the sense of smell continued unimpaired. In a case of disease of the fifth nerve which the writer has witnessed, the patient did acknowledge the perception of certain odoriferous agents; but judging from it alone, he could not say that smell was not impaired; on the contrary it seemed very much so, inasmuch as the patient denied at first any perception of the impression of several agents accounted odorous, and when he did say that he smelt these, it was not of himself, nor until he had been particularly questioned, and then he said it was 'up in his head' that he felt the sensation, and positive must take precedence of negative evidence. Further, it is very likely that in the case of sensations, themselves neither disagreeable nor acute, the vividness of which may depend very much upon association with other and more acute ones, the former may be disregarded where the latter have been lost, and hence the rashness of inferring that brutes have lost certain faculties, because in the course of experiments they do not by the exercise of these give evidence of their existence. The fact of the absence of olfactory nerves in the Cetacea as established by Cuvier, has also led some to the conclusion that the proper faculty of smell may be capable of being transferred at least to the fifth; but until the faculty has been proved to exist in such case, the inference is manifestly not warranted by the premises.

It appears then that there is a distinct perceptive faculty enjoyed by the nostrils, independent of the fifth and dependent on the olfactory nerve; that we possess no positive evidence of the latter nerves being in any case the media by which this peculiar perception is recognized, but that they serve for the recognition only of impressions of contact, pungency, or irritation.

2. *Relation of the fifth nerves to vision.*—That in all animals having at once the faculty of vision and an optic nerve, the latter is indispensably necessary to the exercise of the former cannot be denied:—disease or division of the nerve is uniformly attended by loss of the function; but some circumstances countenance the opinion that the fifth nerve possesses a more important connection with vision than may at first appear. 1. Injury of the frontal and certain other branches of the fifth nerve has been long accounted among the causes of amaurosis. 2. Magendie has found that "on division of the two 'fifth' nerves upon an animal it seems blind." 3. The fact which countenances most strongly the opinion that the fifth nerve is concerned directly in the function of vision is derived from comparative anatomy. It has been stated that in certain animals a special optic nerve is wanting, and the ocular nerve is derived from the fifth pair. Of this it appears universally admitted that the proteus anguinus is an instance; its eyes are situate immediately beneath the epidermis, which is transparent* in front of them; the optic nerve is wanting,† and the only nerve received by the eye is a branch of the second division of the fifth.‡ Whatever vision, therefore, may be enjoyed by this animal, and according to Carus§ it is considerable, must be exerted through the medium of the fifth nerve. Among the mammalia also are several animals which appear to be in the same, or nearly the same state; but anatomists are not agreed on the point: the absence of a special optic nerve in the mole was announced by Zinn,‖ who shewed that its place was taken by a branch of the fifth. Carus and Treviranus, however, maintain that the optic does exist in the animal, but that it is very minute, grey, and capillary; that in the same proportion the fifth nerve is large, and that its second division at its exit from the cranium gives off a branch, which enters the globe of the eye, and according to the former concurs in forming the retina.¶ Serres again positively denies the existence of the optic nerve in the mole, and maintains that these anatomists are mistaken; he states that he has sought the

* Serres.
† Treviranus, Serres.
‡ Ibid.
§ Comparative Anatomy.
‖ De differentia fabricæ oculi humani et brutorum.
¶ Journal Complementaire, vol. xv.

nerve with the greatest care in thirty or forty of these animals, and never succeeded in finding it; and also in confirmation thereof that the optic foramen is wanting in the sphenoid bone. According to him several other of the mammalia are similarly constituted, viz. the mus typhlus, the mus capensis, the chrysochlore, and the sorex araneus. Of these the mole, the mus capensis, and the sorex arensis decidedly enjoy vision, the first according to the observations of Geoffroy St. Hilaire and Cuvier; the second according to those of Delalande, and the third according to Serres himself; and if his view of the anatomical disposition of their ocular nerve be correct, the fifth nerve must in them also take the place of the optic and serve as the medium of sight. Treviranus, though he maintains the existence of a special nerve in the mole, yet says, from the disproportion of the optic and the ocular branch of the fifth, that in that animal the latter ought or must have to fulfil in vision more important functions than the optic nerve.* When to these facts we add the view of the nervous connections of the senses in invertebrate animals advocated by Treviranus, viz. that the nerves of the senses in them are all branches of the fifth pair, the general proposition seems sufficiently probable, viz. that the fifth nerve is capable of acting as a medium of perception to impressions of light. But on the one hand, until it be proved what the exact nature of the optic faculty is which animals devoid of a special optic nerve possess, the question must be held to be undecided. It may be that the faculty is different in the two cases; that where the special nerve is absent, the faculty may amount, as suggested by Treviranus, to no more than a mere perception of light, and that the impression is then not visual, but only one of ordinary sensibility. Such a distinction, in the sense in which that term is understood in reference to the higher animals, is easily conceived, and indeed is demonstrable from the influence of light upon an inflamed or irritable eye, and if such a distinction do naturally exist, the apparent anomaly presented by animals being sensible of light and seeming to enjoy vision without a special optic nerve will be removed, while such a faculty may suffice fully for the condition of the animal. Again, the evidence in favour of the opinion that the fifth is directly concerned in vision where a special nerve exists, seems altogether insufficient. In the first place, though injuries involving the frontal or other branches of the fifth nerve may induce amaurosis, it remains to be proved that the injury of the nerve is the cause of the disease, and that this did not rather arise from the effect of the injury upon other parts concerned in vision; a view which is greatly confirmed by the fact that the mere section of the nerve has not been found to occasion any such affection of vision. In the second place the experiments of Magendie are far from satisfactory. In order to determine the influence of the fifth nerve upon vision, he performed the following experiments, from which he inferred that the section of the fifth nerve destroys sight without abolishing entirely all sensibility of the eye for light, and suggests in explanation either that the fifth is the medium of perception, or that it is necessary to enable the optic to act. After having divided the fifth pair on one side in rabbits, he threw suddenly upon the eye the light of a wax candle, and no effect was produced; the same being tried upon the sound eye, the only effect produced was movements of the iris. Under the impression that this was not sufficiently intense, he tried that of a powerful lamp, but, even with the assistance of a lens, the result was the same. He then tried the experiment with solar light, and by making the eye pass suddenly from the shade to the direct light of the sun, an impression was produced and the animal immediately closed its eyelids. Such data cannot be admitted as sufficient to justify the inference that vision is destroyed by the section of the fifth nerve. In the first place it is to be recollected that the experiment was made upon rabbits, in which Magendie has elsewhere told us that section of the fifth nerve produces strong contraction of the iris, consequently great diminution of the size of the pupil: and of what value, then, is the result that, under the influence of the light of a candle or a lamp, an impression was not made sufficiently powerful to cause the animal to give evidence of it? In the second place the animal did, under all the disadvantages, give sufficient evidence that its vision was not destroyed; there is, therefore, no reason for the conclusion drawn from the experiment related.

On the other hand, Mayo has found that the fifth nerve may be divided within the cranium in the cat and pigeon, and vision continue unaffected; which circumstance shows that the apparent loss of vision in the rabbit was owing to the great contraction of the pupil, while according to Magendie's statement there does not remain any trace whatever of sensibility to the impression of light in the eye after the section of the optic nerve. We must, then, conclude that the optic nerve is the proper medium of perception to visual impressions, and that the co-operation of the fifth nerve is not even necessary to enable the optic nerve to fulfil its function. As the instrument of the general sensibility of the structures of the eye, however, the fifth nerve may be the channel through which impressions not visual, though perhaps excited by an agent of vision, viz. light, may be conveyed.

The conclusion thus drawn from experimental physiology is fully confirmed in man by the history of those cases in which the influence of the fifth nerve has been lost from disease: of these two have been adduced by Bell in the Philosophical Transactions for 1823, one from the observation of Mr. Crampton, the other from that of Dr. Macmichael, in which the surface of the eye was totally insensible, whilst vision was entire; and another, still

* Ibid. vol. xv. p. 210.

more remarkable, has been reported by Mr. Bishop,* in which the functions of the fifth nerve seemed altogether obliterated by the pressure of a diseased growth within the cranium, and yet the patient saw distinctly to the last, the only derangement which occurred in the function of vision being the loss of the power of distinguishing colours, which appears sufficiently accounted for by a certain degree of pressure exerted by the tumour upon the optic nerve. Magendie endeavours to support his views upon this and other points connected with the properties of the nerve by reference to a case reported by Serres, which appears very inadequate, and will be discussed by-and-bye.

Influence of the fifth nerve on hearing.—The great affinity between the sense of hearing and that of touch renders it more easy to conceive how hearing might be excited through the medium of the fifth nerve. As we have seen that the ocular nerve in certain animals is a branch of the fifth nerve, so is the auditory. Among the cartilaginous fishes there are several instances in which this occurs. The origin of the auditory nerve from the fifth in fishes was first announced by Scarpa,† and by him supposed to apply to fish generally. This view is combated by Treviranus:‡ it is admitted in part by Serres; he states that in osseous fishes the auditory nerve is united at its insertion with the fifth; in cartilaginous fishes, that the auditory is sometimes confounded with the fifth, sometimes separated distinctly enough, as in the raia clavata. From his own observations the writer would say, that in the bony fishes the two nerves cannot be said to be united or to arise the one from the other, but only to have a common superficial attachment to the medulla oblongata; and from the analogy of the same nerves in the higher classes of animals, he would not admit, without further proof, a common superficial attachment as establishing identity of ultimate connection with the encephalon. As to the cartilaginous fishes, it appears to him that Serres has fallen into an error with regard to the connection of the auditory nerve. It appears to the writer that the fifth and the auditory are confounded in the raia clavata as plainly as in any other individual of the class; the posterior ganglionic fasciculus of the fifth and the auditory nerve form one trunk for a distance of some lines after leaving the medulla oblongata; they are at all events enclosed within the same sheath:§ but whether they are to be regarded as branches of a common trunk or not, it is difficult to decide. The weight of naalogy is certainly opposed to a conclusion in the affirmative; and, though this were admitted, a difference between the auditory and the other branches of the fifth (as supposed) must still be admitted, inasmuch as the auditory separates from the nerve before the occurrence of the ganglion, and has not itself a ganglion. On the other hand the auditory may be separated from the rest of the nerve, after the division of the common investing membrane, with little or no laceration of fibres. Still it may be asked why, if they be distinct nerves, are they united into one trunk? The opinion that the fifth nerve holds an important influence over the sense of hearing derives support from the circumstance, that in most, if not all, the cases of disease of the nerve, the sense of hearing becomes impaired, though not obliterated.

The last question proposed to be considered with reference to the functions of the fifth nerve is its connection with nutrition.

The opinion that the nerve controls the nutrition of the parts which it supplies has been advocated by Magendie, more particularly with regard to the eye. It has been already stated that we are indebted to this writer for information in regard to results of the division of the entire trunk of the nerve within the cranium. Of these the most prominent is the entire loss of sensibility on the same side of the face, and in regard to the eye especially, loss of sensibility in the conjunctiva, upon which the most irritating chemical agents then produce no impression. These immediate effects of the section were followed by others not less remarkable: on the next day the sound eye was found inflamed by the ammonia, which had been applied to it, while the other presented no trace of inflammation. Other changes, however, supervene. The cornea of the eye of the side on which the section is made, twenty-four hours afterwards begins to become opaque; after seventy-two it is much more so; and five or six days after it is as white as alabaster. On the second day the conjunctiva becomes red, inflames, and secretes a puriform matter. About the second day the iris also becomes red and inflames, and false membranes are formed upon its surface. Finally the cornea ulcerates, the humours of the eye escape, and the globe contracts into a small tubercle. In endeavouring to ascertain the cause of these changes, Magendie, on the supposition that they might be owing either to the continued exposure of the eye to the air or to the want of the lachrymal secretion, divided the portio dura in one rabbit, the effect of which is to destroy the power of closing the eyelids; and from others he cut out the lachrymal gland; but in neither case did opacity of the cornea succeed. The sequence of the effects mentioned after the section of the nerve might naturally lead us to infer that the loss of nervous influence gives rise to them. But such is not the inference drawn by Magendie, nor indeed can it be admitted: absence or subtraction of an influence cannot be directly the cause of an alteration in the condition of an object

* Medical Gazette, vol. xvii.

† De Auditu et Olfactu.

‡ Journ. Compl.

§ Serres seems to have overlooked the fact that there exist two ganglionic fasciculi in the raia clavata; that he has assumed the anterior fasciculus to be the fifth, and described the posterior, with which the auditory is connected, as the auditory and facial nerves: the error will be manifest upon tracing the distribution of the fasciculus.

otherwise than by allowing it to come or return to a state from which it is preserved by the presence of the influence; and there is no good reason, either theoretical or experimental, for believing that the state induced in the case under consideration is one in which the eye would necessarily be, which, in fact, would be natural to the organ but for the restraining influence exerted through the fifth nerve.

It is easy to imagine that the absence of such an influence should render a part slow to take on any vital action; though even this, until proved, is an assumption—an assumption which we are induced to adopt from the frequency with which sensation and pain are found associated with the establishment of certain vital processes, more particularly inflammation, but which is, on the other hand, contradicted by the readiness with which inflammation and its consequences are excited in parts whose nervous faculties are impaired or destroyed by agencies which make little or no impression when those faculties are retained, and which must be demonstrated before admitted, since it is manifest from the occurrence of that process after the destruction of all transmitted influence at least, that the principle—the main-spring of it must reside elsewhere; and hence that, if in the natural state the nerve influence the process at all by means of such a property, it can be only in the character of a secondary and controlling power. It does, however, seem proved by the result of Magendie's experiment, that the interruption of the influence did retard the inflammatory process, inasmuch as the eye, on the side of the undivided nerve, was very actively inflamed the day after the application of ammonia to it, whilst the other eye did not present any trace of inflammation; a circumstance by the way difficult, if not impossible, to reconcile with the doctrine that the process of inflammation is directly influenced in either way, whether positively or negatively, by the power of the nerve; and further, that the division of the nerve should diminish the vital powers of the eye, and thereby render it less able to resist the effects which inflammatory action tends to produce. But indeed there does not appear any reason for admitting that the alterations which took place in the condition of the eye were produced directly by the loss of nervous influence. Having, as he conceived, disproved, by the experiment related, the idea that the alterations were owing to the continued exposure of the eye to the air, or to the want of the lachrymal secretion,—the only other causes which appear to have occurred to him,—Magendie arrived at a conclusion the opposite of that just mentioned, and adopted the opinion that the phenomena "depend upon an influence purely nervous"* exerted by the fifth nerve upon the eye,—"an influence independent of the connection of the nerve with the spinal marrow,"†—an influence "proper to the nerve, which has not its source in the cerebro-spinal system, and which is even the more energetic, the farther we remove from that system to a certain distance," of which the following is his proof. "Alterations of nutrition in the eye are the less complete, the less rapid, as we remove farther from the point of branching of the nerves of the fifth pair, and as we cut, within the cranium, the fasciculus of origin the nearer to its insertion; finally, the section of the nerve on the margin of the fourth ventricle no longer produces any alteration in the state of the eye."* In this view there are plainly two positions advanced, viz. that the nerve does itself exert a proper and independent influence upon the nutrition of the eye, and that it is the section of the nerve which causes the exercise of that influence, or, to use his own words, which is the cause of the inflammation, &c. That the occurrence of the alterations in the eye, in the case in question, is not due to an influence exerted by the brain through the nerve, and that it must proceed from another cause, and that not dependent upon the connection between them, is manifest, since it is consequent upon the interruption of that connection; and therefore, if the nerve do possess the supposed influence, it must be a proper and independent one: but are we, therefore, to infer that the nerve does exert such an influence upon the organ? It appears to the writer that we cannot: for can we suppose that the nerve is endowed with a property to be displayed expressly under circumstances, which it is fair to say were not contemplated in the establishment of natural laws, viz. in cases of mutilation? or is it possible that a separate influence can exist in the nerve and increase in energy in proportion as the nerve is curtailed; for the nearer the section is made to the eye, the more remarkable are the effects; or if any other proof that the nerve does not possess such an influence be wanting, can we suppose that it is possessed for the eye and not for the other parts to which the branches of the nerve are distributed? Why does not inflammation forthwith assail the nostrils, the mouth, and cheeks upon the mere section of the nerve,† as well as the eye? Manifestly be-

* Anatomie des Systêmes nerveux, &c. t. ii. p. 716.

† Journal de Physiologie, p. 304.

* Op. cit. ibid.

† It is stated by Professor Alison, Outlines of Physiology, p. 147, that inflammation, ulceration, and sloughing are produced sometimes on the membrane of the nose and on the gums by section of the fifth nerve, "as was first ascertained by Magendie." The only passages approaching at all to this statement, which the author has found in Magendie's writings, are at page 181, Journal de Physiologie, t. iv, and page 717, Anatomie des Systêmes Nerveux, &c. Desmoulins et Magendie, t. ii. In the first he says, "when a single nerve is cut, there appear alterations in the nostrils, the mouth, the surface of the tongue on that side; the half of the tongue becomes whitish, its epidermis is thickened, the gums quit the teeth; the alimentary matters sink into the intervals which are formed; probably because the animals having no longer their attention attracted by the sensation of the tendency of the matters to pass between the teeth and the gums, push them thither without perceiving it;" and in the second, "a part of the broken food remains on that side, between the teeth and the cheek, and its contact terminates by ulcerating the

cause no such influence exists; and indeed the data upon which it has been assumed, instead of proving the position, leave it precisely as it was; for insomuch as the occurrence of the phenomena upon the section prove the existence of the influence of the nerve, in the same degree does the absence of the phenomena upon the section of the nerve disprove it.

But was the inflammation caused by the section of the nerve? This question, which certainly ought to have been determined satisfactorily before a theory had been founded upon the assumption, appears to the writer to have been decided too hastily in the affirmative. If the section were the cause, no sufficient reason can be assigned why it should occasion inflammation in one part, to which the nerve is distributed, and not in another, yet such is the case; the eye is the only part in which inflammation supervenes, either so uniformly or so quickly as to afford any ground for attributing the process to the section. In the second place, were the section the real and essential cause, it cannot be supposed either on the one hand that non-essential circumstances could influence, or at all events prevent the effect, or on the other, that they could produce it. Now it will presently appear that both the one and the other may take place; and a comparison of Magendie's experiments and their results would alone suffice to shew that the real cause is to be sought elsewhere than in the section of the nerve. Magendie divided the nerve in three different situations; first, through the temporal fossa; secondly, within the cranium, between the Gasserian ganglion and the pons Varolii; and thirdly, at the margin of the fourth ventricle; and his own general account of the results, which has been already cited, is as follows: "those alterations in the nutrition of the eye are the less complete, the less rapid, as we recede more from the point of branching of the nerves of the fifth pair, and as we cut, within the cranium, its fasciculus of origin the nearer to its insertion; finally, the section on the margin of the fourth ventricle no longer produces any alteration." It is plain, then, that the nerve may be cut, and the changes in the eye ensue or not, according to circumstances to be yet explained. On the other hand, that effects similar in kind, if not equal in degree, may be produced by circumstances not essential to their production,—according to the doctrine maintained, but incidentally associated with the supposed cause,—that such effects may be produced by such circumstances, when dissociated from the other and operating separately, the author feels justified in asserting, from the result of some experiments lately made by himself, which lead to the conclusion that similar effects may be produced without the section of the nerve at all, and that an injury in the vicinity of the orbit may excite them though neither the trunk of the fifth itself, nor its ophthalmic division have been divided. In an endeavour to determine the nerves of taste, he undertook the removal of the ganglion of Meckel from the dog; in order to accomplish this it was necessary to displace the zygoma and the coronoid process of the jaw; he attempted it several times before he succeeded, and failed at different stages of the operation; but in almost every instance the eye of the same side became bleared within the next two days. The animal kept it nearly closed: a whitish puriform matter was discharged from it, in quantity proportioned to the case, which concreted between the lids; and the animal made no attempt to remove the matter or cleanse the eye: the affection of the eye was always proportioned to the violence done, and abated with the inflammation of the wound; and in one of the instances in which the ganglion was removed, it actually produced opacity of the cornea, and ulceration in that structure, which continued after the lapse of more than a month from the operation; yet most assuredly neither infra-orbital nor ophthalmic nerves had been divided. Thus, if, on the one hand, the nerve may be cut and the changes not ensue, on the other it may be left uncut, and the changes may occur.

It may be objected that the effects here described fall very far short of those which took place in the experiments of Magendie. That they fall short of those which occurred on the division of the nerve in the temporal fossa is quite true, but it is equally so that they far exceed those consequent upon the section at the margin of the fourth ventricle. The objection, therefore, would be devoid of weight, and if we suppose superadded to the violence already done when the nerves are not divided, the additional violence necessarily inflicted in the division of them, we shall have a ready explanation furnished of the higher degree to which the effects produced amount in one case than in the other.

From the preceding considerations it appears to the author necessary to infer, that the changes which supervene in the eye after the section of the fifth nerve in certain cases, take place independently of the section, as the primary, immediate, or proper cause; for were it otherwise, it cannot be supposed either that the difference of half an inch to one side or the other, as regards the point of section, could so influence the cause as to prevent or allow these changes, or that they could occur, even in degree, without it.

How, then, are the phenomena to be explained? It has been said by Magendie that they are less marked the more we recede from the point of branching of the nerve; but it is to be further observed, that, as we recede from the point of branching of the nerve, we recede

buccal membrane." In neither of those extracts is there mention of inflammation or sloughing; and the ulceration which *is* mentioned, is attributed to another cause than the section of the nerve. On the other hand, the writer has frequently divided the lingual branches of the fifth nerve and preserved the animals for months afterward, and he has been unable to detect any change in the condition of the tongue, except this, that in some the tip of the organ, from being allowed to remain between the teeth, and thus to be exposed to injury, ulcerated, and this continued until the tip was removed, when the extremity of the organ healed, and it appeared to be in all other respects as before.

also from the orbit, the eye and its appendages, and in our operation for the division of the nerve we do less violence either in their vicinity or actually to them, until the operation is performed at such a distance from those parts, that they are not involved in the injury inflicted. Thus the nerve cannot be divided through the temporal fossa without great violence done to the parts in the vicinity of the orbit, and connected with the eye as well as the fifth nerve, as is evident from the result, and as has been explained elsewhere.* In the section between the ganglion and the pons, the violence is inflicted at a part more remote than the former, from the orbit, &c., and here, according to his own account, the effect upon the eye was much less considerable. But the most remarkable fact is, that the alterations of nutrition are much less marked than in the former mode of experiment; there forms only a partial inflammation at the superior part of the eye, and the opacity which ensues occupies but a small segment upon the circumference of the cornea at the superior part; and in the third case the parts injured are so far removed from the eye,—(in dividing the nerve on the margin of the fourth ventricle, Magendie exposed the parts by "opening the spinal envelopes between the occiput and the first vertebra,")—that the effects of the injury could not, under ordinary circumstances, extend to it, and accordingly in it no alteration occurred. It would seem, then, that the great violence† inflicted, either in the vicinity of the eye or actually to its appendages, constitutes the primary and immediate cause of the alterations which took place in the eye in the experiments under consideration. But it is likely they were the result of more causes than one, for there were also engaged in the experiments other agencies, the influence of which must have enhanced greatly that of the violence inflicted by the operation; thus, in the first place, in some of the instances at least,—and we have no evidence that it was not so in all,—a highly irritating agent was introduced, and, in consequence of the insensibility of the organ, probably in considerable quantity, into the eye; and in the second the eye was left under circumstances more than enough to excite inflammation and to produce serious injury to it, though the organ had remained in full possession of all those safeguards with which its sensibility and the sympathetic action established thereby between its several protecting appendages naturally endow it; for "the eye was dry;" and "the eyelids were either widely open and immoveable, or else they were glued together by the puriform matters, which were dried between their margins;" and an organ so circumstanced has abundant cause for inflammation, independently either of nervous influence or of its absence. It may be said that Magendie has proved that neither the open state of the eyelids nor the want of the lachrymal secretion is adequate to the effect. Admitting for a moment that he has, he certainly has not shewn that the combined influence of the two is inadequate to produce it; but the first position is by no means satisfactorily established: his mode of determining the question, whether the inflammation was excited by the eye remaining constantly open or not, was by the division of the portio dura, and his experiment has certainly proved that the effect of the section of that nerve will not excite inflammation in the eye, but no more; inasmuch as such section does not produce a permanently open state of the eye: an eye so circumstanced will be closed during sleep, and even during the waking state it requires attention and experience in such observations to discover that the animal has lost the power of closing the lids by a muscular effort of those parts themselves; for by the sudden exertion of the power of retracting the eye, which inferior animals possess to a remarkable degree, the lids become nearly, if not quite, closed, and the animal appears to wink as well as before, while by rolling the eye the different parts of its surface are in turn brought beneath the lids, and thus no one part is ever left long absolutely uncovered. So great indeed is the power which brutes possess in this respect, that the author has seen a dog in which the portio dura had been divided on one side, presented for observation, and persons aware that the nerve had been divided, yet not able to discover on which side it had been done, and even deny that the lids were paralyzed on either side, until something was approximated to each eye successively, when the uninjured eye was at once closed, but the other remained open, and the animal appeared looking at the object, which it was unable to exclude. It is obvious, then, that the question has not been and cannot be determined in this way.

To the causes already enumerated must be added the loss of the nervous influence, for it is not intended, in what has preceded, to assert that the section of the fifth has no share in the production of the changes in the eye, but only that it is not the primary or essential cause of them. Indirectly it must contribute powerfully to produce and aggravate, or it may even excite

* It is hardly possible to conceive the section effected at the point and in the mode adopted, without a division of most of the nerves and vessels supplying the eye and its appendages.

† A better idea of the injury likely to be inflicted in the experiment will be formed from a brief account of the mode of conducting it. A lancet-pointed style is driven into the cranium through the temporal fossa and through its base, and when carried in to such depth as the experience of the operator teaches him to be sufficient, its point is moved upward and downward, until the loss of sensation in the superficial parts assures him that the fifth nerve has been divided. After such a proceeding the question should rather be, what mischief has not been done than what has. There cannot be any assurance that, in the division of the fifth, the third, fourth, and sixth nerves with the branches of the sympathetic—nay, the optic itself—have not been involved: and if to this be added the almost certainty of dividing the internal carotid artery, from which the supply of blood to the internal structures of the eye is directly derived, and the division of which causes the death of the greater number of the subjects of experiment, an amount of injury will be made out, quite adequate to account for the total loss of the eye, and which must reduce the influence of the fifth in producing it to a low degree indeed.

them; for by destroying the sensation of the organ, it must leave it exposed to the uninterrupted influence of many irritating agents, which naturally would excite inflammation, were it not that we are warned through the sensibility of the organ to avoid or to remove them, but in every such case they are the immediate, and the insensibility only the mediate cause of the effects produced, and such, it appears to the author, is the part played by the section of the fifth in giving rise to inflammation in the eye. It is further to be observed that the occurrence of inflammation in the eye in cases in which the influence of the fifth nerve upon it had been lost, had been noticed and given to the public by Bell prior to the publication of it by Magendie. In the Philosophical Transactions for 1823, (Magendie's memoir dates 1824,) Sir C. Bell reports the case of a patient under the care of his colleague Dr. Macmichael, in which the surface of the eye was totally insensible, and the eye remained fixed and directed straightforward, while the vision was entire. "The outward apparatus being without sensibility and motion, and the surface not cleared of irritating particles, inflammation has taken place, and the cornea is becoming opaque; thus proving the necessity of the motions of the eye to the preservation of the organ." And in the same volume he reports also a case from the experience of Mr. Crampton of Dublin, bearing strongly upon the question, because it shews satisfactorily that the sensation of the organ, and consequently the influence of the nerve, may be obliterated, and inflammation not ensue until a stimulus have been applied, though the conjunctiva manifestly retained its susceptibility to the impression of that stimulus. Mr. Crampton's account of the case is as follows: "When she told me her eye was dead, as she expressed it, to be certain I drew my finger over its surface, and so far was this from giving her pain, that she assured me she could not feel that I was touching it at all. The eyelids made no effort to close, while I was doing this; but the conjunctiva appeared sensible to the stimulus, as a number of vessels on the surface of the eye became immediately injected with blood."

Another circumstance may be advanced in favour of the opinion that the nerve influences the nutrition of the parts, to which it is necessary to allude, viz. the wasting of the muscles of mastication in cases of the loss of the nerve's influence. This fact may be otherwise explained; the development of muscles is always influenced by their exercise, which being lost they waste, and it is neutralized by the counter-fact that, though these masticatory muscles waste, the muscles of the face and its other structures do not. In fine there appears to the writer to be no good reason for attributing to the fifth nerve a direct influence upon the nutrition of the structures to which it is distributed; the existence of such an influence would be incompatible with the simplicity of natural laws, for in such case there must be two such influences in existence, one in the nerve directing the nutrition of the parts with which it is connected, and another elsewhere to direct that of the nerve.

Magendie confirms his view of the influence exerted by the fifth nerve upon the functions and nutrition of the eye, by reference to a case published by Serres in the fifth volume of the Journal of Physiology, which "presented all the phenomena attending section of the fifth pair," and in which there existed complete alteration of the trunk of the nerve in its sensible portion; "followed by loss of sight, of smell, of hearing, and of taste on the same side." Before detailing this case, the writer cannot refrain from observing that in such cases none but unquestionable evidence can be admitted if we would arrive at a certain and unquestionable conclusion. Whether the case of Serres be such, it rests with the reader to decide; and first, what was the condition of the patient in other respects? Serres replies: "His air was dull; his physiognomy gave, at first sight, the idea of imbecility; he seemed to conceive slowly and to comprehend with difficulty, the questions which were put to him. When he wished to reply, it was evident that he experienced difficulty in expressing himself; he pronounced with difficulty, and the little that he said seemed to require, on his part, a considerable effort: his cranium was voluminous compared to the rest of his body; some pupils suspecting a commencing hydrocephalus, thought that they observed a separation between the parietal and temporal bones, but the prominence of the eyes made me reject that conjecture; the maxillary and malar bones were a little separated, which had produced a flattening of the nose; the patient had some difficulty in moving the tongue; the motions and sensibility of the limbs were not affected, only he moved the lower extremities less freely than the upper; he had been for some time subject to epilepsy; he had a sister deaf and dumb." A case so complicated as this, in which there manifestly existed extended disease of the encephalon, must be rejected as altogether inconclusive. But to proceed, the patient was admitted into hospital in *September* 1823: at his *admission* he had a chronic ophthalmia of his right eye, which was considered scrofulous. In the course of *December* he was attacked by an acute ophthalmia of the same eye, attended by *œdema of the lids*, and commencing opacity of the cornea; the ophthalmia was dispersed after ten or twelve days; but the cornea was rendered altogether opaque throughout its whole extent; of course the loss of vision on that side was the necessary result. In the course of January 1824 it was observed that the right eye was insensible, and soon after that the eyelid and nostril of the same side were also insensible, and likewise the tongue on that side, while all was natural on the other; soon after the gums inflamed upon the right; they were red, some white places existed here and there, they were swollen at the circumference of the sockets; the tongue moved always with difficulty; the hearing was not then affected; in July the affection of the gums extended to the left side, but the right was always more affected than the left. During August the gums became separated on the right from the necks of the teeth; there existed between the latter and the gums spaces into which tartar and portions of food had penetrated; the patient suffered from the epileptic paroxysms with variable degrees of severity: he next fell into a general cachexy, with extreme debility, impeded respiration, small frequent pulse, great alteration of countenance, and unusual taciturnity. It is stated that in August he acknowledged deafness on the right, which diminished and again increased; the sensibility was perfectly preserved in all the extent of the right side of the face; the patient died on the 12th of August. Both the brain and the fifth nerve were found after death much diseased, the brain on the left and the nerve on the right side.

The details of the case have been given more at length than may perhaps seem necessary, but the question is interesting, and as the bearing of the case upon it could not be determined otherwise, the writer has endeavoured to give them faithfully. The difficulty of obtaining precise knowledge from so complicated a case has been already adverted to. We come next to inquire how far it substantiates the writer's views, or how far it can be considered to establish the opinion of Magendie. Serres, as has been already stated, announces it as an instance of disease of the fifth nerve followed by loss of smell, sight, hearing, &c. Surely the loss of these several functions, thus announced, should have been satisfactorily established, before asserted; but such does not appear to have been the case. For the first, notwithstanding the announcement, we find Serres himself, after the patient's death, acknowledging, " toutefois l'odorat n'avait pas completement disparu, puisque,"* &c. The sense of smell then plainly was not *lost*. In the next place there was loss of vision, but from what cause? from opacity of the cornea, and, so far as we have data for forming a judgment, from it alone. We have no reason to think that any alteration had been produced in the power of the eye to receive sensations of light, any disturbance in the function of the retina, or any other change than the occurrence of a physical impediment to the exercise of a function, which the organ may have retained in full vigour, had it only been allowed to exert it: the evidence, therefore, afforded by the case, is too imperfect to be of value.

Let us next inquire how far it bears out the opinion that the fifth nerve possesses a proper and direct influence upon the nutrition of the eye: here we shall find ourselves equally at fault for the resemblance which it has been sought to establish. In Magendie's experiments the section of the nerve preceded the occurrence of the phenomena, and it is reasonable to expect, that, here, the loss of sensibility, which we are to regard as the analogue of the section, should have preceded the occurrence of the inflammation of the eye; but no. The patient had a chronic ophthalmia, considered scrofulous at the time of his admission; (he was admitted in September, and in December he was attacked by acute ophthalmia, attended by œdema of the lids; a circumstance not noticed in any of Magendie's experiments;) the inflammation was dispersed, and in the course of January, and not till then, (i. e. four months after his admission and about one after the occurrence of the second inflammation,) the insensibility of the eye was for the first time observed. Surely we have no reasonable grounds here for attributing the inflammation of the eye and the opacity of the cornea to the disease of the nerve, or for supposing that there existed any connexion, in the relation of cause and effect, between them. If we seek for a resemblance in other points, we shall be equally disappointed. It has been already remarked that œdema of the eyelids, which occurred in this case, is not one of the phenomena of Magendie's experiments. Again, the affection of the gums related is altogether unlike: in Serres' case they are stated to have become inflamed, and to have been affected on both sides, only more on the right than on the left; in Magendie's it is simply stated that they separated from the teeth and only on the side on which the nerve had been divided; and, lastly, the continuance of sensibility upon the right side of the face throughout casts an impervious obscurity over the entire.

Besides those effects of the section of the trunk of the nerve which have been discussed, there are others, for which we are indebted also to Magendie, and which deserve notice.

He found after the section of the nerve that the eye was dry, and the motion of winking had ceased; the globe of the eye itself seemed to have lost all its motions; the iris was strongly contracted and immoveable. The loss of sensibility in the conjunctiva, and the suspension of the secretion of the tears, he refers to the loss of the influence of the fifth nerve upon the former part and upon the lachrymal gland: the explanation of the first is in accordance with the previously established properties of the nerve as already ascertained by Mayo, but it is not equally so that the secretion of the lachrymal gland is directly controlled by the same influence, and it remains to be determined whether the effect in this case was not an indirect one, consequent upon the previous insensibility of the conjunctiva. The other results of the section—the immobility of the eyelids, that of the eye, and the permanent contraction of the pupil—he has not satisfactorily explained: the immobility of the lids may, it appears to the author, be attributed with much probability to the insensibility of the conjunctiva or of the internal structures of the eye, and seems a likely consequence thereof: the ordinary action of winking would seem to be called into play through the sensations of those structures, and the cessation of that action upon the loss of their sensibility is as natural an effect as the immobility of the lips

* Journ. de Phys. t. v. p. 245.

on the contact of food consequent upon the division of the infra-orbital and inferior maxillary nerves: and this view derives confirmation from the circumstance that in the instance under consideration the immobility of the lids is not the consequence of paralysis, for on the sudden admission of solar light into the eye, the action of the muscle was excited, and the eyelids were closed. The immobility of the eye itself the author cannot but regard as an incidental circumstance, caused by the complication to which Magendie himself refers, viz. the division of the motor nerves of the eye along with the fifth, and this explanation is rendered more likely, if not confirmed, by the effect of the section when made between the ganglion and the brain, in which case the motor nerves are not involved, nor the motion of the eye affected. It is to be regretted that Magendie has not given a report of a dissection after death of some of the animals upon which the former experiment had been performed, by which the question might have been determined. The permanent contraction of the iris is an extraordinary and as yet unexplained effect: it occurred only when the experiment was made upon rabbits, and is at variance with the results of similar experiments upon other animals, performed both by Mayo and by Magendie himself. In Mayo's* experiments, which were done upon pigeons, in no instance was contraction of the pupil caused by division of the nerves connected with the eye or its appendages. When the optic nerve was divided, the pupil became fully dilated. When the third nerve was divided, the same result ensued; and when the fifth was divided, the iris contracted as usual on the admission of light; in Magendie's experiments again upon cats and dogs the pupil was enlarged.† The fact is, however, confirmed by Mayo, who found that when the fifth nerve was compressed in a rabbit after death, the pupil became contracted slowly and gradually, and then slowly dilated; and when the nerve was divided, the pupil became contracted to the utmost, aod remained so. A corresponding difference between the conditions of the pupil after death in the subjects of experiment has been observed by Mayo, according to whom in the pigeon and cat it is naturally dilated, but in the rabbit, on the contrary, contracted.‡

It has been already stated that Magendie divided the nerve within the cranium both after and before the occurrence of the ganglion: in the latter case—when the section is made between the ganglion and the brain—the results are different in some remarkable respects from those attending the section in the former: the effect upon the senses is equally marked; but the motions of the globe of the eye are preserved almost always, from which the author would infer that the loss of those motions in the former must have been caused by the division of the motor nerves along with the fifth, by the side of the cavernous sinus; and also the changes which occur in the tissues of the eye are much less considerable; the inflammation and opacity ensue, but not to the same extent.

Another very remarkable result of the section is displayed in the animal's mode of progression as related by Magendie: "when the two nerves are cut upon an animal it seems blind, and its mode of progression is most singular; it advances only with the chin leant strongly upon the ground, pushing thus its head before it, and using it as a guide as the blind does his staff: the progression of an animal in this state differs altogether from that of an animal simply deprived of sight; the latter guides itself easily by means of its whiskers, and by the sensibility of the skin of its face; it stops at hollows, feels obstacles, and, in fine, it would be difficult to know whether it is blind or not; while the animal whose fifth nerves have been cut has but one mode of moving, and instead of avoiding obstacles, it persists often in pushing against them for several hours, so as finally to excoriate the skin of the anterior part of the head."*

This account, which is well calculated to excite at first extreme surprise, is after all strictly consistent, and illustrates strongly the importance of the nerves in question: in fact to the animal so circumstanced the head and face must be as a part which it does not possess, or rather of which it has been suddenly deprived, and which it yet believes itself to retain; it can have no consciousness of their existence, while from habit, memory, and ignorance of the real condition of the parts, it yet believes them to be present, and to exercise all their usual functions. Thus the human being whose limb has been removed without any knowledge of what has actually occurred believes that he still possesses it, acts as if he did, and is only convinced of his loss by the evidence of the senses of sight and touch. In like manner the animal acts under the impression that it still possesses its ordinary faculties, and being altogether unconscious of the contact of obstacles in consequence of its loss of sensation in the part which encounters them, it acts as if it were not in contact with them, and endeavours still to advance, while it is unable to make use of sight, if this faculty be retained, as a a guide, because it has lost the correcting and regulating assistance of the sensation of its face as exercised through its whiskers; and hence it does not appear to the author that the apparent blindness of the animal proves real blindness. Unassisted sight cannot teach us the distance of objects; and the animal suddenly deprived of the faculty of sensation may see the object, but not being made aware of its contact, must suppose that it has not reached it, inasmuch as the usual notice of its presence is not given by the sensibility of the face.

Lastly, when the nerves have been divided

* Comment. part ii, p. 4, 5.
† Journal, t. iv. p. 309.
‡ Physiology.

* Journ. de Phys. t. iv. p. 181.

upon both sides, the lower jaw ceases to be supported by its muscles, and falls.*

Influence of disease on the functions of the nerve.—The inferences drawn from the anatomy of the nerve and from physiological experiment conjointly have been confirmed in a remarkable manner by the effect of disease of the nerve upon the functions of the parts to which it is distributed: several instances have been published exemplifying either partially or completely that effect, when, whether from disease of the trunk of the nerve itself or from pressure upon it, its office has been interrupted, all the parts supplied by it are deprived altogether of both their tactile and ordinary sensibility: this loss of sensibility extends to the whole of the corresponding side of the head so far as the distribution of the nerve reaches to the forehead, temple, ear, surface of the eye and its appendages, cheek, nostril externally and internally, lower part of the face, lips, and mouth, the corresponding half of the tongue, of the palate, and the fauces; upon all these parts the roughest contact produces no perceptible impression; inflammation is not attended by pain, the most pungent or irritating effluvia do not affect the nostril or the conjunctiva, and the sense of taste is altogether lost in the anterior part of the same side of the tongue: at the same time the muscles of mastication—the external ones at least—lose their contractile power, remain inactive during the process and waste, whence are produced a flattening and depression in the site of the temporal and masseter, with prominence of the adjoining points of bone: however the special senses continue unaffected apparently, unless in so far as the sense of contact may be necessary to the perfect or ordinary fulfilment of their function, the olfactory function seems much impaired; the patient is insensible to the impression of ammonia, snuff, or other pungent agent, but still acknowledges a perception of odour. Vision continues throughout, and appears unaffected, unless from the supervention of inflammation, by which the eye may be spoiled, or from the extension of the disease to the optic nerve or the brain: in the case before alluded to, which the author has witnessed, vision remained perfect for a considerable time; amaurotic symptoms supervened during the course of the disease; but even after the occurrence of opacity of the cornea in consequence of inflammation, the patient could still distinguish light. Hearing appears to have been affected in most, if not all the cases, in which the disease had attained a considerable degree; it was so in the case seen by the author; the sense of contact would seem associated with the perfect exercise of the sense. The facial muscles retain their contractile power; in the instance alluded to, though the temporal and masseter seemed quite paralyzed, the buccinator acted with energy as ascertained by holding the cheek between the finger and thumb during its contractions; the slight want of adjustment, which may occur about the mouth, seems caused by the want of sensation in the lips. Lastly, in all such cases the eye of the affected side is liable to have inflammation excited in it by incidental causes; for the most part this occurs at an advanced stage of the disease, and can be referred to some exciting cause; it is attended by but little, if any pain, and opacity of the cornea is an usual result.*

* Magendie, Bell.

(For the BIBLIOGRAPHY see NERVE.)

(B. Alcock.)

FŒTUS, Gr. κυημα; Fr. *fœtus;* Germ. *die Frucht;* (normal anatomy). See OVUM.

FŒTUS (abnormal anatomy). Considering the peculiar circumstances of the fœtus in utero, we would, at first sight, be inclined to suppose that, although of course exposed to the risk of injury from accidents or diseases occurring to the mother, it would not be liable to many or serious accidents of its own; nevertheless, observation and experience soon reveal to us a very different state of facts, and force upon us the sad truth that the seeds of life are often sown adulterated with those of infirmity and decay, that disease may mutilate, and death destroy, even before our entrance into life; for as far as investigation has enabled us to reach, we have reason to believe that the child before birth is not only liable to certain affections which may be considered peculiarly its own, but is also subject to almost all those which affect the adult.

Of these affections some appear to be, 1. strictly innate in the constitution of the fœtus; 2. some communicated by infection from the mother's system; 3. some from the father's system, or perhaps *through* that of the mother, she herself not being the subject of the affection entailed, as in certain forms of syphilis, scrofula, and small-pox; 4. some, from strong mental impressions on the mother; 5. some, arising from morbid alterations in the envelopes of the ovum, the placenta, and cord, or in the uterus itself; 6. some, from the influence of external agents, as falls, blows, pressure, &c.

The investigation of these abnormal conditions is invested with a deep interest, not only as an important pathological inquiry, but as conducive to the adoption of measures calculated to be beneficial to both mother and child; to the child, by suggesting the strong necessity for preventing the exposure of the mother to influences likely to affect the welfare of her unborn offspring, as well as for removing their effects by proper remedial means: and to the mother, by affording us occasionally information of the existence of diseased taints in her system, of which we might otherwise long remain ignorant; or by guarding her against the ill effects of unhealthy states of the child; for, although each individual has a separate existence, there is at the

* Mayo, Commentaries and Physiology; Bell, Philosoph. Transactions and on Nerves, 1830; Serres, Journal de Physiologie, t. viii; Noble, Medical Gazette; Bishop, Medical Gazette, vol. xvii.

same time a very close and intimate mutual dependence of the one on the other; and, contrary to what we would at first expect, the health of the mother is more apt to suffer from morbid conditions of the fœtus in utero than is the latter to be injured in its developement by the state of the mother's system. Thus we see how great a disturbance is often caused in the maternal system by a blighted ovum, or a dead and putrid fœtus; while, on the other hand, we frequently observe that women in states of the most infirm health,* both mental and bodily, nay even when sinking under the ravages of some wasting disease, or depressed and worn out by mental suffering, by want of food or excessive fatigue, give birth to full-grown and well-thriven children.

The affections to which the fœtus is liable vary not a little according to the period of its existence at which we consider it; during the earlier periods, when the formative process is in most active operation, and the developement of the different organs is proceeding rapidly, many important and remarkable organic alterations take place; some from arrest of development caused by imperfection in or morbid alteration of the structures of the ovum; some by destruction of parts already formed, by atrophy or inflammation, or both conjoined; some by the effects of excessive secretion and the consequent unnatural distension, &c.; while those affections, to which more strictly belong the name of diseases, affect the more matured fœtus, whose organization approaches more closely that of the new-born child.

In order to give a full account of the morbid and abnormal conditions of the fœtus, we should embrace also those of its appendages or surrounding structures of the ovum; these, however, will be alluded to at present only so far as is absolutely unavoidable, as they will receive full consideration in the articles OVUM and PLACENTA: and in like manner several varieties of malformation will be with more propriety described under the head of MONSTROSITY, while others will be found under the account of the different organs concerned.

The germ, even before its vivification in the ovary, may have a morbid taint communicated to it from the system of the female in whom it resides, or from that of the man with whom she cohabits, so that the tendency to disease or malformation sometimes precedes the first impulse that leads to the establishment of life. Another source of abnormal conditions in the fœtus occurs in the cohesion or intus-susception of germs, in consequence of more than one ovulum being contained within the same vesicle; under which circumstances unnatural union may take place between two fœtuses, and give rise to the production of such anomalies in organization as the Siamese twins, or to other forms of fœtal duplicity, more or less resembling the remarkable instance represented in the annexed sketch of two children born a few years since at Boyle, in the county of Roscommon.

Fig. 146.

They were born alive, and lived for more than a week; after death they were sold to the College of Surgeons in Dublin, in whose magnificent Museum a preparation of their skeleton is preserved.* The writer lately received from the President of the College of Physicians, Dr. Croker, two hen's eggs united at their end by a connecting stalk as thick as one's little finger, which, in common with the two eggs, was covered by a tough white membrane.

From intus-susception of one germ within another, arise also some very singular phenomena, such as the existence of perfect teeth set in bony sockets, long hair, &c. in situations far remote from those in which such structures are naturally formed; and the still more extraordinary fact of fœtuses being found within the bodies of males;† facts which, in the opinion of the writer, can be explained only on the supposition of original intus-susception of germs, constituting that abnormal condition which has been called monstrosity by inclusion;‡ an accident which appears to be by no means confined to the germs of the mammalia nor even of the animal kingdom. The writer has in his museum a small egg about as large as a gooseberry, which was found within another egg of the common hen, which also occurred to Harvey,§ who says, "I have seen an exceeding small egge, which had a shell of its own, and yet was contained within another egge, greater and fairer than it, which egge also had a shell too. And this egge I shewed King Charles my most gracious master in presence

* See several instances recorded by Mauriceau, Malad. des femmes grosses, vol. ii. obs. 439, 497, 530, 622, 629, 656.

* See also case by Dr. Alcock in Dublin Medical Essays, vol. ii. p. 33, and Hall on the Cæsarean operation, p. 470.

† Med. Chir. Trans. vol. i. p. 234, case of a fœtus found in a young man, by Nathaniel Highmore, 1815.

‡ See Archives Générales de Médecine, tom. vii. p. 355.

§ Exercitation xi. pp. 50, 51; Ent's translation.

of many others; and that very year cutting up a large lemon, I found another, small, but yet a perfect lemon in it, which had also a yellow rind."

Many other instances of anomalies resulting from cohesion and intus-susception,* might be referred to, but they will find their place with more propriety under the article MONSTROSITY.

Mislocation of the germ during its growth and development is well known to be productive of serious consequences, not only to the fœtus, but unfortunately involves great danger to the mother also, as in those instances in which it has been developed in the ovary,† the Fallopian tube, the cavity of the abdomen, or in the substance of the uterus constituting interstitial pregnancy.‡

Atrophy.—A very common occurrence to the fœtus in utero is atrophy, or a complete arrest of growth from disease attacking its envelopes, especially the placenta or cord; in which case, a deficient and unhealthy supply of nutrition is furnished to the child, which either perishes completely or has its development retarded to such a degree, as not to present dimensions or characters corresponding to perhaps half the period that has really elapsed since conception; as happened in the following case: a lady who menstruated in the last week of July, began about the middle of August to exhibit unequivocal symptoms of pregnancy, which proceeded regularly till the middle of October, when indications of threatened abortion appeared, with pain, and the repeated expulsion of large coagula and substances of various appearances. After this, the previously existing symptoms of pregnancy entirely disappeared, and it was supposed that miscarriage had occurred and that the ovum had escaped, unnoticed, amidst the masses of coagula. The lady resumed her ordinary habits and went into society as usual, without experiencing any uneasiness or unhealthy symptom, except irregular uterine discharges, which were supposed to be menstrual: so matters proceeded until the 7th January, when, after a long drive, she was seized with periodical pains accompanied by smart uterine hæmorrhage, in consequence of which I was sent for. I found the os uteri open and an ovum partly protruded through it, this I succeeded in disengaging and bringing away; on examination it presented the general appearances as to size, form, and growth of the fœtus, of an ovum of less than two months, but the placenta was as large and as much formed as it should be at three months, and was moreover quite unhealthy, being throughout affected with what is usually called the tubercular state of that organ; the fœtus seemed perfectly healthy, but very small; and the umbilical cord was only about half an inch in length, much hypertrophied, being suddenly enlarged on leaving the placenta, to three or four times its natural diameter, and again as suddenly contracted almost to a thread, where it joined the abdomen of the fœtus. See subjoined sketch, of the natural size.

Fig. 147.

Cruveilhier* relates the particulars of a case in which the effect of disease of the placenta in producing atrophy of the fœtus was strikingly shewn in twins at the sixth month, one of whom possessed the full development and characters belonging to that period, but the other, whose portion of the joined placentæ was thin and unvascular, presented a size corresponding to not more than three months, as shewn in *fig.* 148.

In another case, formerly under the writer's care, the fœtus expelled at the ninth month had only grown during the first three.†

Such cases as the above possess an interest and a demand on our attention of a very important kind, as illustrative of the necessity for carefully examining into the state of the fœtal appendages as to their healthy condition or otherwise, before we venture to pronounce an opinion on the time that has elapsed since conception, merely from the size or general appearance of an ovum or fœtus shewn to us; for here we have, in one instance, an ovum, the size of which and that of the contained fœtus, would indicate a period of *two months'* pregnancy only, whereas *five months* had really elapsed from the time of conception, for the parties had not cohabited since the time of the threatened abortion; and in the other case an ovum of *three months'* growth is expelled *nine months* after conception. Now, in either case, had the husband happened to die, or to have

* See Dublin Journal of Medical Science, vol. iv. p. 294, and as before note †.

† See Dub. Med. Journ. vol. ii. p. 195.

‡ See a full account of this subject in Memoires by Breschet and Geoffroy St. Hilaire; Repertoire Générale d'Anatomie, &c. No. I. pp. 72, 75, 91.

* Anatomie Pathologique, liv. vi. pl. vi; see also Gräetzer, die Krankheiten des fœtus, p. 83.

† See my Exposition of the Signs of Pregnancy, &c. pp. 96, 7, and also pp. 210, 11, and 259, 60, of same work.

Fig. 148.

gone from home, shortly after the time of conception, and the accident to have occurred in the same way, the female might have sustained, though most unjustly, a severe injury to her reputation.

Herniæ.—Hernia is a very frequent occurrence in the fœtus, especially at the umbilicus, where, in the earlier periods of fœtal life, the anterior wall of the abdomen is deficient and the intestines covered by the expansion of the sheath of the cord, into which they project, in some instances considerably; of this there are several specimens in the writer's museum; not unfrequently this natural deficiency remains up to the time of birth, and congenital umbilical hernia is found in the child.

In the simpler forms of this affection the hernial sac contains intestine only, but in other instances which have occurred to the writer, some of which also he has preserved, it contains the liver and stomach in addition to almost the whole tract of intestines: such aggravated forms are in general connected with other malformations, such as spina bifida, spontaneous amputation, &c. which combinations are noticed under their respective heads in the present article. In a specimen which occurred recently in the writer's practice the liver was protruded into the sheath of the cord, but all the rest of the abdominal viscera were contained in the natural cavity. Inguinal hernia sometimes exists before birth, but is rare. Hernia cerebri is noticed elsewhere.

Diaphragmatic hernia, or protrusion of the intestines through the diaphragm into the cavity of the thorax is of rather rare occurrence, or perhaps, more properly speaking, is less frequently observed, because it presents no external physical alteration of form to attract attention.

Like umbilical hernia in the fœtus, it is the result of incomplete developement, because in the earlier periods of fœtal life the diaphragm does not exist, and the thoracic and abdominal cavities are one; and as the muscle afterwards becomes developed from its circumference towards the centre, there occurs occasionally an arrest of formation, and in consequence an aperture is left, through which the intestines and other abdominal viscera, as they increase in size, pass into the cavity of the thorax, displacing the heart and lungs, the latter of which organs are thereby frequently so pressed upon that their developement is prevented, and there is sometimes but a very small portion of them discoverable, especially of the one at the side where the hernia principally exists; which, in a vast majority of the cases which have been met with, has been the left, and then the heart has been pushed over to the right side, where its pulsations in children born alive have sometimes given the first intimation of the existence of the lesion under consideration. In general, children so affected in utero have been either still-born, or have died very soon after birth, a consequence which it appears reasonable to suppose results from the state of the lungs. But in some instances the children have survived under such circumstances. Becker saw one that lived five years; and in a case recorded by Diemerbroëck, where the diaphragm was entirely absent, the child lived seven years, annoyed only with a frequent cough. Riviere and J. L. Petit mention instances of life much more prolonged, in the same condition.

The writer has before him a beautiful specimen of this abnormal condition, for the opportunity of examining which he is indebted to Dr. E.W. Murphy, as well as for permission to have a drawing taken from the preparation in his possession. (See *fig.* 149.)

The opening in the diaphragm in this case is at the left side, rather anterior to and to the left of that which naturally transmits the œsophagus, and appears to arise in this case from separation of the fibres of the muscle; a very large quantity of the small intestine is lodged in the left side of the thorax, from which the heart is pushed away over to the right; the right lung, which lies behind the heart, is natural in structure, but the left does not equal in size half the kernel of an almond, and does not possess the natural pulmonary structure, but appears nearly as solid as the liver. The stomach, spleen, and liver were in their natural situation. The child had also a spina bifida tumour which covered the whole of the sacrum, and deformity of one hand, the thumb of which was attached by a small pedicle to the side of the index finger. In a case related by M. le Docteur Anthony,* which occurred in his practice, the child, which lived

* See Journal Hebdomadaire. Fevrier, 1835.

Fig. 149.

Diaphragmatic Hernia.

a. The heart. *b, b.* The intestines which had passed through the diaphragm and occupy the left side of the thorax, displacing the heart. c, c. Portions of intestine below the diaphragm. *d.* The stomach. *e.* The liver.

half an hour, had no external appearance of any thing abnormal; but, on examination after death, the left side of the diaphragm was found not to exist, and the small intestines and spleen were contained in the thorax; in all other respects the condition of the child exactly resembled that described above.*

Hernia cerebri or encephalocele.—The affection to which these names are applied is not of unfrequent occurrence in the fœtus. It consists of a tumour protruding from the cavity of the cranium through an aperture in the bony structure, covered externally by the integuments, lined internally by the dura mater and arachnoid, and containing portions of the cerebrum or cerebellum, together with serous fluid, with which the cerebral structure is in general infiltrated and softened down; sometimes the contents of the tumour appear to be completely fluid.

This affection is most frequently situated on some point of the central line of the head, commencing at the root of the nose and terminating at the foramen magnum of the occipital bone; these being the situations in which the fœtal head, during a considerable period, consists only of membrane; the writer has seen it in the centre of the forehead at the anterior and posterior fontanelle and in the centre of the occipital bone. According to the observations of Mr. Adams,† the tumour is most frequently situated at some point in the middle line of the proper occipital portion of the os occipitis, as in Dr. Collins's case, to be noticed presently; but it has happened to the writer to observe it more frequently in the other situations above mentioned. In one of the cases related by Mr. Adams, it occurred just over the right eye, and the subject of it had reached his twentieth year when the account of his case was published. (See *fig.* 150.)

Fig. 150.

In such instances the bony vault of the head is usually much smaller than in ordinary cases, being proportioned to the diminished quantity of its contents, and the sutures and fontanelles are found closed.

In the first case of this affection which came under the writer's notice, a tumour, about the size and somewhat of the shape of a fresh fig, hung from the centre of the child's forehead down over the face; it was only partially filled, and apparently with a gelatinous fluid; when compressed towards the forehead the contents were diminished, but, in the same proportion, the child appeared distressed, and the features began to be distorted, the vault of the cranium was in a great measure deficient of its proper developement, the parietal and frontal bones rising very little above the base of the cranium, when they turned over to form the roof of the skull. The child did not present any other external deviation in form; it lived ten days, taking food, digesting, and performing the other common functions like other children, but then pined away and died. On examination after death, it was found that the bag which had protruded and hung over the face was lined by the dura mater and arachnoid, that the cerebrum was entirely absent, as was also part of one side of the cerebellum; the aperture in the frontal bone, through which the hernia passed, was situated just over the root of the nose, in the line of the suture, was about three-sixteenths of an inch in diameter, and with smoothly rounded edges; the sutures and fontanelles were quite closed up. M. Moreau,

* For other instances of this affection, see Archives Générales, tom. vii. p. 142. Transactions Medicales, tom. xii. p. 359.

† See an excellent paper by him in the Dublin Medical Journal, vol. ii. p. 321.

not long since, presented a nearly similar case to the Academy of Surgery at Paris.

In another case, the cast of which was sent to the writer by Dr. Gason of Enniskerry, the hernia appears to have taken place at the anterior fontanelle. J. Cloquet met with a case where it protruded through the posterior fontanelle.* A remarkable case of this affection, occurring in a very unusual situation, was observed at the Hotel Dieu at Paris: a child of about a year and a half old was admitted on account of a small tumour, supposed to be a ganglion, about as large as a nut, and situated at the root of the nose, exactly under the nasal process of the frontal bone. At birth it had been only as large as a pea; it was increased in size, and became redder when the child cried; the child was very irritable; pressure on the tumour gave pain, and produced a general agitation. Dupuytren suspected that the tumour was formed by a prolongation of the brain through some congenital opening in the base of the skull, and on consulting with M. Breschet, the latter declared that he had met with a precisely similar case, in which, on dissection, he had found that the tumour was formed by a portion of one of the anterior lobes of the brain, which was prolonged through a slit in the centre of the ethmoid and sphenoid bones down to the root of the nose.†

As tumours of a very different character are frequently observed on the fœtal head at birth, it is of consequence to be satisfied of the diagnostic characters of the encephalocele, which is at first a rather tense, smooth, and semitransparent tumour, giving generally a more or less distinct sense of fluctuation; it afterwards collapses and becomes wrinkled and smaller in dimension; the integument over it is thin but not discoloured, not unfrequently pale: in shape the tumour is globular or oval, and frequently tapers to a neck where it issues from the head, (see *fig.* 151,) at which point a circular aperture can be detected in the bone, the edges of which are in general smoothly rounded off; the tumour is not painful, but, if it be compressed by the hand, so as to cause a

Fig. 151.

considerable diminution in its volume, the child appears to suffer much distress, sometimes has the features slightly convulsed for the moment, and is rendered stupid and paralytic, as under other circumstances of cerebral oppression; pulsations are to be felt in the tumour synchronous with those of the heart; and, lastly, the volume of the tumour is suddenly increased by any effort on the part of the child, as by coughing, straining, crying, &c.

Most children so affected are either stillborn or live but a very short time; to this, however, there are exceptions; one has already been mentioned, another has been related on the same authority,* and Guyenot brought before the Royal Academy of Surgery in 1774, a man of thirty-three years of age, with encephalocele in the forehead, who had never experienced any disturbance of his intellectual faculties. Lallemand attempted to remove a tumour from the occipital region of a young woman of twenty-three, under the idea that it was a wen; but unfortunately, on attempting to operate, he found that it was an encephalocele; inflammation ensued, and the patient died.

Spina bifida.—An affection in many respects analogous to that just described to which the fœtus is liable, is that which has received the name of spina bifida, and consists of a tumour situated on some part of the spinal column, most frequently over the lumbar vertebræ, but it may be found at any point along the whole length of that column. The writer lately saw a case of it in which the tumour was situated so high on the cervical vertebræ, that it was difficult to determine whether it arose there, or from the base of the occipital bone. A similar case is recorded by Dr. Collins, in which a child was born with a tumour projecting from the back of the head nearly as large as the head itself; it burst, and the child died in ten hours: "The tumour to a considerable extent was covered with hair, the remainder being bare skin of a thin texture, with a blueish tinge; with the exception of one spot the size of a shilling, which had almost the appearance of serous membrane.

"The ventricles of the brain were much dilated and communicated freely with the sac. The membranes were extremely vascular, and the whole contents of the cranium in a dark congested state. The opening through which the tumour had formed was about three-eighths of an inch in diameter, and half an inch behind the foramen magnum. The bones of the head generally were very imperfect as to ossification."†

The most unusual form of it is that in which the tumour appears at the very extremity of the sacrum, where it joins the coccyx. Ruysch, however, met with an instance of the kind, and Genga with another, in which there was also hydrocephalus, the fluid of which was evacuated by opening the tumour on the spine.‡

* Dict. de Méd. tom. viii. p. 52.
† La Lancette Française, Mars, 1835.

* Loc. jam cit. p. 341.
† Practical Treatise on Midwifery, p. 511.
‡ Vide Morgagni, epist. xii. art. 9.

A case occurred not long since in this city, under the observation of Dr. Murphy, in which at the time of the birth of the child, which presented the breech, a membranous bag protruded before it, and was supposed at the moment to be the membranes of the ovum, but it was found to be the covering of a spina bifida tumour, over which the integuments were deficient: it was of considerable size, nearly equalling that of the child's head, and sprung from the very lowest point of the sacrum, as represented in the subjoined sketch:—

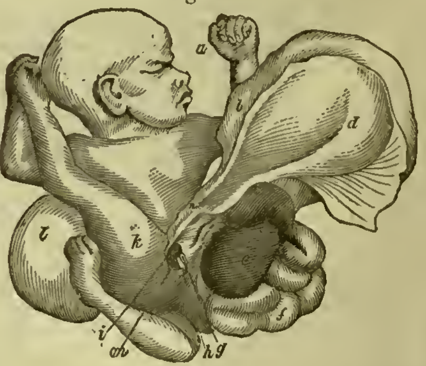
Fig. 152.

In another instance, for the observation of which the writer is also indebted to Dr. Murphy, the tumour occupied the whole length of the sacrum, and was conjoined with diaphragmatic hernia. In some rare instances there have been more than one tumour: in size these tumours vary from the volume of a small nut to that of a child's head at birth; and in their form there is also considerable variety, some being very exactly globular, while others are of the long oval, some pyriform with the tapering pedicle next the spine, and others broader in that situation than externally, and so rather representing the form of a cone. As a general description of the affection, its pathological anatomy is this: there is a deficiency in the posterior arch of one or more vertebræ, arising either from imperfect development of these bones, or their division; through the opening thus caused, protrudes a sac consisting of the investing membrane of the spinal marrow, which sac is in general covered externally by the common integuments, which are sometimes in a healthy state, but more frequently diseased, being sometimes extremely attenuated, either wholly or partially and sometimes in a state of ulceration, or approaching to a state of gangrene; occasionally the integuments are altogether absent, and the membranes form the covering of the tumour; the contents are a fluid of various characters in different cases; appearing sometimes bloody, puriform, and otherwise contaminated, but when presenting its more natural serous condition, it is found, like that of hydrocephalus, to contain a smaller proportion of albumen than the fluid of other dropsies. Sometimes the fluid contained in the tumour can be made, merely by pressure on the latter, to retreat and pass along the spinal canal into the ventricles of the brain, producing the symptoms of cerebral compression; and in such cases also, as in encephalocele, efforts, as of crying, coughing, &c. produce an immediate increase in the size of the tumour: and in the case mentioned by Morgagni, the enlargement of the head from hydrocephalus was diminished, when the spina bifida tumour was opened and its contents allowed to flow out.*

Spina bifida has been found engaging the whole length of the spinal column, which is, however, very rare, and sometimes it has passed, not through a divided or imperfect vertebra, but through a space accidentally existing between the last lumbar vertebra and the first piece of the sacrum.†

This affection of the fœtus, though sometimes found unaccompanied by any other, is in many instances complicated with morbid lesions of an important kind, such as hydrocephalus, malformation of the lower extremities, which are apt to be curved inwards, or otherwise distorted, deficiency in the coverings of the abdomen, and umbilical hernia, hare-lip, &c.: in one instance in the writer's museum, in which there was adhesion between the fœtus and the amnion, spina bifida is accompanied by malformation of the lower limbs, and an enormous umbilical hernia, in which are contained almost all the abdominal viscera.‡ (See *fig.* 153.)

Fig. 153.



b, a membranous pouch, which contained the abdominal viscera during uterine existence.
d, the placenta and its membranes.
e, the liver. *f*, intestines.
g, external opening of vagina.
h, an aperture in the situation of the meatus urinarius.
l, spina bifida tumour.

* Epist. xii. art. 9.
† Andral, Mohrenheim, Portal.
‡ [Some time ago the Editor was favoured by his friend Mr. Hale Thomson, Surgeon to the Westminster Hospital, with an opportunity of examining a remarkable case of double spina bifida. There

The spinal marrow is sometimes healthy, but more frequently it is morbidly affected and sometimes deficient; it is sometimes displaced from the spinal canal and lodged in the cavity of the tumour, especially when the latter occurs over the lumbar vertebræ; sometimes the cauda equina has been contained in the tumour, and its component nerves found separated and floating in the fluid, or spread over the walls of the tumour.

Children thus affected seldom survive, whatever treatment may be adopted; some rare exceptions have, however, been met with, in which life has been continued even up to adult age; as in the case related by Mr. Jukes,* in which the woman had arrived at the age of twenty at the time of writing the account; the tumour, which had been at birth about the size of a pigeon's egg, had acquired dimensions much greater than those of the head; after birth, the limbs, which had been well formed, became in a few years curved inwards, and the woman was gradually reduced to a most miserable condition. A similar case of survival to the age of twenty is mentioned by Warner.†

A case has been recently recorded in which an enormous tumour of this kind delayed the delivery of the body of the child for two hours after the birth of the head, which it equalled in size, extending from the third cervical vertebra to the eighth rib, and containing a quart of fluid, which communicated with the ventricles of the brain.‡

were two tumours, the lower one of very considerable size, and on its posterior wall constricted along the mesial line; this tumour occupied the whole sacral region. It was distended by a clear straw-coloured fluid; and an imperfect septum, corresponding in situation to the constriction already mentioned, projected into its cavity. The second tumour was in the lumbar region, and seemed to be a hernia of the spinal meninges, occasioned by a deficiency in the laminæ on one side of only two lumbar vertebræ; it was consequently small, and communicated with the canal by a narrow neck. The lining membrane of this tumour was overspread by an intricate plexiform arrangement of nerves. In this case there were several malformations; one ankle-joint was in a state of luxation occasioned by the non-developement of the articular extremities of the bones. The intestinal canal was very imperfect, the small intestine composed of a very few coils, and only the cœcal extremity of the large existing, which opened on the pubic region of the abdominal parietes. The bladder was absent, each ureter terminating in a small sac, which opened on either side of the misplaced anus just mentioned. For a space about an inch and a half in diameter, immediately around where the ureters and intestine opened, the skin of the abdomen was raw, very red, and resembled greatly the exposed mucous membrane of the bladder in cases of extrophy of that viscus. The left kidney had its hilus directed outwards instead of towards the spine; the ureter consequently turned in behind the kidney in order to reach its destination. The uterus and vagina were natural. This case has already been alluded to in a note at page 390, vol. i. of this work. Ed.]

* See Lond. Med. and Phys. Journ. vol. xlvii. p. 106.

† Cases in Surgery, 4th edit. p. 134.

‡ See Lancet, No. 261, p. 698.

Cranial tumours.—It has been already suggested that there were other tumours observable on the head of the child at birth of a totally different character from the encephalocele, but which might be mistaken for it; an error into which it is said that the celebrated Ledran fell: these tumours are generally the result of pressure during labour, producing ecchymosis and sometimes bloody effusion between the scalp and the cranial bones; they differ in all respects from the encephalocele; they are darker coloured, without any pulsation, situated over the solid part of the bones, especially over the parietal of one or other side; they cannot be diminished at the instant by pressure, nor does pressure cause the internal distress which results from it when applied to the hernia cerebri; and lastly, no opening can be ascertained in the bone; but with regard to this last point of diagnosis, I wish to direct attention to a circumstance calculated to embarrass the examiner and lead him into error; in examining tumours of this kind, it is not unusual to find around their base a defined and slightly elevated circular margin, which at first one would be almost certain was the circumference of an aperture in the bone, but on further examination it will be found, that if the point of the finger be pressed within this circular margin, it will there meet with as decided and firm a resistance as it did outside of the base of the tumour. I have known this peculiarity lead to the pronouncing of a very erroneous opinion as to the nature and prognosis of such a tumour.

These tumours have been found to contain bloody serum, or pure blood, either fluid or coagulated, and sometimes both; the effusion takes place either between the bone and the pericranium, or external to the latter and under the integuments: the former variety has been called cephalæmatome by Nægele,* who, as well as Schmitt, has given an account of it.

Having stated that these bloody tumours are generally the result of pressure during labour, I should add that I have reason to believe that they are formed occasionally quite independently of any such cause. I very lately attended a patient who gave birth to a child which had hardly arrived at seven months, with an easy and expeditious labour, yet the infant had a very large tumour covering the greater part of the right parietal bone, having all the characters of the cephalæmatome, and was not removed till the termination of a month.

Injuries of the cranial bones.—The same causes which give rise to the formation of the bloody tumours just described, not unfrequently produce fractures or depressions of the flat bones of the cranium, especially of the parietals; more particularly in cases of contracted pelvis, where the promontory of the sacrum projects considerably inwards; though I have known such accidents happen without the concurrence of any such state of the pelvis, but from the interposition of an arm between the head and the bony wall

* Zeller, Comment. de Cephalematomate, &c. Heidelberg, 1822.

of the pelvis: in one case where the labour required version of the child, the arm got between the side of the head and the pubes and produced so much difficulty in the delivery, that the left parietal bone was completely depressed. Siebold has reported a case in his journal, in which the labour was painful and tedious, and the child was born dead: a large bloody tumour was found over the right parietal bone; and on exposing the bone, it was traversed by three distinct fissures passing in different directions: no instruments had been used.* But I have reason to know that these injuries of the cranial bones may occur, not only independently of contracted pelvis, but even of slow or difficult labour. I some time since attended a lady in her second labour, and after about three hours from its commencement, she gave birth to a healthy boy, but with a depression in the left temporal bone which would readily have contained an almond in its shell; by degrees the depression disappeared, and at the end of a few months no trace of it remained; the lady's first labour was easy, as were also those that succeeded the birth of this child, and no such injury was observable in any other of the children. More recently I was informed by Mr. Mulock, of a case in which, on the subsidence of a cranial tumour, a spicula of bone was felt distinctly projecting under the integuments; the labour had been slow but natural. When these injuries of the fœtal head were first observed, they were attributed to violence by Haller, Rosa, and others, the error of which opinion was first perceived by Rœderer and Baudelocque, and it is needless to say how important is the distinction, especially in a medico-legal point of view.

Fractures of the long bones have been observed sometimes as the result of injuries sustained by the mother, but in other instances independent of any such cause, and apparently depending on some defect in their composition. I saw an instance in which a woman, when eight months pregnant, was precipitated from the second story of a house into the street, by which the hip-joint was dislocated, and she was otherwise much injured; she fell on her face, yet the uterus was not ruptured; labour came on that night, and the child was born dead with several of its bones broken: the woman recovered well. A case is quoted by Dugés on the authority of Carus, in which a woman fell on her belly and caused a fracture in the leg of the child, which was born with the fracture complicated with wounds in the soft parts; gangrene supervened and detached entirely the fractured limb.† Marc‡ relates a case, in which all the bones of the limbs and several others were found fractured, the mother not having met with any accident, and having had an easy and quick labour; the child was born alive and lived for some days: on examination after death the number of fractures were found to amount to forty-three, some of them just beginning to unite, and others almost completely consolidated.

* See Med. Chir. Review, No. 37, July 1833, p. 211.

† Dict. de Méd. et de Chirurgie Prat. tom. viii. p. 293.

‡ Dict. des Sc. Méd. tom. xvi. p. 63.

In a case which occurred to Chaussier, in which also the labour was quick and easy, and the mother had not sustained any previous accident, the child was born alive and survived twenty-four hours; its limbs were malformed, and after death no less than one hundred and thirteen fractures were discovered in different conditions, some of them being already quite consolidated, while others were apparently quite recent.*

Fractures independent of any external injury or defect of nutrition are supposed by some to be produced by violent spasmodic contractions of the fœtal muscles, which are capable of very energetic efforts, at a time when the fœtal bones have very little power of resistance. It appears reasonable to believe, that such spasmodic action of the muscles might be induced by causes violently disturbing the nervous system of the mother, since we know that such influences acting on a nurse will cause spasmodic and convulsive affections in the child at her breast; and we further know, that even in the adult a quick muscular effort has been followed by fracture of a bone, but how far such analogies are applicable to explain the lesion in question I would not pretend to determine.

A similar explanation has been supposed applicable to the instances of dislocations which have been discovered in the fœtus, and one in particular related by Chaussier appears to correspond to such a supposition. A young, delicate, and nervous lady, in the ninth month of pregnancy, suddenly felt such violent and rapid movements of the child that she was near fainting; these tumultuous motions were three times repeated in the course of ten minutes, and then there succeeded a perfect calm; the remainder of the pregnancy passed on well, the labour was easy, the child was pale and weak, and had a complete dislocation of the left fore-arm.† In another instance mentioned by Marc‡ there were found, in addition to congenital dislocation of both hip-joints, no less than seven other luxations.

But by far the most remarkable pathological lesion to which the fœtus in utero is subject, is that in which portions of its limbs are removed by a process which has been with propriety denominated spontaneous amputation.

This singular fact has been mentioned by several authors of credit, as Richerand,§ Desormeaux,‖ Billard,¶ and Murat,** though none of them appear to have witnessed any case of the kind themselves; but they all agree in

* For a full account of the dissection, see Bullet. de la Fac. de la Soc. de Méd. de Paris, 1813, No. 3.

† Discours prononcé à la Maternité, Juin 1812.

‡ Dict. des Sci. Méd. t. xvi. p. 66. See also une Mémoire sur un deplacement originel ou congenital de la tête des femurs, par M. le Baron Dupuytren; Repertoire d'Anatomie, t. ii. partie 1.

§ Elemens de Physiologie, p. 477.

‖ Dict. de Méd. t. xv. p. 404.

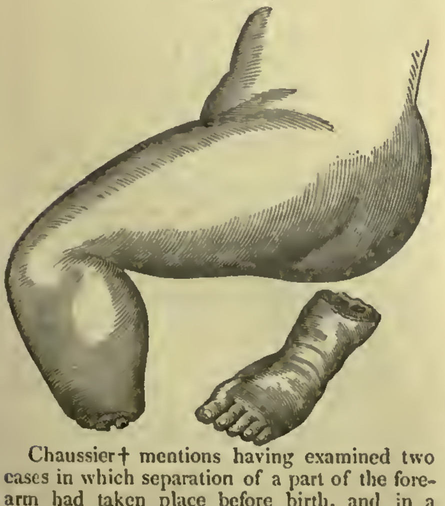
¶ Maladies des Enfans, p. 623.

** Dict. des Sci. Méd. t. xvi. p. 70.

regarding it as simply the result of inflammation and gangrene. Haller evidently was not aware of any such case, for although he gives a long list of extraordinary mutilations of the fœtus, he considers them as the result of imperfect development or malformation, and not of separation or *removal of parts already formed;* for he expressly objects to the authors who have furnished such descriptions, that they cannot even quote one instance in which "manus truncata, aliusve artus, in membranis fœtus seorsim a corpore, repertus sit."* Having sought with diligence through authors, the only cases which I have been able to find are those which I shall now briefly mention.

In the 54th volume of the Lond. Med. Phys. Journ. Mr. Watkinson states, that being in attendance on a lady twenty years of age in her first labour, which was natural and easy, he discovered, on the birth of the child, that the left foot had been amputated a little above the ankle, and the part was *nearly* but *not quite healed*, the bones protruding a little. The child was alive, but survived only a few minutes; on making further search the amputated foot was found in utero, and it, also, was *nearly healed.* There did not appear to have been any hæmorrhage from the limb; the separated foot was *much smaller* than the other; it shewed *no mark of putrefaction*, but appeared to be in a state of *perfect preservation*, not being even discoloured. The mother had not met with any accident nor any particular mental emotion, and she was sufficiently independent to render unnecessary any over-exertion on her part. Mr. Watkinson offers no opinion on the nature or cause of the accident. The annexed sketch represents the condition of the parts.

Fig. 154.



Chaussier† mentions having examined two cases in which separation of a part of the fore-arm had taken place before birth, and in a third case he found the separated portion of the arm and hand lying apart, and *the stump of the limb healed.*

Chaussier also attributes the accident to gangrene as the cause which would most obviously account for its production, though it does not appear from his account that there were present any of the pathological evidences of that condition; and in the case first related the child was born alive, and it is expressly mentioned that neither the stump of the limb nor the part amputated shewed any symptom of disorganization or disease, not being even discoloured.

The next case was one occurring in my own practice, and appears to me of great importance as exhibiting the amputation absolutely in progress, under the influence of the agent which I believe to be the general, and, most probably, the invariable cause of its occurrence.

About eight years since I attended a patient under circumstances of considerable danger from hæmorrhage attending abortion in the fifth month, and on the expulsion of the fœtus its singular conformation fortunately attracted my attention strongly, and induced me to examine it with care. The head was mis-shapen and monstrous, the brain covered only by integument, and towering upwards like a helmet over the head; but the circumstance deserving of especial notice was the appearance of complete ligaments surrounding the limbs, and on examining them closely I found that they consisted of distinct threads, passing from both hands downwards to the legs (see *fig.* 155); at one end,

Fig. 155.

each of these threads or fine cords had formed a complete ligature round the middle of each hand, causing a distinct depression where it passed, the part of the hand below it being almost completely undeveloped. From the hands these cords descended towards the legs, which were crossed, and surrounding them in this position just above the ankles, compressed them so tightly that fully two-thirds of their whole thickness were thereby divided, *without, however, causing any breach in the skin;* nor

* Elementa Physiologiæ, t. viii. p. 135.
† Discours prononcé a l'Hospice de la Maternité, 1812.

was there the slightest appearance of disease or even discolouration of any of the parts, but the feet were, like the hands, imperfectly developed and mis-shapen. The mother was about twenty-five years of age, and was at the time labouring under fever, but had been previously in perfectly good health, and had not met with any accident either in the way of bodily injury or mental agitation.

About four years after the occurrence of the case just detailed, another was brought under my observation through the kindness of Dr. J. Labatt.

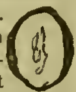
A healthy woman gave birth to a still-born child in the eighth month of gestation; it was affected with an umbilical hernia of great size, formed by the protrusion of the liver, stomach, and small intestines, but the state of the limbs is the point of interest connected with our inquiry: both were mis-shapen, and, as happened in Mr. Watkinson's case, *the left* exhibits this remarkable pathological lesion, and exactly in the same situation. Just above the ankle there is a deep depression all around the limb, and sinking to such a depth as to leave only the bones and skin unaffected by it, the diameter of the undivided part being less than half an inch, while that of the leg, just above the depression, is an inch and a quarter. The appearance of the groove is exactly such as would be made by tying a string very tight round the plump limb of a child, and in my opinion could not have been produced in any other way. The part had been very much handled and examined by several before I saw it, so that I was not surprised at not finding any ligature on the limb, but the mark of it was so distinct in the bottom of the depression as to leave no doubt of its previous existence there having produced the constriction of the part. It is important also to observe, as con-

Fig. 156.

firmatory of this view of this matter, that *the integuments are not at all broken or divided*, but are merely carried inwards with the constricting agent, so that, had the separation of the limb been completed, each stump *would appear skinned over*, except at the ends of the bones, and so present the appearance of being *partially healed*, as described by both Watkinson and Chaussier: the foot was a little swollen and somewhat discoloured; it seemed turgid with blood, but was without any appearance whatever of gangrene.

In both the instances here before us, from the condition of the limbs and the impossibility of the parts under the ligatures continuing their growth under such circumstances, it could scarcely be made subject of doubt that had the children continued to live and grow, the parts of the limbs below the constriction would have separated, and so undergone spontaneous amputation.

The next case to which my attention was drawn was one very politely communicated to me by Dr. Tyson West, of Alford, Lincolnshire, in consequence of his becoming acquainted with my account of this matter. Dr. West attended a patient at the Westminster Lying-in Hospital in 1805, who, after a natural and easy labour, gave birth to a still-born child which had but one leg, the other limb exhibiting positive proof of having been spontaneously amputated some time before, the stump being *partially healed and nicely rounded*, about an inch and a half below the knee: the unhealed portion of the stump was about this size.



He accounts for the amputated portion of the limb not being found in consequence of the occurrence of a most dangerous accident which threw all the parties concerned into great alarm and confusion; but he adds that it struck him at the time, and he is still of the same opinion, that the division of the limb was effected by *some stricture round it*.*

When first announcing the discovery of this fact, in 1832,† I stated that the origin of these ligatures, and still more their application so as to stricture the limbs, were circumstances on which I did not feel prepared to pronounce an opinion with any reasonable probability of its being satisfactory, and I am sorry that five years' additional consideration of the matter has not enabled me to solve the difficulty completely; but I am happy to find that, so far as I have ventured to point out a proximate cause of this singular phenomenon, my views have been assented to, and my explanation adopted, by all who have subsequently expressed their opinions on the subject, and especially by Professor Gurlt, of the Royal School of Medicine at Berlin, author of a work on pathological anatomy, (whose investigations render him peculiarly qualified to form an opinion on such a subject,) who has written a commentary on my original paper,‡ in which he adopts, as correct, my explanation of this curious fact, and, in addition, undertakes to account for the formation and application of the ligatures.

He commences his observations by rejecting in toto the notion of the agency of gangrene: his words are: "To explain this most re-

* A notice of this case was inserted by Dr. West in the Lond. Med. and Surg. Journ. for 1832, vol. i. p. 741.

† See Dublin Medical Journal, vol. i. p. 140.

‡ See Medicinische Zeitung, 1833, N. 3, p. 13.

markable phenomenon, the utterly unfounded hypothesis has been formed, that these spontaneous separations are the result of gangrene, although there are no traces of it to be discovered on the stump, it being actually, to a certain extent, healed, and no change of colour to be seen:" and he immediately adds, "a case lately observed by Montgomery of Dublin appears to contribute a natural explanation of this remarkable fact, inasmuch as it indicates the cause of this separation." He then repeats the details of my first case, and proceeds to say he "believes that both the formation of these threads, and the amputation of the limbs, which are most probably in all cases produced by them, may be explained by the history of the formation of the fœtus." He then enters into a minute detail of facts well known to all who are acquainted with the mode in which the development of the fœtus takes place, and observes, "I look upon these threads as prolongations of the egg membrane from which the fœtus grows, whether this skin (or membrane) be taken as the navel bladder or the amnion:" and he subsequently objects to their being considered as formed by organized lymph, which I considered them to be, and still remain of the same opinion.

The prolongations of the membrane, Gurlt thinks, are afterwards, by the constant motions of the fœtus, twisted into slight but firm cords or threads, which may involve different portions of the fœtal limbs, (as we sometimes find the umbilical cord several times round the neck, or other parts of the child's body,) so as to stricture them and cause their separation; and in this way Professor Gurlt explains the presence of the ligatures concerned in the production of spontaneous amputation. I dissent from this as a general explanation, for a reason presently to be stated; but it is only justice to the author to mention that the condition of both the children which I examined was in other respects such as favours his theory, for whenever such unnatural adhesions take place between the amnion and the fœtus, they give rise to a monstrosity of a peculiar kind, and this is observable in both these cases, and in others also: in one there is protrusion of the brain and monstrous formation of the head in other respects; and in the other the liver, stomach, and great part of the intestines were contained in a hernial sac, external to the body. But notwithstanding the support thus derived from analogy, there is one circumstance which appears fatal to the explanation when applied to the first case described by me, which is, that in all cases where these membranous connections have been observed giving rise to monstrosity, one end of the cord or thread-like band has always been found attached to the amnion, and the other to the fœtus, but here *both* ends of the cords are attached to the limbs, and afford no evidence of having been connected with the amnion; and it was for this reason that I abstained at first from offering the explanation now proposed by Professor Gurlt, which I then thought, and still consider inapplicable to the specimen which I was then describing, and equally, or perhaps still more so, to that described by Zagorsky, to be mentioned presently, see *fig.* 159; though, at the same time, I am quite ready to admit that ligamentous bands so formed would be fully adequate to the accomplishment of such an effect: and I now know also that strictures from another source, and which from their nature must possess very little constricting force indeed, are in some instances found sufficient so completely to act on and indent the limb, that, could their action be continued, which, however, is scarcely possible, they might ultimately induce a similar mutilation. While I was engaged in committing these observations to writing, I received a most interesting preparation from Dr. W. O'B. Adams, in which the coiling of the umbilical cord round *the left leg* of the fœtus at three months had deeply indented it, as represented in the subjoined *fig.* 157. Here, it will be

Fig. 157.

observed, at least three-fourths of the thickness of the limb are divided by the pressure of the umbilical cord, which was coiled around it, and which, both in this and *fig.* 158, is removed from the strictured part where it originally lay, in order to show more distinctly the effect produced by it.

Within the last few months another instance of the same effect produced by the same agent just above *the left knee* of a fœtus at about the same period of growth, occurred with a patient of the writer's, and under his immediate observation, as shewn in the annexed *figure*, 158.

Fig. 158.

I am very much disposed to believe that Morgagni witnessed a fact of this kind; at least his description of the appearance in a monstrous fœtus between the fifth and sixth month, greatly resembles it, of which he says, "All the limbs were in a very bad state, the upper limbs from the elbows downwards; for to the arms, which were very short and distorted, distorted hands were likewise added. And the inferior limbs terminated, likewise, in distorted feet, *but the left leg* was either *broken from the funiculus umbilicalis having been applied round it*, or was more distorted than the other parts:"* and he afterwards, with great reason, conjectures that the binding of the cord round the leg may have been the cause of the child's death, by interrupting the circulation through it. It is a very extraordinary fact, that in every one of these cases, as well as in several others, the injury was sustained by *the left extremity*.†

In the course of the last year Dr. Simpson of Edinburgh published an excellent paper on this subject;‡ into which he has collected a vast quantity of curious information and many most important cases from authors, to which he has added not a few from his own observation, together with several highly apposite remarks; and I am happy to find that he also assents to, and, indeed, strongly confirms my view both as to the agent which produces the change and its consisting of organized lymph, such as is usually elaborated under the influence of inflammatory action, from which it is well known that several varieties of fœtal deformities arise;* and it is a matter of every day observation how completely lymph so effused will be converted into distinct firm threads, uniting opposite serous surfaces, especially those which move freely on each other, as the pleuræ and the peritoneal coverings of the abdominal viscera.†

From the cases referred to by Dr. Simpson, I shall now notice three which appear more particularly illustrative of the true nature of this remarkable lesion, and confirmatory of my original account of it.

Zagorsky has described‡ a malformed fœtus of the fifth month, which, in addition to several other deformities, was deficient of the right leg, the thigh ending in a rounded and cicatrized stump, in the centre of which was a small projecting point: from this was prolonged a slender thread-like membrane, strong in proportion to its size, that ran directly across to *the left leg*, which it encircled, a little above the ankle, like a tightened ligature, see *fig.* 159, and formed in it a depression of considerable depth, while the portion of the extremity below the ligature was, as well as the appended foot, rather tumefied. From about the middle of the transverse thread-like membrane a small body of an oblong form was suspended, which, on examination, proved to be the right foot perfectly formed, as its general outline and five toes demonstrated, but not larger in size than the foot of a fœtus of the tenth or twelfth week.

Beclard mentions§ the case of a very deformed hydrocephalic fœtus, whose *left leg* was divided by a transverse depression that penetrated as deep as the bones, and resembled that which would have been produced by a tight ligature. The two opposite surfaces of this indentation *were both cicatrized*, and almost touching one another. "It is evident," says Beclard, "that if this fœtus had remained in utero for some time longer, it would have been born with an amputated and cicatrized leg, the remains of which might have been found in the liquor amnii."

* Epistle xlviii. art. 53, vol. ii. p. 758, of Alexander's translation.

† For other instances of impressions made on the fœtal limbs, &c. see Van de Laar, Obs. Obstet. Med. p. 41, and tab. 11; Meckel, Patholog. Anat. Bd. ii. s. 137; Sandifort, Thesaurus, tom. iii. p. 235, tab. 11, fig. 5.

‡ See Dublin Medical Journal for November, 1836, vol. x. p. 220.

* See Geoffroy St. Hilaire's investigations in his work on "Monstruosités Humaines;" Meckel's Handbuch der Pathologischen Anatomie, Bd. ii. s. 138; and a paper on the diseases of the placenta, by Dr. Simpson, in the Edin. Med. and Surg. Journ. vol. xlv. p. 305 et seq.

† Dr. Hildebrand of Berlin has also noticed my cases with some remarks: see Gräfe, und Walthers Journal der Chirurgie, Bd. 18, 11, p. 325: 1832. The latest author on the subject is Graetzer, die Krankheiten des fœtus, Breslau, 1837, p. 69.

‡ Memoirs of the Imperial Academy of Sciences of St. Petersburgh for 1834, sixth series, vol. iii. p. 3, 7.

§ Bulletins de la Faculté, &c. for 1817, tom. v. p. 213.

Fig. 159.

Albert F. Veiel quotes a case from Froriep's Notizen, Bd. xii. p. 26, of a fœtus " whose *left foot* was separated, during pregnancy, from the bone, and the fore foot was born *by itself, quite healed*."*

The following case was recently published in the American Journal of Medical Science, by Dr. F. P. Fitch of New Boston. On the 17th March a healthy woman, then in the seventh month of pregnancy, suddenly discharged the liquor amnii. On the 21st a substance escaped from the vagina, which proved to be a perfectly well-formed fœtal foot, apparently separated at the ankle-joint, and in a complete state of preservation. On the 5th April she was delivered of a seven-months' child, which lived about half an hour. At the left side of the centre of the forehead there was a horny protuberance of the size of the middle finger; the face, also, was greatly deformed. Upon the foot, the place of separation was contracted to the size of a small pin's head, and *the healing process had apparently been as perfect, and progressed very nearly as far as that on the lower extremity of the limb.*†

Within the last few months a child of a month old was brought to me from the county of Westmeath, in consequence of its having been born deprived of the left hand. On examination I found the forearm of that side presenting, a little above the wrist, the appearance of a perfectly well-formed stump, as it would be found after amputation by the surgeon's knife; with this difference, however, that the mark of cicatrix did not extend across the stump, but was confined to a small circular depression in its centre; the child was otherwise quite perfect and healthy. Unfortunately I could not obtain any information as to whether the hand had been found at the time of delivery or not, the poor woman having been attended only by an ignorant country midwife. Three cases, very similar to the above, are described by Dr. Simpson.*

I feel almost convinced that the removal of limbs in this way is by no means so uncommon an occurrence as the paucity of cases hitherto recorded would, at first sight, lead us to conclude; but the reason appears to me to be this, when the separated portion of limb was not accidentally discovered, the imperfection seems to have been considered quite as a matter of course, and without further examination, as arising from imperfect development or monstrosity, and, consequently, no search was made for the deficient part; and, even if search was made, the amputated member might have been so small as to escape undiscovered, involved in the membranes, or buried in coagula; even though the child to which it belonged had attained considerable size, because its separation may, as we have seen, take place a considerable time previous to birth; this is noticed in Mr. Watkinson's case, and is still more strikingly exemplified in that described by Zagorsky, see *fig.* 159.

With regard to the theories which have been advanced to account for such accidents as that which we have been considering, some, regarding them as the effects of mental emotions in the mother, or of accidents encountered by her, have attempted to support their views by details which Haller truly designates as " adeo fabulosa ut fidem auferant;" those who attributed this phenomenon to gangrene did so from theory, and have received no support for their opinions even from the facts which they have themselves recorded; for it is expressly mentioned that the parts which were the seat of the injury seemed otherwise healthy, were not discoloured, and at the point of division were either partially or entirely healed over. The explanation which facts fortunately enabled me to offer does not depend on conjectural reasoning or theoretical speculation for its support, but its proof may be " oculis subjecta fidelibus" by the mere inspection of the parts, which are preserved in my museum; and with regard to the nature of the process by which the solution of continuity is effected, and the foot, or other part amputated, it appears to be strictly that of disjunctive atrophy, and in a great degree similar to that by which the separation of the funis from the umbilicus is accomplished.

Convulsive affections.— Having alluded to convulsive movements of the child in another place as the occasional cause of certain physical injuries to it, such as fractures and dislocations, a few words on the subject will hardly be misplaced here, although the affection itself may perhaps not come exactly within the scope of this article. The variety in the activity of

* " Der linke Fuss während der Schwangerschaft sich von dem Beino ablöste, und der Vorderfuss für sich, bereits geheilt, geboren wurde."

† American Journal of the Medical Sciences, No. xxxv. for May 1836, p. 90.

* Dublin Medical Journal, vol. x. p. 226.

fœtal motion is a matter of common observation, for, while some women suffer much and almost constant annoyance from the excessive restlessness of the child, others are hardly conscious of its movements.* That this is not altogether dependent on a real difference in the quality of the fœtal motions, but in a great degree the result of the greater or less nervous irritability of the mother's system, must be acknowledged; but, on the other hand, I think we can hardly doubt that some of those paroxysms of excessive turbulence are true convulsions, and that the child sometimes thus dies before birth, either under their influence or by so entangling the cord as to compress it, and put an end to the circulation through it. The writer feels persuaded that he has met with such cases, and he has read of others in which, after a violent convulsive motion of this kind, which had nearly caused the mother to faint, all motion of the child has ceased to be felt, and, after the lapse of a few days, delivery has taken place, and the dead-born child has exhibited appearances perfectly corresponding with the belief of its having died at the time of the convulsive struggle. In October 1834 the writer attended a very nervous lady with her second child, which, after about two hours of easy labour, was born completely dead, although full-sized and well thriven; the cord was twisted round the neck and also round one of the arms. She told me that three days before she was suddenly startled by the excessive motion of the child "as if it was struggling in convulsions;" this continued for a minute or two, and was so violent and distressing as to force her to exclaim, and nearly to produce fainting; from that moment she never felt the child move.†

Effects of mental impressions on the mother.—In the enumeration of the different causes or sources of abnormal alterations in the fœtus we should not omit to include powerful impressions made on the mind or nervous system of the mother; for although the writer would be very far from wishing to advocate or countenance either the indiscriminate doctrine of effects produced by the mother's imagination, or the ridiculously absurd fabrications by which it has been attempted to maintain it, he cannot help thinking it quite consistent with reason and the present state of our knowledge, to believe that such impressions may injuriously affect the fœtus, and it will at least be always safe and prudent to act on such a presumption; for "although," to use the words of Morgagni,‡ "I do not approve these things, (that is, the absurd stories,) there are cases wherein it seems to me to be very hard to depart totally and altogether from that opinion which is common to the greatest men."* In a case related by this celebrated writer, a mental impression was quickly followed by the death of the child;† and if such an influence can thus destroy its life, it is surely not unreasonable to admit that it may have the power of modifying organization.‡ An instance of this kind occurred under my own observation about three years ago, so remarkable that I trust I shall be excused if I think it presents something more than a mere though striking coincidence.

A lady, pregnant for the first time, to whom I recommended frequent exercise in the open air, declined going out as often as was thought necessary, assigning as her reason, that she was afraid of seeing a man whose appearance had greatly shocked and disgusted her; he used to crawl along the flag-way on his hands and knees, with his feet turned up behind him, which latter were malformed and imperfect, appearing as if they had been cut off at the instep, and he exhibited them thus and uncovered in order to excite commiseration. I afterwards attended this lady in her lying-in, and her child, which was born a month before its time, and lived but a few minutes, although in every other respect perfect, had the feet malformed and defective precisely in the same way as those of the cripple who had alarmed her, and whom I had often seen. Now here was an obvious and recognized object making a powerful impression of a disagreeable kind, complained of at the time, and followed by an effect in perfect correspondence with the previous cause, there being between the two a similarity so perfect that, with the distinguished author above referred to, I "will not easily suppose that chance could have been so ingenious, if I may be allowed to speak thus, and so exact an imitator;"§ and though I must acknowledge in the words of Van Swieten "that I do not understand the connexion of the cause acting upon the mother with the effect observed in the fœtus,"‖ I also agree with him, that it must not therefore be denied that such a thing has really happened. For some other observations on this subject the writer begs to refer to a work¶ of his recently published.

Effects of inflammation, &c.—The fœtus in utero, even at early periods of its developement, is liable to a large number of organic alterations, and even to lose its life, in consequence of inflammation attacking the uterus of the mother, the fœtal appendages, or its own system. From such causes arise a variety of pa-

* See some observations on this subject in the writer's Exposition of the Signs of Pregnancy, chapter v. p. 87.

† See Desormeaux, Dict. de Méd. tom. xv. p. 398. Dugés, Dict. de Méd. et de Chir. Pratique, tom. viii. p. 295. A slight spasmodic sensation communicated from the child to the mother, and sometimes repeated several times at pretty regular intervals, like the efforts of hiccup, has been by some attributed to the existence of that affection in the child; but with what degree of reason the writer is not prepared to venture an opinion.

‡ Epist. xlviii. art. 54.

* He refers to Boerhaave, Prælect. ad Instit. § 694, and to Van Swieten.

† Epist. xlviii. art. 18.

‡ A celebrated writer of the present day, Esquirol, is led from observation and experience to refer one of the species of congenital predisposition to insanity, to the impression of terror on the mind of the mother while pregnant.

§ Epist. xlviii. art. 54. Vide epist. lxvii. art. 16.

‖ Commentaries, sect. 1075.

¶ An Exposition of the Signs and Symptoms of Pregnancy, chap. i. pp. 14 et seq.

thological changes in the fœtus, as atrophy, arrest of developement, amputation of limbs, and many other affections, as detailed in the different sections of the present article.

With respect to those which seem distinctly referrible to inflammation arising in the fœtal system and invading particular organs, the instances are very numerous indeed; especially in the thoracic and abdominal cavities, in which striking indications of violent inflammatory action have been frequently observed, both by the writer and by others.

During the investigations made conjointly by Madame Boivin and M. Chaussier, they met with several cases of well-marked peritonitis, some of which were accompanied by considerable effusion, which, however, did not exist in others; but in all there were found numerous adhesions between the intestines.* Desormeaux records a case in which a child at birth displayed all the evidences of violent enteritis,† but afterwards recovered. In a case related by Dugès, all the abdominal viscera were found agglutinated by a yellow coloured and firm lymph; there were false membranes on the liver, the spleen, the bladder, &c.; the epiploon was adherent to the intestines, which were agglutinated into a lump, and were yellow, hard, and thick.‡ Other instances of this form of inflammation are detailed by Billard,§ Carus,‖ Cruveilhier,¶ and others.

The stomach and intestinal canal have frequently been found much diseased at birth. In one instance of a still-born child I found the stomach in a state of intense inflammation, and on its internal surface there were no less than twenty-five patches of ulceration. Dr. C. Johnson of this city found a similar condition existing in the colon: the specimen is deposited in the Museum of the College of Surgeons, Dublin. Cases of this kind are also described by Billard,** who mentions an instance in which he found in the duodenum a pediculated excrescence of a red colour and uneven like a strawberry; it was as large as a bean, and in its structure, &c. resembled the vascular tumours found in the intestines of adults. In the same child there was also evidence of chronic inflammation of the lower portion of the ilium, with thickening of the mucous membrane, which was of a slate colour.†† In another case examined by the same writer, the ilium and all the colon were found presenting the characters of the disease named by Laennec sclerosis, and consisting in a scirrhous induration of the submucous cellular tissue of the intestine. In a case observed by Cruveilhier the small intestines presented several patches of ulceration, and the coats so thickened that their calibre was quite effaced.* Desormeaux thinks, and apparently with good reason, that several of the strictures and obliterations of hollow canals, such as closing of the œsophagus, intestinal canal, anus, urethra, &c. ought to be referred to the influence of former inflammation, to which cause also there is great reason to ascribe many instances of congenital blindness, and especially those in which there is opacity of the cornea.

The liver is not unfrequently the seat of inflammatory and other lesions before birth, a variety of which have been noticed by different writers; intense sanguineous congestion has been often met with. Billard mentions two instances in which the organ was found softened and giving out an odour of sulphuretted hydrogen. It has also been found with tubercles scattered through its substance at birth.† Hoogeveen describes a tumour which was found attached to the liver of a fœtus of six and a half months: it was hard and unequal, and as if composed of particles of soft stone or cherry kernels.‡ Considerable serous effusion in the abdominal cavity has been often observed.

The organs contained in the thoracic cavity appear to be peculiarly liable to the invasion of inflammatory action, and frequently exhibit other abnormal conditions also. Cruveilhier goes so far as to say, that lesions of the lungs are so frequent in the fœtus, that in his opinion disease of the lungs carries off as many new-born children as adults.§

The lungs have been found hepatized in still-born children, two instances of which occurred to Andral,‖ who says he found in another case numerous abscesses in one lung.

M. Husson examined two children, one of which was dead-born in the seventh month, and had tubercles softened and in a state of suppuration in the lungs, the mother being healthy. I have met with instances of tubercles in the lungs at birth, but in the cases which came under my observation, the mothers were affected with consumption; under which circumstances I have, in several instances, found in the placenta a deposit of what appeared to be perfect tubercular matter.

Cruveilhier¶ has noticed instances of tubercular induration, grey consolidation, scattered masses of tubercular character containing pus, and, in one case, there was serous infiltration of the pulmonary tissue, which was of an olive green colour. Billard** relates similar cases of pulmonary lesion, as does also Lobstein,†† who

* Recherches sur l'Avortement, &c. p. 56, note; see also Bulletin de la Fac. de Méd. 1821, and Procès verbal de la Maternité, Jan. 1812.

† Dict. de Méd. art. Œuf, tom. xv. p. 403.

‡ Recherches sur les Maladies les plus importantes et les moins connues des enfans nouveaux-nés, par Ant. Dugès, D.M. Paris, 1821.

§ Maladies des Enfans, p. 444.

‖ Gynækologia, ii. p. 251.

¶ Livraison xv. pl. xi. p. 2, ob. 2.

** Op. jam cit. p. 296 et seq. Atlas, pl. v. and also p. 372.

†† Ibid. p. 373, 4.

* Anat. Pathol. liv. xv. pl. ii. p. 4, ob. 7.

† See Billard ut supra, p. 421, and Meissner, Kinderkrankheiten, i. s. p. 92.

‡ Tract de Morb. fœtus humani, p. 63; see also Bonetus, Sepulch. Anat. tom. iii. p. 104, Orfila, Leçons de Méd. Leg. Paris, 1828, i. p. 292, and Andral's Pathol. Anat. translated by Townsend and West, vol. ii. p. 704.

§ Liv. xv. pl. xi. p. 5.

‖ Op. jam cit. p. 703.

¶ Op. jam cit. liv. xv. pl. xi. pp. 4, 6.

** Malad. des Enfans, pp. 499, 618.

†† Pathologischen Anatomie, i. p. 321.

found in the fœtal lungs a calcareous concretion.

Pleuritis.—The effects of inflammation attacking the pleura before birth are not unfrequently seen. Billard relates the case of a child which died on the fourth day after birth, in whom the pleura was found greatly thickened, and there were existing between its opposite surfaces bands of adhesion as firmly organized as those found in an adult, eight or ten years after a pleurisy.*

In a case described by Cruveilhier, the child died thirty-six hours after birth, and there was found double pleurisy with effusion of a sero-lactescent pseudo-membranous fluid; and in another instance described by the same writer, in addition to anasarca, ascites, and purpura, there existed hydrothorax, in a seven months' child, which had lived only twelve hours :† other instances are related by Veron, Orfila, and others.

Purulent effusion.—The formation of pus has been frequently observed in the fœtus, both in the form of secretion from the lining membranes of cavities, and in distinct circumscribed abscesses.

In cases of pleuritis and peritonitis, as already noticed,‡ the abdominal and thoracic cavities have contained sero-purulent fluid. Cruveilhier found pus between the dura mater and skull in a still-born child.§

Abscesses have been found in the thymus and thyroid glands and in the supra-renal capsules, see p. 334; and Andral found several in one lung.||

Ollivier (d'Angers) has given an account of the examination of a fœtus of three months and a half, under the skin of whose neck an abscess was found.¶

I have very often seen small superficial abscesses or pustules existing at birth, especially about the neck, face, and head.

Dropsical effusions.—Several forms of serous effusion have been already mentioned as taking place during fœtal life, and affecting either the cellular tissue, the great cavities of the abdomen and thorax, those of the brain, or confined to particular organs and their appendages.

Thus notice has been taken of the occurrence of general anasarca, ascites, hydrothorax, hydrops pericardii, serous infiltration of the lung, hydrocephalus, and hydro-rachitis or spina bifida. In one instance which I examined some years since there was general anasarca and serous effusion into every one of the cavities; the mother was healthy, but was in the habit of drinking enormous quantities of ardent spirits.

The degree to which the head sometimes becomes enlarged in utero by dropsy is as extraordinary as it is well known, and the difficulty of delivery thus produced is equally a matter of frequent observation with practitioners in midwifery. In one specimen in my possession, the long diameter of the head is six inches, the transverse five and five-eighths, and the circumference nineteen inches: this case gave rise to the necessity of performing cephalotomy. In another instance of twins I was called in, in consequence of delivery of the first child being found impracticable, the head being firmly retained after the expulsion of the rest of the body. I succeeded in extricating it, without perforation or instruments of any kind; it measured eighteen inches and a half in circumference.* In a case related by Perfect,† the head, when extricated from the pelvis, measured more than twenty-four inches in circumference. In an instance of an hydrocephalic *twin*, described by Dr. Patterson,‡ the circumference of the head was nearly twenty-one inches.

Cases have also occurred in which enlargement of the fœtal belly from ascites has been sufficient to impede delivery; no such case has come under the writer's observation, but others have met with them.§ In another section of this article a case is noticed, in which immense distension of the fœtal bladder produced great difficulty in effecting the delivery. See p. 335. In such cases hydrocele has been sometimes observed at birth, and in other instances also.||

Ollivier (d'Angers) has described a case of dropsy confined to the cavity of the great epiploon in a well-formed child dead-born at the eighth month: the laminæ of the peritoneum were separated by a serous fluid of a yellow colour, and perfectly limpid, in which were floating flakes of albumen: the posterior layer of the epiploon was slightly opaque. The tumour distended the abdomen enormously, and there was fluctuation as in ascites: there were present all the characters of circumscribed inflammation of the epiploon.¶

Induration of the cellular tissue.—This peculiar affection, in the great majority of instances, does not invade the system for some days after birth, and even then it is of rare occurrence. My experience has not afforded me an opportunity of examining more than two cases, which were not congenital.

It has been already described in this work (see CELLULAR TISSUE, p. 516), and it appears only necessary to add here that the affection is sometimes found fully established at birth. "Many children," says Andral,** "come into the world with this affection," and we have the testimony of Billard†† and others to the same effect. Jaundice has been more frequently found than any other affection in

* Op. jam cit. p. 501.
† Anat. Pathol. liv. xv. pl. xi. p. 2, obs. 4.
‡ See Billard, Malad. des Enfans, p. 445.
§ Liv. xv. pl. xi. p. 6, obs. 10.
|| Anat. Pathol. by Townsend and West, vol. ii. p. 703.
¶ Arch. Gén. de Méd. Mai 1834.

* An accurate cast of it is preserved in the writer's museum.
† Cases in Midwifery, vol. ii. p. 525.
‡ Lond. Med. and Surg. Journ. Sept. 17, 1836, p. 86.
§ See Gardien, Traité complet d'Accouchemens, tom. iii. p. 106; Dugès, Dict. de Méd. et de Chir. Pratique, tom. viii. p. 303.
|| Graëtzer, Die Krankheiten des Fœtus, p. 159; Billard, Malad. des Enfans, p. 630.
¶ Archives Générales de Méd. Mai 1834.
** Anat. Pathol. by Townsend and West, vol. ii. p. 580.
†† Malad. des Enfans, p. 178.

conjunction with this œdema of the cellular tissue. Of seventy-seven cases examined by Billard, thirty were affected with jaundice.*

For a very full account of this subject see Graetzer, die Krankheiten des Fœtus: section *sclerodcrma.*

Cutaneous affections.—Lesions of the skin are probably the most numerous class of affections to which the fœtus in utero is liable.

Some of these appear to be in a great measure mechanically produced in consequence of the occurrence of other diseases, as in cases of spina bifida, encephalocele, and other tumours of the head. In these instances the skin covering the tumour is first attenuated as it is distended, and subsequently it disappears altogether, and not unfrequently becomes ulcerated. In some instances the injury observed on the skin is the result of inflammation either attacking the skin itself or the membranes of the ovum; in the former case abscesses may form and ulceration be produced. I have frequently seen instances of both, and also very distinct cicatrices, which must have been a considerable time in existence. Ollivier (d'Angers) describes a remarkable case of ulceration on the legs of a child born with clubbed feet.† I have more than one instance in my museum of destruction of the skin from adhesion having taken place between the fœtus and the membranes. Excrescences from the skin have been observed by the last-named author, Billard,‡ and others. The writer once attended a lady who gave birth to a very fine healthy child with two excrescences attached by pedicles over the third phalanx of each little finger. Nævi of different kinds existing at birth are matters of common observation, and in not a few instances petechiæ have been observed in the form usually denominated purpura hæmorrhagica.§

Very many instances of the eruptive diseases have been noticed in the immature fœtus and child at birth. Vogel and Rosen mention instances of chilbren born with the traces of measles, and Guersent says‖ he saw an infant born with the eruption on it, having taken the disease from the mother.

In the course of the last year I attended a patient who was delivered a month before her time, when just recovering from an attack of scarlatina; the child's skin exhibited the eruption in several places: it recovered.

* Ibid, p. 179. See also Dentschberg, Dissert. de tumor. nonnul. congenitis, Vratislav, 1822, p. 21; and Abbild. t. ii. Leger, Considerations sur l'induroissement du tissu cellulaire chez les nouveaux-nés. Denis, Theses de Paris, n. 159, année 1824, de l'indurcissement du tissu cellulaire, &c. and Recherches d'Anat. et de Physiol. Pathol. sur plusieurs Maladies des Enfans nouveaux-nés, Paris, 1826, p. 145. Orfila, Leçons de Méd. Lég. p. 375. Alibert, Nosol. Naturelle, p. 495-499.

† Arch. Gén. de Méd. Mai 1834.

‡ Maladies des Enfans, p. 79.

§ See Billard, op. jam cit. p. 92, 3. Gräetzer, p. 60. Cruveilhier, liv. xv. pl. ii. p. 2, 3, obs. 4 and 5.

‖ Dict. de Méd. t. xviii. p. 513. For several other references see Graetzer, die Krankheiten des Fœtus, p. 46.

Small-pox has been observed on the child at birth and under remarkable circumstances, as in cases where the mother had not been affected with the disease during gestation. See cases by Jenner, Med. Chir. Trans. vol. i. p. 269; and a very remarkable one by Mead, in which "a certain woman who had formerly had the small-pox, and was now near her reckoning, attended her husband in the distemper. She went her full time and was delivered of a dead child. It may be needless to observe that she did not catch it on this occasion, but the dead body of the infant was a horrid sight, being all over covered with the pustules; a manifest sign that it died of the disease before it was brought into the world." Works, edit. 1767, p. 253.

Billard* mentions having seen in the Museum of Guy's Hospital a fœtus of six months covered with pustules of small-pox, which was born when the mother was just recovering from the disease.

"Mary Gatton had confluent small-pox in the seventh month of her pregnancy; eighteen days from the first attack of the eruptive fever she was taken in labour and delivered of a child, which seemed to have been dead five or six days. Its body was covered with confluent small-pox. The pustules were white and full of matter, and from their size seemed to have nearly attained their maturity."†

"A lady was inoculated in the seventh month of her pregnancy, and on the ninth day from the accession of the eruption, which was moderate, she received a fall; from that period the motions of the child were no longer perceptible: in eight days after she was taken in labour, and delivered of a dead child covered with a great quantity of variolous pustules, which were prominent and in a state of suppuration."‡

Pemphigus has been observed on the child at birth by Lobstein,§ Joerg,‖ and others.

When the system of either parent retains a taint of syphilis, the child very frequently exhibits at the time of birth unequivocal evidence of being contaminated by the disease, and sometimes of having already fallen a victim to its ravages; though in the majority of such cases the children are born alive, often apparently healthy, and do not exhibit any appearance of disease for a few weeks.

In many instances children so tainted are born in a state of complete putridity, and with the skin either already stripped off or quite loose and detached; in other instances, which are much more rare, the children have been born alive, with a well-marked syphilitic erup-

* Op. jam cit. p. 97. See also Graetzer, op. cit p. 27.

† Paper by Dr. Bland in Simmons' Lond. Med. Journ. vol. ii. p. 204.

‡ Mem. Lond. Med. Soc. vol. iv. p. 364.

§ Journ Complem. du Dict. des Sci. Med. t. vi. p. 1.

‖ Handbuch der Kinderkrank. 1826, p. 310. See also Siebold, Journal für Geburtshülfe, &c. iv. Bd. 1, St. 1823, s. 17. Meissner, Kinderkrankheiten 1. p. 406, 410. Wichmann, Beitrag zur Kenntniss von Pemphigus, p. 15.

tion on the skin, as in the cases recorded by Cruveilhier,* Dr. Collins,† and others. I am indebted to Dr. Collins for a very accurate drawing of one of his cases; the skin of the child generally was of a very dark hue; scattered over different parts of the body were brownish or copper-coloured blotches, intermingled with pustules and with large vesicular patches containing a straw-coloured purulent fluid, along with which there were also numerous superficial ulcerations of a bright red colour.

Affections of the heart and pericardium.—Independently of the innumerable irregularities of structure and malformation to which the heart is liable, experience has shewn that both it and its pericardium are sometimes attacked by disease in utero.

Denis gives an account of a case of hypertrophy of the heart at birth.‡ The following case of scirrhous tumours in the heart is described by Billard.§ On opening the body of a child of three days old he found on the anterior surface of the heart along the interventricular line three projections of a whitish colour; they were buried in the substance of the wall of the left ventricle and the interventricular septum, projecting a little into the cavity of the organ. When cut into, they creaked under the scalpel, and the cut surface exhibited closely interlaced fibres, perfectly resembling, both in appearance and form, those of scirrhus. Cruveilhier details a highly interesting case of aneurism of the right auricle and ventricle in consequence of the obliteration of the orifice of the pulmonary artery. The child was born at eight months and a half in a state of extreme debility, and lived only five days, all which time the respiration was imperfect, embarrassed, and almost convulsive. On examination the heart was found enormously enlarged, filling more than half the thorax, and pushing back the lungs, which were of small size. The right cavities were so enlarged as to constitute seven-eighths of the whole organ; the valve of the right auriculo-ventricular opening was attached and fixed in such a way that the blood passed as freely from the ventricle into the auricle as in the opposite direction, and there were floating granulations on the free edge of the valve. The orifice of the pulmonary artery was completely obliterated, but otherwise the artery and its divisions were healthy.‖ "How could life," asks Cruveilhier, "be maintained for five days? there did not pass a drop of blood into the lungs from the right ventricle. I think that the entrance of the blood into the lungs was partially accomplished through the ductus arteriosus; it is probable that life would have been maintained if the foramen ovale had remained free and open." It appears to me that the explanation here offered by the author is probably correct, as I once saw an instance in which a child affected with the morbus cœruleus lived a year and a half, and on examination we found that the aperture of the pulmonary artery was completely obliterated where it should have joined the right ventricle, but the aorta had an opening into it from both ventricles, and the ductus arteriosus was quite open and free; and my opinion then was that in this way sufficient blood was transmitted to the lungs and revivified for the imperfect support of life; the foramen ovale was open. Billard also met with an instance of aneurism of the ductus arteriosus in a new-born child: the heart was larger than usual, the duct was of the form of a large cherry-kernel and filled with fibrinous coagula disposed in layers, as they are found in the aneurisms of adults.* How far this affection truly deserves the name of aneurism seems somewhat doubtful; but the writer, not long since, met with a similar condition of the ductus arteriosus when examining the body of an infant which died suddenly.

Pericarditis.—Evidences of the existence of this disease have also been frequently met with. In a child only two days old Billard found between the opposite surfaces of the pericardium adhesions so firm as to lead to the conclusion that they must have been formed during fœtal life;† and in the case of a child which lived only an hour Cruveilhier found, in addition to anasarca, ascites, and purpura, effusion in the sac of the pleura and a great quantity of fluid in the pericardium.‡ Speaking of this affection, Andral says, "It is a fact which one would never imagine, *a priori*, that irritation of the pericardium terminating in the formation of false membranes or purulent effusion into its cavity is a common enough disease in the fœtus, even more so, perhaps, than in the adult."§

The thymus gland.—Considering the number of pathological lesions to which we have just seen that the lungs are liable, although being organs in a state of complete quiescence during fœtal life, we cannot be surprised that the thymus, which attains so great a degree of development (if not its greatest) before birth, should frequently exhibit evidences of morbid over-action, and accordingly several instances of the kind have been recorded.

Cruveilhier relates a case of a child which lived only a few minutes, and under whose sternum there was a large collection of pus which was lodged partly in the thymus and partly in the anterior mediastinum; the thymus

* Anatomie Pathol. liv. xv. pl. 11, p. 6, obs.

† Practical Treatise on Midwifery, &c. p. 508, 11. On this subject see Doublet, Mémoire sur la Verole des Enfans nouveaux-nés, Paris, 1781. Dr. Beatty, Trans. Assoc. Coll. Phys. in Ireland, vol. iv. p. 31. Haase, de Syphilidis recens natorum pathogenia, Lipsiæ, 1828. J. F. H. Albers, Ueber die Erkenntniss und für der Syphilischen Hautkrankheiten, 1832. Wendt, Kinderkrankheiten iii. Aufl. p. 109. Dugès, Dict. de Méd. et de Chir. Pratique, vol. viii. p. 298. Colles, Practical Observations on the Venereal Disease, 1837, p. 262.

‡ Recherches d'Anat. et de Phys. Pathol. &c. des Enfans, p. 353, Paris, 1826.

§ Maladies des Enfans, p. 647.

‖ Anat. Pathol. liv. xv. pl. ii. p. 4, obs. 8.

* Op. jam cit. p. 567, and atlas pl. 8.

† Ibid, p. 571.

‡ Anat. Pathol. liv. xv. pl. ii. p. 3, obs. 5.

§ Pathol. Anat. by Townsend and West, vol. ii. p. 702, 3.

was much enlarged, contained several tuberculated cells filled with pus. He considers it a tubercular affection of the thymus, or in other words, a chronic inflammation of that organ.*

Veron † found the thymus at birth very voluminous, much inflamed, and containing a quantity of pus.

The thyroid gland.—This organ has been found exhibiting similar lesions to those just described, instances of which are recorded by Francus,‡ Carus,§ Hufeland,|| and others.

Abnormal conditions of the fœtal bladder.—The consideration of this subject necessarily involves the disputed question, whether urine be secreted by the child before birth, of which, however, the writer feels fully convinced by facts within his own observation.

In the year 1824 I attended a patient who was delivered of a still-born child, which had an unusual prominence of the lower part of the abdomen; on laying my hand over the part, I ascertained the existence of a tumour of extraordinary firmness, which, on opening, I found to be the bladder, distended to the size of a large orange, remarkably tense, and containing a fluid having the appearance of urine: it was not, however, chemically examined; the ureters were so distended that their coats were diaphanous, the diameter of those canals being nearly an inch, and they were very much convoluted in their length, which greatly exceeded what is usual: the pelves of the kidneys were in a similar state of distension; the urethra, where it joined the bladder, was completely impervious.

In the course of the last year I was in attendance on a lady who had in her former labours suffered frightfully from hæmorrhage coming on after the birth of the child; as a means of preventing the recurrence of so dangerous an accident, I conducted the delivery with the greatest caution, and allowed the uterine contraction to effect the expulsion of the child, even to the feet: but while it was lying with the legs and thighs still within the vagina, the penis became partially erected, and a stream of urine was expelled in an arch, to the amount of at least six or seven ounces.

The following case, related by Mr. Fearn,¶ is a striking example of the degree to which the bladder may be affected before birth. After the expulsion of the child's head, the extraction of the body was found impracticable, even after mutilation of the upper extremities, and evisceration of the thorax. An elastic tumour was now felt in the situation of the diaphragm; this was punctured, and immediately an immense quantity of reddish watery fluid escaped, and the delivery was easily completed. On examination, the child appeared to have arrived at the seventh or eighth month; the parietes of the abdomen were large and flaccid, and in its cavity was an immense sac, the coats of which were three or four lines in thickness, and traversed in every direction by numerous large vessels gorged with blood. This sac was, after careful dissection, distinctly made out to be the urinary bladder which had been enormously distended by the secretion from the kidneys; its muscular fibres were much hypertrophied; it had no communication with the urethra; the penis was well developed, but the urethra passed down along it only as far as its membranous portion. The kidneys were flabby, and their secreting and tubular portions much attenuated, owing to the distension the pelvis of each had undergone; the ureter on each side, when inflated, was nearly an inch in diameter, and at one side the valvular opening into the bladder was large enough to admit readily the point of the little finger. The bladder when filled with water *contained upwards of two quarts.* The rectum terminated in a blind pouch in the pelvic cavity, and there was, consequently, no anal opening.* There was besides an arrest of development of the right lower extremity, the limb becoming suddenly wasted immediately below the knee, and having attached to it a foot no larger than, and in every way resembling that of an embryo of the tenth or twelfth week. The body appeared in other respects to have been tolerably well nourished.

In a case mentioned by Dr. Lee,† which occurred to Mr. Hay of Osnaburg-street, the child's abdomen was so large at birth in the eighth month that it passed with difficulty through the pelvis, and the enlargement was found to arise from an accumulation of fluid within the kidneys, produced by an impervious state of the ureters. The right kidney, which resembled a thin cyst filled with a watery fluid, was larger than the head of the child; the left did not exceed half this bulk; it contained four ounces, and the other nine, of a fluid resembling urine, and which, when examined by Dr. Prout, was found to contain the chemical constituents of that fluid. The child had also a double hare-lip and clubbed feet.

Mr. Howship examined the body of a child which died a few hours after birth in the eighth month; it had distorted feet, imperforate anus, and the lower part of the abdomen was occupied by a large circumscribed tumour, which proved to be the bladder, the coats of which had acquired a very extraordinary degree of strength and thickness; the ureters were thin and membranous from distension and curiously contorted, and terminated in what appeared like a congeries of small hydatids no larger than garden peas, loosely connected together by a cellular texture; these were the kidneys in a morbid state: the urethra was impervious. Mr. Howship alludes to two other nearly similar cases.‡

* Anat. Pathol. liv. xv. pl. ii. fig. 2.

† Mem. dans la seance de l'Acad. Royale de Med. 26 Août, 1825.

‡ Eph. N. C. Dec. II, an. v. obs. 223.

§ Leipz. Lit. Zeit. 1816, p. 238; 1817, p. 301; 1819, p. 452; 1820, p. 241, and Gynækologia ii. p. 253.

|| Journal, 1827, Bd. 64, p. 26.

¶ See Lancet, vol. ii. for 1834-35, p. 178.

* The writer had lately an opportunity of examining a specimen of this peculiarity in Dr. Murphy's collection.

† Med. Chir. Trans. vol. xix. p. 238.

‡ Treatise on the Urine, &c. 1823, p. 374, 6.

Other instances of this condition of the urinary apparatus are recorded by other writers,* and in particular Meckel has related a case in which it was conjoined with several other very remarkable deviations.†

Urinary deposits.—It is no slight confirmatory proof of the secretion of urine by the fœtus, that urinary deposits have been discovered in the kidneys, ureters, and bladder. Brendelius mentions two cases, in one of which a child only two days old, and in the other one of eight days old, passed calculi before death; and calculi were also found in their bladders.‡

Loeseke found a calculus in the kidney of a new-born child.§ Hoffman relates the case of a German princess who was afflicted with renal calculus, and gave birth to a daughter, who from the hour of birth suffered excruciating pain when passing water; the child died when three weeks old, and on examining the body a calculus as large as a peach kernel was found in the bladder.‖ Orfila saw two cases in which there were calculi in the bladder and in the kidneys at birth.¶

Premature developement of teeth. — It is hardly necessary to remark that at an early period of fœtal existence the teeth begin to be developed, and it is equally a matter of common observation that they do not in general emerge from their alveoli and pass through the gums until several months after birth. But many instances have been observed in which some of them have been found developed and projecting above the gums at birth.

I have before me at this moment four teeth of this kind taken from the gums of the only two children of a patient of mine; in each child the two middle incisors of the lower jaw were found projecting at birth, and in each instance it was found necessary to extract them after a few days, in consequence of their cutting the child's tongue and preventing it from sucking.

Louis XIV. and Mirabeau are well-known instances of this premature developement of teeth, and many other cases are recorded by different authors; for several references see Gräetzer.**

This abnormal condition of the teeth has been frequently found accompanying certain deformities of the face, especially hare-lip and cleft palate.

Intestinal worms.—However repugnant to our ideas of probability the existence of worms in the intestines of the fœtus in utero may at first sight appear, too many instances of the fact have been observed by authors of credit to allow of any doubt remaining on the subject; I must, however, add that no case of the kind has come under my own observation. So far back as the writings of Hippocrates, we have an account of a tapeworm found in a fœtus; and it seems very probable that in the instance mentioned by Hufeland,* in which he found a tapeworm thirty ells long in a child of six months old, the animal must have existed in the child before birth. Kerkringius† found in a fœtus of six months and a half, whose abdomen was much enlarged, worms of the kind usually met with in children (ascaris lumbricoides or vermicularis). Dolæus‡ speaks of a dead-born child in whose intestines he found a knot of worms; and similar observations have been made by Schrœter and others. According to Rœderer and Wagner the whipworm (trichuris) was found in a case in which the fœtus participated in the disease (morbus mucosus), under which the mother was labouring at the time. Other instances are noticed by Brendel,§ Bloch,‖ Rudolphi,¶ and Gräetzer.**

Imperforate anus.—Cases of imperforate anus, of the ordinary kind, are too numerous and too well known to require any particular observation; but this imperfection has been occasionally accompanied by other peculiarities deserving to be noticed; one or two are, therefore, subjoined in addition to the full account of congenital malformations of this part given in the article Anus.

Dr Steel has recently recorded the particulars of a case of a new-born infant, who was observed, one or two days after birth, to have feculent matter, mingled with the urine, discharged by the urethra. The parts behind the scrotum were perfectly natural in every respect, except the want of an anus, of which there was not the slightest vestige; the spot where it should have been was smooth, and of a uniform colour with the adjacent parts; the sphincter muscle was evidently wanting, and there was nothing to indicate an accumulation of fæces in the vicinity.

For the first three or four weeks the child continued fretful, and was evidently declining in vigour and growth; but from that period to a short time before its decease it apparently suffered but little, nor did its growth or strength seem to be at all impeded. It was born on the 13th of April, and in the latter part of the ensuing March its bowels became obstinately obstructed, the scrotum enlarged, and became extremely tender; and on the 30th of the same month it died.

On dissection, two apple-seeds of a large

* See Billard, Maladies des Enfans Nouveaux-nés, &c. p. 431 et seq.; Ollivier d'Angers. Archiv. Gen. de Méd. t. xv. p. 371; Mr. Wilson, Med. Chir. Trans. vol. xix. p. 248.; Ruysch, Sandifort, Wrisberg, Chaussier, and Vrolik have described such cases.

† Journ. Complem. des Sciences Méd. t. xiii. p. 335.

‡ Program. de Calcul. Vesic. et ceteris Natal.; also Obs. Anat. Dec. iii. ob. 1.

§ Obs. Anat. Chir. Med. p. 39.

‖ Dissert. inaug. de morbis fœtus in utero materno, Halæ Magdeb. 1702.

¶ Leçons de Méd. Lég. Paris, 1828, t. i. p. 297.

** Die Krankheiten des Fœtus, p. 141.

* Journal Bd. 18, st. i. p. 3, quoted by Bremser; Traité des Vers intestinaux, p. 181.

† Specilegium Anatomicum, Amstel. 1670, obs. 79, p. 154.

‡ Encyclop. Med. lib. vi. cap. 10, p. 1011.

§ Pallas, dissert. de inf. viv. p. 59.

‖ Preisschrift über die Erzeugung Eingeweidewürmer, Berlin, 1782, p. 38.

¶ Entozoa i. p. 387; Pallas, p. 43.

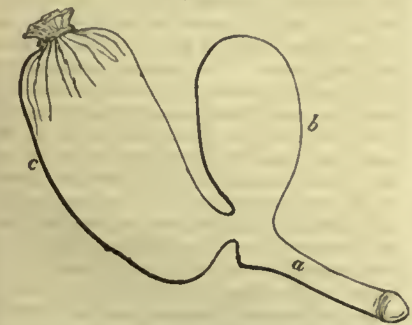
** Die Krankheiten des fœtus, Breslau, 1837, p. 107.

size, together with a portion of the capsule or hull which surrounds them, were found lodged in the urethra, about three-fourths of an inch from its termination; they were so situated as completely to obstruct the passage, and a small opening had been formed immediately behind them in the urethra, through which some of the contents of the bladder had been infused into the cellular tissue, and extended to the scrotum, producing inflammation and gangrene, and so causing the child's death.

The contents of the abdomen appeared perfectly natural, except the colon sinistrum or descending colon, which was found to be entirely destitute of the sigmoid flexure; the gut passed along the left lumbar and through the iliac regions in nearly a straight line to the neck of the bladder, into which, after making an abrupt but imperfect curve, and being suddenly contracted in its dimensions, it was inserted just behind the base of the prostate gland. The aperture which united the gut and bladder into one common receptacle for their respective contents was of sufficient capacity to admit a large-sized goose-quill; through this aperture the urine found a ready egress into the intestine, where, becoming united with the contents of that receptacle, it was forced back into the bladder, and finally excluded through the urethra. The space between the perineum and the termination of the intestine was occupied by a soft fatty substance, but there was not the slightest vestige of a gut.*

The subjoined woodcut represents the parts of one half the natural size when merely inflated.

Fig. 160.



a, the penis. *b*, the bladder. *c*, the colon.

We have given the above in detail, not merely on account of the remarkable nature of the anatomical deviation, but as connected with the still more interesting fact, that life was under such circumstances sustained, and healthy defæcation accomplished for nearly a year after birth.

M. Roux of Brignolles operated successfully in May, 1833, on a new-born child, in whom the same malformation appears to have existed; no trace of anus could be discovered in the perineum, and the rectum terminated at the urethra, through which some fæcal matter was discharged; the infant lived, and enjoyed good health.*

Rickets.—Deformities of the bones arising from rickets have been occasionally observed both in the child at birth and in the immature fœtus; but the instances have been few in number; the writer has never had an opportunity of examining a case of the kind, but they have been described by authors of credit. Pinel has given an account of a ricketty fœtus of eight months, in which the deformity was chiefly confined to the lower extremities.† Chaussier‡ examined another at the Maternité at Paris, in which there was distortion of the back and thorax, with softness and flexibility of the bones. Several other writers of respectability have described this affection.§

Jaundice.—The fœtus in utero, as well as the child at birth, has been found exhibiting all the characters of true jaundice. In the case of a lady, related by Dugés,‖ who was herself liable to frequent attacks of this disease, and had biliary calculi, all her children were born dead, and strongly coloured by jaundice. It is not, however, always fatal to the child affected with it before birth.

Cirronosis.—Under this name¶ Professor Lobstein of Strasburg has described** an affection of the fœtus in which the serous or transparent membranes, as the peritoneum, pleura, pericardium, and arachnoid, were stained of a strong yellow colour, which in some instances was found to pervade also the brain, spinal marrow, and the great sympathetic nerves. The cause of this peculiar colour is altogether a matter of doubt, but it differs from jaundice in not affecting the parenchymatous cellular tissue of internal organs, the subcutaneous cellular tissue, nor the skin, and it is found so early as the third and fourth months, a period at which the bile is not as yet secreted. For a more ample account of this affection see the article Cirronosis.

Accidental morbid tissues observed in the fœtus.—Some of these have been already incidentally noticed under different heads in the present article, but it appears desirable to

* American Journal of the Medical Sciences, No xxx. p. 404.

* See Medical Gazette for June 28th, 1834; or the American Medical Journal, No. xxx. p. 531, where there is an account of the mode in which the operation was performed.

† La Médecine éclairée par les Sciences Physiques, tom. i. p. 111.

‡ Dict. des Sci. Méd. tom. xvi. p. 67.

§ Loder, Index Preparator. &c. Mosquæ, 1823, sec. ii. D; Sartorius, Rachit. Congenit. Obs. 4to. Lipsiæ, 1826, cum tabulis; Romberg, De Rachit. Congenit. Berolinæ, 1817, cum tabulis; Otto, Seltene Beobachtung, 1 Sam. tab. i. fig. 1.; Sœmmering, Abbildung. u. Beschreib. einiger Missgeburten, p. 30. pl. xi; Bordenave, Mém. de Mathem. et Phys. tom. iv. p. 545; Lepelletier, Maladie Scrofuleuse, Paris, 1830; Henckel, Abhandl. Chirurg. Oper. Th. ii. p. 14; Glisson de Rachitide, p. 178.

‖ Dict. de Méd. et de Chir. Prat. t. viii. p. 301.

¶ From κιρρος, yellow, and νοσος, a disease.

** In the Repertoire Générale d'Anatomie, &c. No. i. p. 141, and plate iv.

advert to them here as a group for the sake of distinction.

Tubercles have been found by the writer and others, as already referred to, in the lungs, liver, brain, spleen, peritoneum, and mesentery, the glands of which have been found by Œhler in a state of complete scrofulous degeneration, not only in children born of a scrofulous mother, but in others also: in some instances the tubercular formations were found in a state of suppuration.*

Scirrhous tumours have been already described as found in the heart.

The only instance of fungus hæmatodes in the fœtus of which the writer is aware, is one which he had, not long since, an opportunity of observing † with Dr. Alcock and Dr. Evanson in a child which lived only nine weeks; at birth an unusual fulness was observed about the perineum and anus, which increased rapidly until these parts became greatly protruded, and a tumour was formed of the size of a very large orange; convulsions came on, and the child died after much suffering: on examination, the tumour was found to be a perfect specimen of fungus hæmatodes.

BIBLIOGRAPHY.—*Licetus (Fortun.)* De perfecta constitutione hominis in utero, &c. 4to. Patavii, 1616. *Alsaro della Croce, (Vincent)*, Disquisitio generalis ad historiam fœtus emortui nonimestris, &c. 4to. Romæ, 1627. *Riolanus (Joan.)* Fœtus historia, 8vo. Parisiis, 1628. *Fridericus (Joan. Arnoud.)* Τυμνασμα ιατρικον fœtum quoad principia, partes communes et proprias, differentias, morbos et symptomata, eorumdemque curationem offerens atque exponens, 4to. Ienæ, 1658. *Frank de Frankenau, (Georg.)* De impuberibus generantibus et parientibus, fœtu in fœtu, embryo in embryo, et fœtu ex mortuâ matre, &c. *Duettel, (Phil. Jac.)* De morbis fœtus in utero materno, 4to. Halæ Magdeb. 1702. *Valentini*, De morbis embryonum, Giessæ, 1704. *Storch*, Kinderkrankheiten, Eisenach, 1750. *Socin (Joan. Abel.)* De fœtu hydropico, 4to. Basilæ, 1751. *Jæger*, Observationes de fœtibus recens natis jam in utero mortuis, &c. 4to. Tubingæ, 1767. *Raulin*, Traité des Maladies des Enfans, Paris, 1768. *Gruner*, De Nævorum Originibus, Jenæ, 1778. *Zierhold*, De notabilibus quibusdam quæ fœtui in utero contingere possunt, Halæ, 1778. *Hoogeveen*, Tractatus de fœtus humani morbis, 8vo. Lugduni Bat. 1784. *Engelhart*, Dissertatio inaug. Med. sistens morbos hominum a primâ conformatione usque ad partum, 4to. Jenæ, 1792. *Chaussier*, Discours prononcé à l'hospice de la Maternité, Juin 1810 et Juin 1812. *Ej.* Procès Verbal de la distribution des prix, 1812. *Ej.* Bulletins de la Faculté de Médecine, Paris, 1813 et 1821. *Murat*, Dict. des Sciences Méd. art. Fœtus, Paris, 1812. *Feiler*, Pädiatrik, Subzbach, 1814. *Oehler*, Prolegomena in embryonis humani pathologiam, Diss. inaug. Lipsiæ, 1815. *Joerg*, Zur Physiologie und Pathologie des Embryo, Lipsiæ, 1818. *F. B. Osiander*, Handbuch der Entbindungskunst, Tubingæ, 1819. *Seeligmann*, Dissertatio de morbis fœtus humani, Erlangæ, 1820. *Zuccarini*, Zur Beleuchtung der Krankheiten der menschlichen Frucht, Erlangen, 1824. *Desormeaux*, Dict. de Méd. tom. xv. art. Œuf; Paris, 1826. *Prosper, S. Denis*, Recherches d'Anat. et de Physiol. pathologique sur plusieurs maladies des Enfans nouveaux nés. Paris, 1826. *Hufeland*, Die Krankheiten der Ungebornen und die Vorsorge, &c. Journal der praktischen Heilkunde, 1827. *Meissner*, Kinderkrankheiten, Leipzig, 1828. *Hardegg*, De Morbis fœtus humani, Tubingæ, 1828. *Billard*, Traité des Maladies des Enfans nouveaux-nés et à la mammelle, Paris, 1828. *Bergk*, De Morbis fœtus humani, Lipsiæ, 1829. *Cruveilhier*, Anatomie Pathologique du corps humain, Paris, 1829. *Andry*, Mémoire sur les Maladies du fœtus, &c. Journal des Progrès, 1830. *Zurmeyer*, De Morbis fœtus, Bonnæ, 1832. *Grüetzer*, Die Krankheiten des fœtus, Breslau, 1837.

(W. F. Montgomery.)

* See section on the state of the Lungs, and Billard, p. 648.

† See his Exposition of the Signs and Symptoms of Pregnancy, &c. p. 152.

FOOT, BONES OF THE (in human anatomy).—The foot *(pes;* Gr. πους; Fr. *le pied;* Germ. *der Fuss)* forms the inferior segment of the lower extremity, being united to the leg at the ankle-joint nearly at a right angle, so that in the erect position on a plane surface the foot is horizontal. The outline of the foot circumscribes an ovoidal figure, the long axis of which is directed from before backwards; and in the same direction the foot is divided into three segments, the anterior one surpassing that behind it in mobility, but falling short of it in solidity. These divisions are the tarsus, metatarsus, and the toes.

The size of the foot, taken as a whole, varies in different individuals: it always exceeds that of the hand, chiefly, however, in length and thickness, its breadth being less than that of the hand. In the hand we find divisions precisely analogous to those of the foot above mentioned and similarly constructed, with this difference, that the solid part of the foot is more solid and more developed in every way than the corresponding part of the hand, but the moveable parts possess less mobility than the analogous segments of the hand. The parts of the foot and hand, as Mr. Lawrence observes, are disposed inversely in respect to their importance. The posterior portion of the former and the anterior of the latter are of the most consequence and possess the most remarkable characters. In short, the foot is nothing more than the hand so modified as to afford a firm basis of support to the inferior extremity in the erect posture. One of the most remarkable of these modifications is that manifest in the metatarsal bone of the great toe, which corresponds to the metacarpal bone of the thumb. The latter bone is connected with the carpus so that it forms an acute angle with the second metacarpal bone. It enjoys at its articulation with the carpus a considerable degree of mobility, in virtue of which exists the opposable faculty of the thumb. On the other hand, the metatarsal bone of the great toe enjoys but a very limited degree of mobility at its articulation with the tarsus: it lies parallel to the adjacent bone and possesses considerable strength. These remarkable differences, says Mr. Lawrence, are easily understood when we consider that the great toe, as one of the points on which the body is supported, requires solidity; while the thumb, being concerned in all the numerous and varied motions of the hand, must be organised for mobility. Those animals in which the inferior segments of both anterior and posterior extremities are eminently required for prehension have the inferior segments of all four extremities organised as hands, and are thence denominated Quadrumanous.

The most elevated part of the foot is at its posterior part, where it contributes to form the ankle-joint; thence it inclines forwards, gradually expanding transversely, and presenting a more or less convex surface from behind forwards. This is the *dorsum pedis*, the instep.

The inferior surface likewise expands as it proceeds forwards. It is slightly concave in the transverse direction, and more manifestly so in the antero-posterior one; this latter, however, varies in a degree proportionate to the convexity of the dorsum. This is the *planta pedis*, the sole.

The internal edge of the foot corresponds to the great toe, the external edge to the little toe, the anterior to the ends of the toes, and the posterior extremity of the foot is formed by the os calcis.

I. *Tarsus* (Germ. *die Fusswurzel*).—Nearly the posterior half of the foot is occupied by the tarsus, which is arranged in the form of an arch, convex superiorly, on the highest point of which rests the weight of the leg. Seven bones enter into the formation of the tarsus; they are arranged in two sets or rows. The posterior row is formed by the *astragalus* and *os calcis*, the anterior row by the *os naviculare*, the *os cuboideum*, and the *three cuneiform bones*. Through the medium of the first two bones of the anterior row that row is articulated with the posterior.

1. *Astragalus* (*αστραγαλος, τετρωρος, os balistæ, talus*; Fr. *l'astragale*; Germ. das *Knochelbein* oder *Sprungbein*).—This bone is situated between the tibia and the os calcis, and has the navicular bone in front of it. In point of size it ranks second among the tarsal bones, the os calcis being first.

The astragalus is commonly divided into three parts for the purposes of description, viz. the *head*, *neck*, and *body*. The head is that convex portion which forms the anterior part of the bone, and which is entirely articular. This smooth, oval, articular head is adapted to the posterior concavity of the navicular bone. The aspect of this surface is forwards, inwards, and slightly downwards. On the inferior part of the head we notice another articular facet, planiform, situated internally, and generally continuous with the articular surface last described. By means of this facet the astragalus moves on a corresponding surface on the upper and anterior part of the os calcis.

The head of the astragalus is connected to the body by a narrow contracted portion called *the neck*, which is rough on all its surfaces, giving insertion to ligaments and perforated by numerous foramina for the transmission of vessels. The external side of the neck presents a remarkable excavation, which affords insertion to and contributes to bound a space for the lodgement of a strong ligament which passes between the astragalus and os calcis.

All that portion which is behind the neck constitutes what is called *the body*, on which we notice five surfaces. *a*. The *superior* surface forms an articular trochlea, convex from before backwards, and slightly concave transversely; it articulates with the inferior extremity of the tibia:* immediately in front of it there is a roughness of very limited extent, which affords insertion to ligamentous fibres. *b*. The *posterior* surface is almost wholly occupied by a well-marked groove, which passes obliquely downwards and inwards, and is destined to lodge the tendon of the flexor pollicis longus. *c*. The *external* surface is occupied by a triangular facet, whose base is direct upwards and is continuous with the articular part of the superior surface of the body; this facet articulates with the fibula. It is bounded below and behind by a rough portion for ligamentous insertion. *d*. The *internal* surface is also articular in its upper half for the adaptation of the inner malleolus: it, too, is triangular, and by its base is continuous with the superior surface. Below this internal malleolar facet the bone is rough and irregular, and here the internal lateral ligament of the ankle-joint is inserted. Lastly, the *inferior* surface is occupied almost entirely by a concave articular facet, oval, with its long axis directed from within outwards and forwards; this facet is articulated with a corresponding one upon the os calcis. Immediately in front of it there is a deep and narrow depression which separates it from an oval planiform facet for articulation with the sustentaculum of the os calcis.

2. *Os calcis* (*πτερνα, σκελις*; Fr. *le calcaneum, os du talon*; Germ. *das Fersenbein*; *the heel-bone*).—This is the largest bone of the tarsus; it occupies the most posterior part of the foot, and is situated immediately underneath the astragalus, of which it constitutes the principal support. Its greatest extent is from before backwards. It is somewhat flattened on the sides: its direction is horizontal, the foot in standing resting upon the most posterior part of its inferior surface. This horizontal direction of the heel-bone is one of the arguments which anatomy affords in support of the assertion that the erect posture is natural to man.

We notice six surfaces upon this bone.

a. The *superior* surface, or that upon which the astralagus rests. On it we observe in front three articular facets, separated from each other by distinct intervals: the first or smallest is situated at the anterior edge of the surface and at its internal angle, and is articulated with the facet on the inferior part of the head of the astragalus; it is not constant. The second is posterior and internal to the last, separated from it by a rough depression about a quarter of an inch in extent. This is oval, slightly concave, and is marked upon a projecting portion of the bone which overhangs the anterior part of the internal surface, and which is known under the name of *processus internus*, or *sustentaculum cervicis tali* of Albinus; it supports and is articulated with a corresponding facet on the under surface of the neck of the astragalus. A narrow groove on the outside of the

* See further description in the article ANKLE-JOINT.

facet last named separates it from the third and largest one; this is articulated with the facet which is on the inferior surface of the body of the astragalus; it is oval, convex, and its long axis directed forwards and outwards. Immediately in front of this articular facet there is a hollow, rough, non-articular surface for the insertion of the ligament which connects the astragalus to the os calcis, and behind the facet the remaining portion of the superior surface of the bone is also non-articular, slightly excavated from before backwards, varying in length in different subjects, and on this variety depends the diversity in the length of the heel. *b.* The *posterior* surface, oval in its outline, rough and fibrous in its inferior half, where the tendo Achillis is inserted, smooth in its superior half where a bursa is placed, over which the tendon glides. *c.* The *inferior* or *plantar* surface, nearly equal in extent to the superior, and in the natural position directed obliquely upward and forwards. Here we find, in examining the parts from behind forwards, first, two tubercles, upon which the heel rests in standing, and which seem peculiarly to characterize the human heel-bone. These tubercles are separated from each other by a depression; the internal one is greatly the larger—it affords attachment to the short flexor of the toes; the external one is small and pointed, and to it are attached the abductor minimi digiti muscle and the plantar fascia. Secondly, in front of these tubercles the bone is very rough and flat to within half an inch of its anterior margin, where it is slightly grooved transversely. The whole of this portion gives insertion to the strong calcaneo-cuboid ligament. *d.* The *anterior* or *cuboid* surface, which is entirely articular, triangular, with its base upwards, slightly concave, and articulated with the cuboid bone. *e.* The *external* surface, quite subcutaneous, so that here the bone is greatly exposed to injury, and may be easily got at for surgical operation. It is slightly convex, its posterior half being double the size of the anterior in vertical measurement; at the anterior part of the former there are two superficial grooves directed obliquely forwards and downwards, separated by a slightly prominent tubercle. The anterior of these grooves gives passage to the tendon of the peroneus brevis, the posterior to that of the peroneus longus. *f.* The *internal* surface, excavated in its whole extent, lodges the tendons and nerves which are passing from the back of the leg to the sole of the foot; at the junction of its anterior and posterior halves it is overlapped by the sustentaculum, the inferior surface of which is grooved by the tendon of the long flexor of the great toe.

3. *Os cuboideum, (os cubiforme,* Fr. *le cuboide,* Germ. *das Wurfelbein.)*—This bone forms the external one of the second row of tarsal bones; it is situated between the os calcis behind and the fourth and fifth metatarsal bones in front; in point of size it ranks next to the astragalus. Six surfaces may be described upon it. *a.* The *superior* or *dorsal* surface, forming an inclined plane, directed downwards and outwards; it is rough for ligamentous insertion. *b.* The *external* surface, more properly an edge, very limited in extent, chiefly occupied by the commencement of the groove for the peroneus longus muscle. *c.* The *inferior* or *plantar* surface, which in front presents a deep groove directed obliquely forwards and inwards, parallel to the anterior edge, and destined to lodge the tendon of the peroneus longus. The posterior edge of this groove is very prominent, and with the remainder of this surface, which is rough, affords insertion to the calcaneo-cuboid ligament. *d.* The *internal* surface has at its upper and posterior part a triangular plane articular facet for articulation with the external cuneiform bone, and sometimes a smaller one for articulation with the navicular; the rest of this surface is irregular and rough for ligamentous insertion. *e.* The *anterior* or *metatarsal* surface is wholly articular, and is divided by a vertical line into two facets, an outer one triangular and plane for the fifth, and an inner one quadrilateral and very slightly concave for the fourth metatarsal bone. The external of these facets is inclined obliquely outwards and backwards. *f.* The *posterior* surface is oval, with its long axis directed downwards and outwards; it is wholly articular and adapted to the anterior surface of the os calcis.

4. *Os scaphoideum* (from σκαφη, *navis, os naviculare,* Fr. *le scaphoide,* Germ. *das Kahnbein,* oder *Schiffformige Knochen,*) forms the posterior and internal bone of the second tarsal row, and is placed between the three cuneiform bones in front and the astragalus behind. It is oval in shape, with its long axis directed obliquely downwards and inwards; the small end of the oval is situated internally and inferiorly, and presents a distinct prominence or process *(tuber ossis navicularis)*, which gives insertion to some fibres of the tendon of the tibialis posticus.

Four surfaces may be described upon this bone. *a.* The *superior* or *dorsal* surface, of great extent, convex, very rough for the insertion of ligaments, and perforated by foramina. *b.* The *inferior* surface, irregularly concave, and very rough, also affording insertion to ligaments. *c.* The *posterior* surface, entirely articular, oval and concave, adapted to the head of the astragalus, although considerably less in extent than it. This constitutes what is called the *glenoid cavity*. *d.* The *anterior* surface, also articular and convex, divided by two lines which converge from above downwards, into three triangular surfaces for articulation with the three cuneiform bones.

5. *Ossa cuneiformia* (Fr. *les os cuneiformes,* Germ. *die Keilformigen Knochen.)* These bones are interposed between the navicular bone behind and the three internal metatarsal bones in front; they are arranged in the form of an arch, of which the middle cuneiform is the central or key-bone. Each is very distinctly wedge-shaped; the two outer ones have the acute edge directed downwards, but the internal one has it directed upwards.

The *internal* cuneiform bone is at once distinguishable from the others by its great size. By means of an oval concave articular surface, whose long axis is vertical, it is articulated with the anterior and internal part of the navicular bone, and in front a large and irregular, slightly concave articular facet adapts it to the posterior extremity of the metatarsal bone of the great toe. Its *inner* surface is convex and rough for ligamentous insertion; on it, towards its anterior part, we observe an impression, sometimes an eminence, for the insertion of the tibialis anticus tendon; and its *plantar* surface, the base of the wedge, is thick and prominent, and affords insertion to ligamentous fibres as well as to those of the tibialis posticus tendon. The *external* surface is articulated in front with the second metatarsal bone, and behind with the middle cuneiform, by means of an oblong articular facet, which extends along the upper part of this surface from before backwards parallel to the acute edge. The remainder of the external surface is rough for ligamentous insertion, excepting a small portion about the sixth of an inch broad, which, extending along the posterior edge, is articular and continuous with the posterior surface of the bone.

The *middle* or second cuneiform bone is the smallest of the three; its base is uppermost, rough and convex; its *posterior* surface is triangular with the base superior; it is articular and adapted to the middle facet on the anterior surface of the navicular; its *anterior* surface is also triangular and articulated with the second metatarsal bone; its *inner* surface is articular along its upper and posterior edges, and rough in the remainder of its extent; this surface is in contact with the inner cuneiform. The *outer* surface is articular along half of its upper edge and the whole of its posterior, but rough in the remainder, and by means of the articular portions is connected with the external cuneiform bone.

The *external* or third cuneiform bone is second in point of size; it is bounded on the outside by the cuboid, behind by the navicular, on the inside by the middle cuneiform, and in front by the third metatarsal bone. Its *posterior* and *anterior* surfaces are both plane and articular, the one for the navicular, the other for the third metatarsal bone. The base of the wedge is situated on the dorsal surface of the foot, and is rough. The *internal* surface presents at its posterior edge a facet for articulation with the middle cuneiform, and in front another for the second metatarsal; the remainder is non-articular. The *external* surface presents, towards its upper and posterior angle, a plane triangular facet, which is adapted to a similar one on the inner surface of the cuboid, but in the rest of its extent it is rough and non-articular.

Structure of the tarsal bones.—Like all the short bones, those of the tarsus are composed of a mass of spongy tissue surrounded by a thin and papyraceous layer of compact. Hence these bones are remarkable for their extreme lightness.

Developement. — In the third month the cartilaginous framework of these bones is already apparent. The largest two begin to ossify before birth; the os calcis commences at from the fifth to the seventh month, by a single point of ossification situate about the middle of the bone rather nearer to its anterior part, and the ossification is not completed till eight or ten years after birth, when another point appears in the posterior part of the bone, and by the extension of it to the first point, which is finished about the fifteenth year, the process is completed. The ossification of the astragalus commences about the sixth month. The cuboid and navicular begin to ossify immediately after birth by one point each, and the three cuneiform bones are ossified, the internal about the end of the first year, the middle and external about the fourth year.

II. *Metatarsus (der Mittelfuss).*—This segment of the foot is composed of five bones placed parallel to each other in front of the tarsus, with which their posterior extremities are articulated. These bones are distinguished numerically, counting from within outwards; a distinct interosseous space intervenes between each pair of bones, which in the recent state is filled by muscle. From the arched form of the tarsus, the metatarsus naturally takes a similar arrangement by reason of its articulation with it, and consequently we observe that it is convex on its dorsal surface and concave on its plantar.

The metatarsal bones possess certain general characters in common; they belong to the class of long bones, and consequently each has its shaft and two extremities. The shaft in all is prismatic, slightly curved, convex on the dorsal, concave on the plantar surface; two of the surfaces of the shaft are lateral, and correspond to interosseous spaces; the third is superior, and corresponds to the dorsum of the foot.

The *posterior* or *tarsal* extremity of each metatarsal bone is wedge-shaped, the base of the wedge being on the dorsal aspect. Three articular facets may be noticed on each, excepting the first and fifth. The posterior of these is triangular and plane, articulated with the tarsal bones; the remaining two are lateral, and adapted to corresponding ones on the metatarsal bones on each side.

The *anterior* or *digital* extremity of each metatarsal bone presents an articular head or condyle, flattened upon the sides, oblong from above downwards, and much more extended inferiorly or in the direction of flexion than superiorly or in that of extension. This is articulated with the posterior extremity of the metatarsal phalanx. On each side of the condyle there is a depression, and behind that an eminence to which the lateral ligament of the metatarso-phalangeal joint is attached.

In addition to the characters above mentioned, there are certain special characters belonging to particular metatarsal bones which enable us to distinguish them from each other.

The *first*, or metatarsal of the great toe, is distinguished, 1. by its considerable size and its being the shortest of the five bones; 2. its tarsal extremity is semilunar and concave, and has no lateral articular facet; 3. its digital extremity has on its plantar portion two concavities separated by a ridge, with which the sesamoid bones articulate. The second characteristic is one which peculiarly distinguishes this bone.

The *second* is the longest; it extends farther backwards than any of the others, and is lodged in a mortise-shaped cavity formed by the three cuneiform bones.

The *fifth* has the following characters:—1. it is shorter than the second, third, and fourth; 2. it has no lateral articular facet on the outer side of its tarsal extremity; 3. on this same side it is prolonged backwards and outwards into a long pyramidal process, which gives insertion to the tendon of the peroneus brevis. This process being quite subcutaneous, it is a useful guide to surgeons in the partial amputation of the foot at the tarso-metatarsal articulation.

The *third* and *fourth* resemble each other very closely; the third, however, is a little longer than the fourth, and the posterior articular facet on the fourth is more quadrangular than triangular.

The *structure* of the metatarsal bones is that of the long bones in general.

Developement.—Each metatarsal bone has two points of ossification; one for the body, the other for the anterior extremity, except in the case of the first, in which the second ossific point is for the tarsal extremity. Between the third and fourth months the osseous point of the body commences, and in the full-developed fœtus the body is completely ossified. In the course of the second year the point for the extremity appears; the epiphysis of the first metatarsal bone is united first, about the eighteenth year, and this union precedes that of the others by about twelve months.

Toes (Digiti pedis; Fr. *les orteils;* Germ. *die Zehen).*—The toes are numbered from the inner or great toe; they gradually diminish in length from the first to the fifth: the four outer ones consist each of three portions or *phalanges;* the great toe has only two. The phalanges are best named from their relations, viz. *metatarsal*, *middle*, and *ungual.*

The *metatarsal* phalanges are considerably the longest. The *shaft* in each is prismatic, like that of the metatarsal bones, convex on the dorsal, concave on the plantar surface. On the *posterior* extremity is a concave facet, articulated with the anterior head or condyle of the corresponding metatarsal bone. The *anterior* extremity is less swollen than the posterior: it is marked by an articular surface, which extends much more on the inferior surface than the superior; this is concave transversely, but convex from above downwards, and is articulated with the posterior extremity of the middle phalanx. All the metatarsal phalanges possess these general characters: that of the great toe is very considerably thicker than the others, and is slightly longer; the remaining ones differ but little in size: they progressively diminish towards the fifth.

The *middle* phalanges are very short, but possess pretty nearly the same general characters as the metatarsal. The posterior extremities are articulated with the last-named phalanges by means of an articular surface, concave from before backwards and convex transversely. The articular surface on the anterior extremity is convex. The great toe is deficient in the middle phalanx; they diminish in size from within and outwards. They have been compared to the pieces of the coccyx, but may be easily distinguished by the articular surfaces.

The *ungual* phalanges (so called from being next the nail, *unguis)* are five in number, and decrease in size from the first to the fifth; that belonging to the first very much exceeding the rest in size. The posterior extremity of each is expanded, and has an articular facet for articulation with the middle phalanx. The central part or shaft is flattened, slightly convex on its dorsal surface: its anterior extremity is still more flattened and slightly expanded, presenting a thin convex margin. It is rough on its inferior surface where the dense and adipose cellular tissue constituting the pulp of the toe is connected with it, and on its superior surface it is smooth, where the nail is applied upon it.

The structure and mode of developement of the phalanges are pretty much the same as those of the metatarsal bones: their complete ossification, however, takes place at a much later period.

For the modifications in the number, forms, and arrangement of the bones of the foot in the animal series, see Osseous system (Comp. Anat.) and the articles on the various classes.

Joints of the foot.—These may be classed as the joints of the tarsus, metatarsus, and toes.

Joints of the tarsus.—The bones constituting the first row of the tarsus are connected together by means of two articulations, one posterior, the other anterior. The first *(posterior astragalo-calcanien articulation)* is formed by a convex oval surface on the os calcis, which is received into a deep concavity on the astragalus. A synovial sac lines these surfaces; the posterior part of this sac is covered by the fatty substance which is placed between the back of the ankle-joint and the tendo Achillis, and on the removal of the fat the sac is observed to be strengthened, especially in its centre, by a few ligamentous fibres. On the inner side this sac is strengthened by the tendon of the flexor pollicis proprius and its sheath behind, and by the internal lateral ligament of the ankle-joint in front; both of which very much protect the articulation and strengthen the union of the bones. Anteriorly there are no proper fibres applied upon the synovial membrane; but the interosseous ligament to be described presently, amply supplies the want of them. On the outside a few ligamentous fibres are applied to the synovial membrane.

The *anterior astragalo-calcanien articulation* is formed by a slightly convex surface on the astragalus, which is received by a concavity on the upper surface of the sustentaculum of the os calcis. This articulation is furnished with a synovial membrane, which is only a prolongation from that of the joint between the astragalus and scaphoid.

The chief bond of union between the astragalus and os calcis is by means of the *interosseous ligament (apparatus ligamentosus cavitatis sinuosæ*, Weitbr.): this ligament occupies the hollow which is manifest on the outside between the os calcis and the neck of the astragalus. It consists of a series of strong ligamentous fibres, which arise all along the inner part of the depression on the astragalus in a curved course, and descend vertically, or nearly so, to be inserted into the corresponding depression between the two articular surfaces on the os calcis. A considerable quantity of fat occupies this space, and covers this ligament, and is intermixed with its fibres.

The bones forming the second row of the tarsus are articulated as follows:—

The scaphoid or navicular bone is articulated with the three cuneiform, by means of the triple surface already described on the former bone; to each division of which one cuneiform is adapted *(cuneo-scaphoid articulation)*. A common synovial membrane lines the surface on the scaphoid, the surfaces of the cuneiform bones, and passes in between them to line the lateral articular facets on the latter bones. The three cuneiform bones are connected to the navicular by means of six ligaments, which pass from the former to the latter; three on the dorsal surface and three on the plantar. The dorsal ligament of the internal cuneiform extends directly from behind forwards, those of the others proceed obliquely forwards and outwards. The internal cuneiform has likewise an internal ligament, which proceeds from its internal part directly backwards to the navicular; it lies above the tendon of the tibialis posticus. As to the plantar ligaments, that of the internal cuneiform is the strongest: it is extended between the tubercle on the navicular bone and that on the cuneiform, and is in part confounded with the tendon of the tibialis posticus, which sends a process outwards to the other cuneiform bones, and strengthens the ligamentous fibres which belong to them.

The cuneiform bones are articulated to each other by means of the lateral facets, which are lined by synovial membrane prolonged from that of the cuneo-scaphoid articulation. Each joint is strengthened by a *dorsal*, a *plantar*, and an *interosseous* ligament. The two former are extended transversely from one cuneiform bone to the other, the dorsal being considerably the stronger. The principal bond of union, however, is by the interosseous ligament, which is extended between the non-articular parts of the lateral surfaces of each cuneiform bone.

The cuboid bone is articulated with the external cuneiform *(cuboido-cuneen articulation)* in a manner so similar to that by which the cuneiform bones are articulated with each other as to render a separate description superfluous. Its synovial membrane is continuous with that of the cuneo-scaphoid, and its ligaments are precisely similar to those of the cuneiform articulations.

The cuboid bone is united to the scaphoid by means of ligaments. The outer extremity of the latter bone is in contact with a small portion of the inner surface of the former, near its posterior superior angle, and sometimes a small articular facet indicates the point of each bone where contact is established. The ligaments which pass between these bones under all circumstances are a *dorsal* ligament, directed obliquely from without inwards, a *plantar* ligament, transverse and very thick, and an *interosseous* ligament extended between the corresponding surfaces of the two bones, excepting where the facets are found, when they exist.

Articulation of the two rows of tarsal bones to each other.—This is effected by means of the astragalus and os calcis behind, and the scaphoid and cuboid in front.

Astragalo-scaphoid articulation.—The head of the astragalus is received into a cavity which is in greatest part formed by the glenoid cavity of the scaphoid bone, and is completed inferiorly and internally by a ligament *(the inferior calcaneo-scaphoid)*, which extends from the sustentaculum of the os calcis to the inner part of the inferior surface of the scaphoid. On the outer side and inferiorly the head of the astragalus is supported by a short ligament *(the external calcaneo-scaphoid)* which is attached posteriorly to the inner part of the os calcis, and in front to the external extremity of the scaphoid. The extension of the recipient cavity for the head of the astragalus by means of the ligaments just named was rendered necessary by the considerable excess in the size of the head of the astragalus over the glenoid cavity of the scaphoid. By means of these ligaments, too, the os calcis is connected with the scaphoid, although there is no articulation between them.

The astragalo-scaphoid articulation is strengthened by but one proper ligament, and that is situated in the dorsal aspect; it is the *superior astragalo-scaphoid ligament*, and is attached posteriorly to the neck of the astragalus, and in front to the margin of the glenoid cavity; the transverse extent of this ligament is equal to that of the scaphoid bone on its dorsal surface; the direction of its fibres is forwards and outwards. It is a thin fibrous expansion, covered superiorly by the extensor brevis digitorum muscle, and on its inferior surface lined by the synovial membrane of the joint.

Calcaneo-cuboid articulation.—The articular surface on the os calcis is slightly concave in the direction from above downwards; that on the cuboid is convex in the same direction. The two surfaces are closely adapted to each other, and their union maintained by the following ligaments:—1. The *superior* or *dorsal calcaneo-cuboid ligament*, which consists of but a few fibres extending from the superior and anterior part of the os calcis to the cuboid. 2. The *internal calcaneo-cuboid ligament*, a short, strong, quadrilateral ligament from three to four lines in breadth, placed in great part over the superior aspect of the joint; the fibres pass with a slight obliquity inwards from the os calcis to the cuboid. 3. The *plantar* or *inferior calcaneo-cuboid ligament*, the strongest and largest of the foot ligaments, seems destined not alone for the articulation under consideration, but also to strengthen the arch of the tarsus generally on its plantar surface. It is attached behind to the inferior surface of the os calcis, commencing from the angular depression between the two tubercles. After leaving the os calcis a distinction between its superficial and deep fibres becomes very manifest; the former proceed forwards and inwards, pass under the cuboid bone, forming an adhesion to the posterior lip of its groove, then pass under that groove and its contained tendon, and are ultimately inserted into the posterior extremities of the third and fourth metatarsal bones. The deep fibres diverge immediately after they have left the os calcis, and are inserted into the whole inferior surface of the cuboid posterior to the groove.

It will be observed that the two joints last described lie beside each other in the same line, a circumstance which favours the surgical operation of partial amputation of the foot in that line. Each joint, however, has its proper synovial membrane lining the cartilaginous incrustations of the bones and the articular surfaces of the ligaments; that of the astragalo-scaphoid is the more lax, and indicates the existence of a considerable range of motion in that joint.

Motions of the tarsal joints.—All these joints belong to the class Arthrodia, some of them being planiform. The motion in all is that of simple gliding, limited by the strength, number, and position of the ligaments. The close inspection of the bones of the metatarsal row, and the firm ligamentous bands which pass between them, occasion a very limited mobility of the bones of that row. Between the astragalus and os calcis, on the other hand, the motions are much more manifest; these are gliding motions in the direction from before backwards and vice versa, or from side to side. When the foot is turned inwards or outwards the latter motion is called into play, and the gliding in the antero-posterior direction takes place when the weight of the body presses on the foot, causing its elongation and the diminution of the curvature of its antero-posterior arch. When the weight presses, the astragalus glides forward upon the os calcis; when the weight is removed, the bone returns to its former condition by gliding backwards.

But the greatest mobility exists in the articulation between the two rows of tarsal bones. There, indeed, the principal motions of the tarsus take place. The motions of the foot, which many have erroneously attributed to a supposed power of lateral motion in the ankle-joint, really take place in this line of articulation. When the foot is turned so that its sole is directed outwards, the scaphoid glides from above downwards on the head of the astragalus, the astragalus glides from within outwards on the os calcis, in consequence of which the hollow space between the last-named bone and the neck of the astragalus is diminished, the interosseous ligament relaxed, the external lateral ligament of the ankle-joint likewise relaxed, and the internal lateral ligament rendered tense. On the other hand, when the sole of the foot is turned inwards, which may be done much more completely than in the opposite direction, the scaphoid glides from below upwards upon the head of the astragalus, the inferior surface of the os calcis is turned inwards, the astragalus glides upon the last-named bone from without inwards, enlarging the interosseous space, stretching the ligament which occupies that space, and also rendering tense the external lateral ligaments of the ankle-joint. It is therefore natural to expect, as Bichat has remarked, that in those sprains which result from too great inversion or eversion of the foot, the ligaments of the articulations between the tarsal rows should suffer most.

Tarso-metatarsal articulations.—The plane surface on the wedge-shaped tarsal extremity of each metatarsal bone is applied to corresponding plane surfaces on the cuneiform bones and the cuboid. The first, second, and third metatarsal bones, counting from within outwards, are articulated with the first, second, and third cuneiforms, and the fourth and fifth with the cuboid; the second metatarsal, however, is additionally articulated with the first and third cuneiforms, by its lateral surfaces being, as it were, mortised into a cavity formed by these three bones, and each of the other metatarsal bones is articulated with its fellow on each side of it. These articulations have the following common characters: they are planiform arthrodiæ, each articular surface is covered by a thin layer of cartilage, and they all have ligaments similarly arranged in two sets, dorsal and plantar.

The first tarso-metatarsal articulation has a greater extent of its articular surfaces than those of the others. Its plantar ligament is of great strength and extends from the great cuneiform, directed obliquely forwards and outwards to the first metatarsal bone, continuous posteriorly with the cuneo-scaphoid ligament, and strengthened by fibres from the tendon of the tibialis posticus, and on the outside by fibres from the tendon of the peroneus longus. The dorsal ligament consists of short and parallel fibres; its breadth is equal to that of the cuneiform bone; it is a weak and membranous ligament. This articulation has a synovial membrane distinct from that of the other tarso-metatarsal joints.

The second tarso-metatarsal articulation is the most solid of all, from the fact of the posterior extremity of the metatarsal bone being fitted into the mortise-shaped cavity formed by the cuneiform bones. Its ligaments, it may naturally be expected, are more complicated than those of the other joints of this row; thus it has *three dorsal* ligaments, a middle one, possessing common characters with those of the other joints, proceeding directly from behind forwards from the second cuneiform to the second metatarsal bone; the others are extended, one from the internal cuneiform obliquely outwards to the second metatarsal, the other from the third cuneiform obliquely inwards to the same bone. We find, moreover, *two plantar* ligaments, one short and direct, passing from the second cuneiform bone to the second metatarsal, the other much longer and more oblique, coming from the first cuneiform. Lastly, this articulation has an *interosseous* ligament, which is extended from the lateral facet on the external surface of the first cuneiform to a corresponding one on the internal surface of the second cuneiform.

Each of the remaining tarso-metatarsal articulations has its *dorsal* ligaments, of which those of the third and fourth are direct, and that of the fifth is extended obliquely outwards from the cuboid to the fifth metatarsal bone. In all three, the place of plantar ligament is supplied by the sheath of the long peroneal tendon, and the fifth receives additional strength from fibres given off from the tendon of the peroneus brevis. In the third there is an interosseous ligament between the third and fourth metatarsal bones, and from the anterior part of the external surface of the third cuneiform to the fourth metatarsal.

The five tarso-metatarsal articulations have four synovial membranes amongst them: the first, as has already been mentioned, has a distinct one; the second lines the contiguous surfaces of the first and second cuneiform bones, and is prolonged over the mortise-shaped cavity and the articular portions of the second metatarsal. The third lines the articular portions of the third cuneiform and third metatarsal, and is prolonged on either side of the latter in the form of two culs-de-sac into the space between the latter bone and the second metatarsal on the inside, and the fourth on the outside. In fine, the fourth synovial membrane is common to the fourth and fifth tarso-metatarsal joints.

Metatarsal articulations.—The four external metatarsal bones are articulated with each other by means of the contiguous articular facets on the lateral surfaces of their posterior extremities. They are maintained in apposition by *interosseous* ligaments which pass from one metatarsal bone to the other, being inserted into rough surfaces immediately above the articular portion of each bone. Moreover, these joints have *dorsal* and *plantar* ligaments, which consist of ligamentous fibres directed transversely from one bone to the other. The plantar ligaments are considerably stronger and thicker than the dorsal.

The anterior extremities of the five metatarsal bones, although not articulated together by surfaces which play upon each other, are yet connected by a common transverse ligament which passes from one bone to the other, being attached to the plantar surface of each bone, and covered by the sheaths of the flexor tendons.

Metatarso-phalangeal articulations.—The convex articular surface of the anterior extremity of each metatarsal bone is adapted to the concave surface on the posterior extremity of each posterior or metatarsal phalanx. A separate synovial membrane lines the articular surfaces of each joint; and two lateral ligaments, one on either side, maintain the surfaces in apposition. On the dorsal aspect each joint is strengthened and protected by the extensor tendons; and on the plantar a strong, thick, almost cartilaginous substance is extended from the metatarsal bone to the phalanx. This substance protects the joint inferiorly; it is grooved on its inferior surface, and contributes to form the sheath for the flexor tendon, which runs along the plantar surface of each toe.

The metatarso-phalangeal articulation of the great toe presents some points of difference from the others; its surfaces are more extensive, and on the plantar aspect the head of the metatarsal bone has a pulley-like form, from the existence of a ridge in its centre, on either side of which there is a superficial depression: each depression receives a sesamoid bone, which, being formed in the substance of the inferior ligament, thus contributes greatly to strengthen the joint in this situation.

Articulations of the toes.—These are ginglymoid joints, all closely resembling each other both in the forms of the articular surfaces, and also in the bonds of union by which the contiguity of these surfaces is maintained. The articular surfaces are pulley-like; an internal and an external lateral ligament belong to each joint; and the plantar aspect of each is protected by a ligamentous structure similar to that already described in the metatarso-phalangeal joints.

Motions of the metatarsal joints.—At the tarsal extremities the metatarsal bones enjoy but a very limited mobility in consequence of the strong and compact manner in which they are articulated with the tarsus; their motions consist in a very limited and scarcely perceptible gliding upwards and downwards. At their phalangeal extremities, however, the metatarsal bones are capable of a greater, although still a very limited, degree of motion.

Motions of the metatarso-phalangeal joints.—These are flexion and extension, with a slight degree of lateral inclination or abduction and adduction, and also, of course, circumduction or the rapid succession of the preceding four. The lateral motions are very limited, being most manifest in the joint of the great toe. Flexion is limited by the extensor tendon and the superior fibres of the lateral ligaments; extension by the inferior fibres of the lateral ligaments, by the inferior ligament, and by the flexor tendon.

Motions of the phalangeal joints.—Flexion and extension only are enjoyed by these joints, the extent of which is principally controlled by the lateral ligaments and by the due antagonism of the flexor and extensor muscles.

Viewing the human foot as a whole, we cannot fail to notice how admirably it is adapted as an instrument of support, and for the purposes of progression. For the former end the solid and yet elastic mechanism of the tarsus is mainly useful; this part is placed immediately under the tibia, which transmits the weight of the body to the astragalus, the highest bone of the tarsus; from this bone, again, the weight is transmitted to the os calcis in the backward direction, and to the anterior row of tarsal bones in front, where the transverse extent of the tarsus is considerably increased, in order to enlarge the basis of support. It is worthy of remark that the solidity of the anterior part of the tarsus is less on its inner than on its outer side, the effect of which is to increase the elasticity of the former part without materially diminishing its strength. The object of this arrangement appears to be explained by the observation that the weight of the body is transmitted by the astragalus principally to the inner side of the tarsus. It is toward the inner side also that the concavity of the under surface of the tarsus is most evident, by which not only can the sole of the foot adapt itself to the irregularities of surface to which it is applied, but it is enabled to yield under the superincumbent weight, and so to counteract the effects of sudden concussion in walking, leaping, &c.

In the foot anatomists have described two arches as connected with its mechanical arrangements. The first is best seen in a profile view of the foot; it is termed the *antero-posterior* arch; upon this arch we rest when the toes are applied to the ground, the posterior extremity of it being the heel, the anterior the balls of the toes, and the astragalus resembling the keystone of the arch. The second is the *transverse* arch, which may be most satisfactorily demonstrated by a transverse section made along the line of the cuneiform bones. The effect of the constant and violent exercises of the foot to which public dancers are accustomed is to increase the mobility of the different parts of the foot, to an extent which unfits it, in a great measure, for its office as an instrument of support in standing or walking, as may be observed, says Sir C. Bell, in any of the retired dancers and old *figurantes*. By standing so much on the toes, he adds, the human foot is converted to something more resembling that of a quadruped, where the heel never reaches the ground, and where the paw is nothing more than the phalanges of the toes.

The following considerations connected with the human foot may be quoted as so many indications that the erect attitude is natural to man: 1. the articulation of the foot at right angles with the leg; 2. the great comparative size of the foot, contrasted with that of other animals; 3. the great transverse extent of the foot; 4. the predominance of its solid parts, the tarsus and metatarsus, over its moveable part, the phalanges; 5. the direction of the metatarsal bone supporting the great toe; its situation and want of mobility; 6. the limited mobility of the phalanges of the foot as compared with those of the fingers; 7. the horizontal position of the os calcis;* the excess of its transverse extent at its posterior over that of its anterior part, and the developement of its tubercles; 8. the great strength and developement of the calcaneo-cuboid ligament; 9. the early ossification of the bones of the foot as compared with those of the hand.

The extraordinary extent to which art can modify the positions of the several bones, and the form of the whole foot, is remarkably exemplified in the case of the Chinese foot. It is well known that, among other barbarities practised on Chinese females, their feet are from an early period subjected to the most violent pressure, with the view of reducing them to that diminutive size which is esteemed a point of great beauty. Hence the anatomical examination of a foot thus compressed is a point of great interest, not alone to the physiologist, but also to the surgeon, as indicating what properly applied force may do when employed at a sufficiently early period. An interesting account of such an examination was communicated in the year 1829 to the Royal Society by Mr. Bransby Cooper, from whose paper we extract the following statements.

The foot at first view had the appearance of being congenitally deformed; it was remarkably short; from the heel to the great toe its measurement did not exceed five inches; it was very much contracted in its transverse dimensions, and the instep extremely high, being unusually convex not only from before backwards, but also from side to side.

"The position of the os calcis," to use Mr. B. Cooper's words, "is very remarkably altered: instead of the posterior projection which usually forms the heel, a straight line is preserved in this direction, not deviating from the line of the tibia; and the projecting point which forms in an ordinary foot the most posterior process into which the tendo Achillis is inserted, touches the ground, and becomes the point d'appui for sustaining the whole weight of the body. The articular surface of the os calcis in connexion with the cuboid bone is about half an inch anterior to and two inches above this point; while the astragalar joint is behind and somewhat below the calco-cuboidal articulation; consequently the direction of the os calcis, (in its long axis,) instead of being from behind forwards, is from below upwards, with the slightest possible inclination forwards. The most prominent parts of the instep are the round head of the astragalus and the cuboidal articulation of the os calcis. From this the remaining tarsal bones slope downwards at nearly a right-angular inclination to join the metatarsal bones, whose obliquity is still downwards, until they rest on their phalangeal extremities."

The points of support are the os calcis, the anterior extremity of the metatarsal bone of the great toe, and the dorsal surface of the fourth and fifth toes, which are bent under the foot so as to press the ground at this part.

(R. B. Todd.)

* "Even the Simiæ and the bear," says Mr. Lawrence, "have the end of the os calcis raised, so that this bone begins to form an acute angle with the leg; the dog, the cat, and other digitated quadrupeds, even the elephant himself, do not rest on the tarsus or carpus, but merely on the toes; the cloven-hoofed ruminants and the Solipeda touch the ground merely with the extremities of the third phalanges, and the os calcis is raised nearly into a perpendicular position."

FOOT, ABNORMAL CONDITIONS OF THE.—The dislocation of any of the bones of the foot is an accident of unfrequent occurrence, particularly of the tarsus and metatarsus, where the ligaments are powerful, and the joints very limited in their motions. When a displacement does occur here, the violence necessary to produce it is often so great, that the foot is destroyed. Cases, however, are met with where a dislocation of one or more of these bones has been successfully treated without loss of the limb. Sir A. Cooper mentions several instances. The astragalus alone, without the other bones of the foot, is never thrown backwards, nor is it ever thrown directly inwards nor directly outwards, but it may be dislocated forwards on the instep and then may incline inwards, so as to be situated below and in front of the inner malleolus, or it may incline outwards and be placed below and in front of the outer malleolus; the rest of the foot in the latter case is thrown inwards, and in the former outwards.

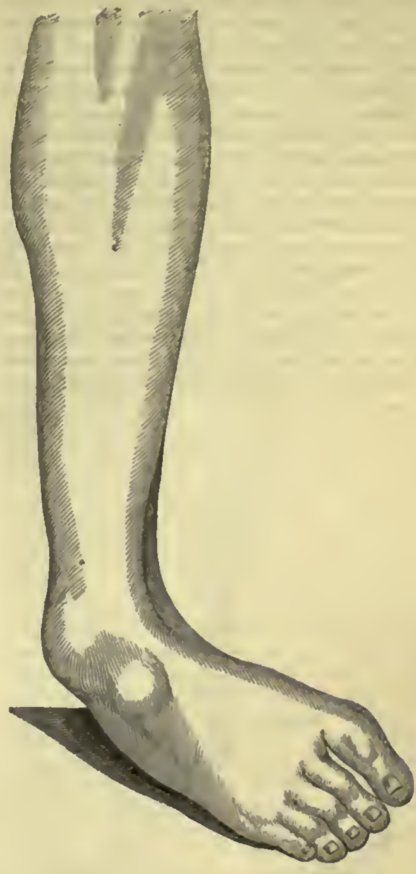
In these cases there is what Boyer calls a double luxation of the astragalus, for this bone is not only expelled by violence from the mortise-shaped cavity formed for it by the bones of the leg, but is at the same time driven from the space formed between the os calcis and os naviculare, where it naturally rests or plays in standing or progression.

Most of the ligamentary ties which bind it to the other bones of the foot and leg are violently ruptured, yet in these cases the surgeon almost invariably finds great difficulty in extracting the bone from its new situation, and to return it back to its original space in general is quite impracticable.

One reason for the difficulty the surgeon experiences in replacing the luxated astragalus may, we imagine, be found in this, that the bones once expelled by violence, the muscles attached to the tendo Achillis, and, indeed, all those of the leg before and behind, act so on the foot as to have a powerful and effective influence in effacing the interspace between the os calcis and articulating surfaces of the tibia and fibula, so that there is now no room for its return.

Moreover, it should be recollected that the astragalus is sometimes only partially luxated, and perhaps at the same time has revolved on its long axis in such a way that it shall be placed as it were on its side, as we have known an example, in which the pulley-shaped surface of the astragalus looked outwards, the peroneal articular surface looked downwards towards the os calcis, and the facet for articulation with the tibial malleolus was placed upwards in contact with that part of the tibia which was naturally shaped for articulation with the upper part of the trochlea of the astragalus: when the astragalus is thus rotated on its longitudinal axis, a broader part of the bone is wedged in between the tibia and os calcis than the vertical height of the astragalus would measure, and hence there is difficulty in restoring the bone or removing it. *Fig.* 161 represents the simple dislocation. More than

Fig. 161.



one example is mentioned by Sir A. Cooper in which this bone was removed entire after a compound dislocation of it, and yet a very tolerable use of the foot was regained.

A heavy weight falling upon the foot will sometimes displace the double articulation between the first and second row of tarsal bones. When this accident has occurred, the appearance which the limb assumes bears a striking resemblance to the internal variety of the club-foot. In fact this state of the parts really constitutes neither more nor less than the pied-bot, with the exception of the difference of the cause, the state of ligamentous connections, and the facility of reduction.

Dislocation of the other tarsal bones is very rare, yet Sir A. Cooper has seen the inner cuneiform bone displaced in two instances, in neither of which could the bones be reduced. See also Dict. des Sciences Médicales, art. Pied.

The joints of the toes, as they are more moveable and their ligaments more lax, are more easily dislocated than the other joints of the foot, and especially the great toe, which has more extent of motion than the rest, and is more exposed to the influence of accident.

Congenital displacement of the bones of the foot is by no means an uncommon occurrence, and though in our English systematic works on surgery this case has met with little notice, yet, as a subject of great importance to the comfort and well-being of a numerous class of sufferers, it is by no means undeserving of a place in a professed work on surgery. As, however, the scope of the present is not strictly surgical, we shall, in this article, content ourselves with a pathological description of the principal varieties of these deformities, and in doing this we shall freely avail ourselves of the assistance of an able article on the "Pied-bot," by Bouvier, in the Dict. de Médecine et de Chirurgie Pratiques.

The ankle-joint is not generally implicated in congenital deformities of the foot; displacement of the bones may occur to an extreme degree, and yet the natural form and functions of the ankle remain. But this rule is by no means universal. The ankle-joint may be the sole seat of the unnatural condition, or it may share it in common with the bones of the foot; but these cases are rare, they form only the exception to the general rule. There are three principal forms of distortion to which the foot is congenitally subject: 1. when the foot is turned inwards, which has been termed *varus:* 2. when it is turned outwards, called *valgus:* 3. when the foot is permanently extended, and the patient can only put the toes to the ground, termed *pes equinus.* Almost all the varieties of club-foot may be referred to one of these species.

1. When the foot is turned inwards, *(varus,)* the following modifications in the form of the parts present themselves. (See *figs.* 162, 163.) The dorsum faces forwards, the sole is turned

Fig. 162, 163.

backwards, and very considerably curved upon itself. The inner side of the foot is uppermost, the outer side rests upon the ground, the heel is more or less turned inwards and upwards. The integuments of the outer side are thickened by pressure, and there is a sort of provisional cushion, of a somewhat elastic nature, formed under it, while the thickness and hardness of the integuments of the sole are not found to the usual degree. The joints that suffer most in this malformation are, as might be expected from a review of their natural structure, the double articulations between the first and second row of tarsal bones. The scaphoid bone is twisted inwards in such a manner, that the dorsum of it presents forwards and its apex backwards, and the navicular cavity is brought to the inner edge of the astragalus. The cuboid bone generally preserves its relation to the scaphoid, being more or less displaced from the os calcis, and turned under the foot. The cuneiform bones, the metatarsus, and toes, are little altered in their relation to those tarsal bones to which they join, the peculiarity of their position and direction being entirely the result of the alterations in the scaphoid and cuboid, just mentioned. The os calcis is turned, so that its outer side is inclined towards the ground, and further than natural from the outer malleolus; the inner hollow side is inclined upwards and inwards, and nearer to the inner malleolus than natural, and the heel itself is elevated. By this means the articulations between this bone and the astragalus are altered somewhat, particularly if the ankle-joint itself remains natural, the astragalus not having partaken of the general malposition; this bone is then thrown in some degree upon the outer side of the os calcis. The astragalus, we have said, rarely shares in the general deformity; when it does it is tilted outwards, so that its upper surface inclines towards the external malleolus, and the articular portion itself becomes altered in form, as is also the corresponding portion of the tibia; in one instance related by Bouvier, the astragalus, by the pressure of the inner side of the tibia above and of the calcis below, was reduced to a mere thin edge on this side, the whole bone being something in form of a wedge between them.

2. In the *valgus,* (see *fig.* 164), where the foot is turned in the opposite direction to that

Fig. 164.

which has been just described, the whole state of the foot seems to be pretty nearly the exact converse of every thing there mentioned. The same bones are affected, and in the same relative degree; and the same analogy which exists between the one condition and the phenomena of adduction, is found between the other and those of abduction. The dorsum faces more or less directly forwards, the plantar surface backwards, the inner side of the foot rests upon the ground, the outer is uppermost. The tibia frequently here participates in the deformity so far as to have a curve inwards, and the inner ankle consequently approaches to the ground. The double articulation between the first and second row of bones in this case also suffers the most. The astragalus sometimes projects in front, and lower than in the varus. The distortion is sometimes carried to such an extent that the foot is turned nearly upwards and at the side of the fibula. The os calcis is twisted outwards, with the heel elevated, its hollow inclining towards the ground. The scaphoid and cuboid bones are, as we have said, most displaced; the first being nearest the ground, the last placed uppermost, and near the outer malleolus. The cuneiform bones, and the other bones of the foot, retain their relation to the bones to which they are articulated, their unnatural situation being the result of the displacement of these.

Fig. 165.

3. The *pes equinus*, (see *fig.* 165,) so named from the resemblance in the position of the tarsus to that of the horse, differs from either of the others in its anatomical characters. When it has arrived at a considerable pitch, the tibia is found partially dislocated backwards upon the os calcis; the scaphoid and cuboid are carried backwards, towards the sole of the foot, leaving the upper part of the head of the astragalus and cuboides projecting; the cuneiform and metatarsal bones are displaced sometimes in a similar manner. Thus the whole foot is more arched than natural, independently of its altered position; the sole is shortened and hollowed, the dorsum is elongated and projecting.

A very interesting history of yet another form of this disease by M. Holz of Strasburg, is given in the 13th vol. of the Lancet, in which the foot was turned completely back, having the dorsum resting on the ground, the plantar surface being uppermost. The deformity was in both feet. Walking was not painful; the patient rested his weight on the tarsus; the metatarsus and toes did not touch the ground. He wore common half-boots, the toes of which pointed backwards and the heels forwards. The man died, and upon examination of his feet the following state of parts was found. The skin of the dorsum upon which he trod was hard and callous. The bones of the leg were well formed; the astragalus was dislocated forwards; the calcaneum forwards and outwards, and the cuboid downwards on the calcaneum. The dorsal surface of the foot was very convex, excepting at the spot which touched the ground; the plantar surface very concave. The superior articular surface of the astragalus was turned directly forward and a little downward; its posterior surface also looked forward, and the tibia rested on the inferior, in a great degree, and on the small process of the calcaneum. The connexion of the scaphoid with the astragalus was more natural; the scaphoid was, however, turned a little backward. The cuboid rested by its posterior part on the inferior surface of the os calcis. The articular surfaces of the astragalus and os calcis gave attachment to ligamentous fibres. The three cuneiform bones, the metatarsal bones, and the toes had not experienced any sensible change in their position.

The descriptions now given are of extreme cases in each of the species of deformity. Of course the degree of departure from the natural form varies in every case. In the varus, every intermediate shade between the extreme mentioned and the mere state of permanent adduction occurs. The state of fixed abduction may, in the same way, be called the milder extreme of the valgus, while the pes equinus shows its simplest form in the mere fixed extension of the foot.

We also find in some instances a combination of more than one form of the deformity in the same foot. The most frequent of these is the state of permanent extension, of the pes equinus, with the adduction of the metatarsal bones and phalanges, constituting a variety of the varus. (*Fig.* 166.) The same complication of the pes equinus with the valgus is rare, but does sometimes occur. A congenital deformity, so

Fig. 166.

far as we know not mentioned, has once fallen under our notice, namely, a dislocation of the tibia backwards upon the upper and posterior part of the os calcis, so that the prominence of the heel was entirely lost, and the foot flexed to such a degree, as that the dorsum lay in contact with the anterior part of the leg.

The alterations from the normal state of the ligaments, bones, muscles, and articular surfaces, in these cases of deformity, are easily comprehended. The ligaments are of course elongated on the one side of the dislocated joint, and shortened on the other side; the bones are altered in shape, occasionally, where pressure is produced by a neighbouring bone, and sometimes a portion of the bone is twisted, and drawn towards the unnatural situation of that one with which it articulates. The muscles are elongated or shortened, according as their points of attachment are, by the deformity, approximated or further separated. The articular surfaces undergo great alterations: they are altered in shape and situation by the friction of the parts in contact producing a new synovial surface upon its new situation, while a part, or the whole of the natural joint loses its polished surface, and becomes adherent to the integuments, while, in many instances, the altered position of a bone brings it into contact with another, with which naturally it had no such relation, and here again a preternatural synovial articulation will form, in accordance with the same law of the animal economy, by which long-continued pressure will produce a synovial bursa. As a general observation, we may state, that the whole limb is smaller, shorter, and feebler than the sound one, and that this defect increases by comparison with the sound one, as the child grows. M. Cruveilhier has also found that individual bones are sometimes singly defective in their growth, while occasionally only the portion of a bone which is subjected to pressure is checked in its developement.

The deformities described above are generally congenital, but they are also occasionally produced after birth by accidental causes; though in this case there is no difference in the nature of the distortion or in the anatomical condition of the parts, yet they are less frequently cured, because the same carelessness or bad management which has too often occasioned the accidental form of the disease to creep on unheeded, makes the parents indifferent as to the cure, while the deformity, which has not mismanagement for its cause, is immediately remarked on the birth of the child, excites alarm in the mind of the parent, and means are early adopted for its removal.

This part of our subject leads us to notice a deformity, of not uncommon occurrence, but one which has met with little notice from writers, although the inconvenience and suffering occasioned by it, great in degree, and, as far as we have known, permanent in duration, will entitle it to the consideration of the surgeon. We allude to that state of the foot wherein the arch is lost, and the foot rests flat upon the ground. It is met with generally, but not always, in those children of the lower classes who are obliged, in their early youth, to engage in laborious occupations, and particularly in lifting heavy weights, before the powers of the system are developed, though we have known it to occur where none of these causes could be traced. It happens generally, not in the very weak, nor in the firm and robust children, but in those who have the promise of developement on a large scale, and are rapidly growing. It comes on insidiously, and is rarely detected until too far gone to admit of a complete cure. The marks of this disease are an evident alteration in the shape of the foot. The dorsum has comparatively lost its convexity, the concavity of the sole is entirely gone; the scaphoid bone projecting below unnaturally, and the inner malleolus falling considerably inwards. The relative position of all the rest of the foot appears natural. The patient complains of pain and tightness at the upper part of the instep passing through to the sole upon attempting to elevate the heel while standing. Indeed, in aggravated cases, he cannot lift himself at all upon the metatarsus, while every step upon an uneven surface is accompanied with pain. The anatomical characters of this distressing disease consist, as far as a close examination of the living parts can detect, for we have had no opportunity of dissecting them, in a relaxation of that ligament which passes between the os calcis and navicular bone, and on which the fore part of the astragalus rests and moves. It will be quite evident, from an examination of these parts and their connexions, that this supposition is sufficient to account for the symptoms that are apparent, and the idea is borne out by the fact of the point of the scaphoid being further separated than natural from the tubercle of the os calcis, which may be readily ascertained by the touch. We conceive the remote cause to be a certain degree of inflammatory action in the elastic ligament just mentioned, produced by over-exertion, before the part had acquired its full developement and strength. The morbid action being continued by the continuance of the irritation, the elasticity of the ligament is impaired, and it can no more support the weight laid upon it; it consequently yields, and is stretched. This view receives some support from the fact of the tenderness upon pressure constantly found in this precise spot, and from the relief afforded to the more distressing symptoms by the application of leeches and counter-irritations.

Another deformity of the foot occasionally met with is exactly the reverse of the preceding; this is too great a convexity of the arch, by which the foot is considerably shortened, and the bearing, anteriorly, taken from the under side of the heads of the metatarsal bones, and thrown partly upon the bases of the first phalanges and upon the metatarso-phalangeal joint itself. From the tense state of the plantar fascia we must suppose that this structure is shortened, and indeed we have been inclined to consider this contraction of the fascia as in some degree a cause of the deformity, which Dupuytren has proved to be the fact in the parallel case of contraction of the fingers, by shortening of the palmar fascia. With this view, in a case of deformed foot which lately came under our notice, we divided the fascia plantaris, and certainly with considerable temporary benefit. We have not been able to ascertain why the relief was not permanent, as the patient lives at a distance; but it might not improbably arise from his returning to work too soon, and leaving off the extension of the foot which had been adopted.

(A. T. S Dodd.)

FOOT, REGIONS OF THE.—The surgical anatomy of the ankle having already been given, (see ANKLE, REGIONS OF,) it remains for us, in this article, to describe the foot properly so called, that is, all of the lower extremity beyond the ankle. This part comprises much that is practically interesting and important, both in its pathology and surgery, which must be evident when we consider the vast number of ills which are endured in the feet. The foot, considered as an entire region, is naturally and obviously subdivided into dorsal and plantar regions. In the first of these we observe, 1st, the dorsum, or instep, extending from the front of the ankle to the heads of the metatarsal bones; 2d, the toes themselves.

I. *Region of the dorsum.*—We see the instep falling, with a gentle curve, forwards from the ankle, and forming the anterior portion of that arch, which posteriorly runs through the ankle-joint to the heel, and the crown of which, formed by the astragalus, bears the weight of the whole body. This most remarkable provision for the safety and efficiency of the body is well deserving of particular examination, and we shall return to it when describing the plantar region. The curve of the dorsum just mentioned is running forwards to the head of the metatarsal bone of the great toe; there is another arch, a lateral one, running across the foot, of which the inner end is abrupt, as it bends over the inner side of the ossa naviculare and cuneiforme interna; the outer end slopes off more gradually to the os cuboides and metatarsal bone of the little toe. The use of this arch is best seen also in the sole, though it presents itself to the view most strikingly on the dorsum.

The principal points which claim our attention in this region are:—

1. The *integuments,* which are here rather thinner and softer than in other parts of the limb, but varying considerably in texture according to age, sex, and habit: they are also rather thinner on the outer than on the inner side. 2. The *subcutaneous cellular tissue.* This is rather loose, and freer from fat than in other parts of the body, permitting free movement of the superficial parts upon those beneath. This laxity of the cellular tissue is greatest on the middle of the instep; and accordingly we see in children and females, where there is a large quantity of superficial fat, and in effusions of water or other fluids, that the skin of this part rises most, while across the ankle and the roots of the toes there is an appearance like a ligature arising from the comparative closeness and shortness of this cellular web. In this layer also we find several large veins and some branches of nerves. The dorsal veins of the foot run in very irregular directions, varying in size in different subjects, but mostly collected into two plexuses, which form in front of the inner and outer ankles, the *saphena major* and *minor* veins. The course of these veins, though various, is generally as follows:—The *saphena major* begins to shew itself pretty conspicuously on the middle and inner side of the instep, and running to the inner ankle receives in its course numerous additions, and then passes over the internal malleolus. The *saphena minor* is seldom found in a notable trunk on the foot; we see only on the outer side of the dorsum several small branches communicating with the inner plexus, and taking their course towards the outer ankle; there they form sometimes one, but generally two branches, which pass sometimes over, generally behind the outer malleolus. It is the first of these veins that is principally important in surgery, as it occasionally, and we think it might with advantage be more frequently, opened for the detraction of blood. It is immediately brought into view by a ligature placed above the ankle, and in opening it we must bear in mind that, from its superficial situation, from the looseness of the enveloping tissue, and from the greater distance of the ligature from the point to be punctured, the vein is much more liable to roll and to foil our attempts than the vein at the elbow: we must, therefore, take the precaution of putting the fore-finger above, and the thumb below the spot where the lancet is to enter, which will retain with facility the vein in its place.

The varicose distention to which the trunks of the saphena veins in the leg are peculiarly liable, is often found extending to their minute commencing branches on the dorsum of the foot; so much so that the whole of this region is irregularly distended, and covered with the knots and ramifications of the distended veins. This morbid state is dependent upon the same causes as the varicose affection of the veins of the leg, and can be remedied only by the same means, but with this additional disadvantage, that the mechanical means adopted for their relief by pressure, owing to the more conical form of the foot, can with greater difficulty be retained.

Besides the veins, we find imbedded in this same layer of cellular tissue a number of nervous filaments, which should be remembered as occasionally interfering with operations on this part. The last portion of the saphenus or long cutaneous nerve runs so near to the saphena major vein that some of its twigs pass in front of and some behind it, and have been occasionally punctured in opening this vein; but this should form no stronger an objection to this operation than a similar arrangement of the nerves, and a similar accident in bleeding, which occasionally happens, should be allowed as an objection to venesection at the bend of the arm.

3. The next layer brought into view by dissection is a thin expansion of fascia, continuous with the anterior annular ligament of the ankle, and formed of fibres running in various directions, principally transverse and spreading over the whole of the dorsal region, but principally at the upper part. The observations which have been made on this same fascia when covering the ankle may be applied also to the part just described, (see ANKLE-JOINT, REGION OF,) with this exception, that as the dorsal fascia is much thinner and more incomplete than that over the ankle, matter would here not be so tightly bound down, nor would it present so strong an obstacle to the pointing of it outward.

4. On removing the layer of aponeurosis a muscular and tendinous stratum is exposed, comprehending the entire muscle of the extensor brevis digitorum and the tendons of several of the long muscles situated on the leg. The first of these has a thick fleshy belly, and occupies the outer part of the dorsum of the foot, sending its tendons down, like so many rays, to the bases of the toes. The tendons are spread over the foot in the following order:—on the inner side the tibialis anticus passing to be inserted, by a broad attachment, into the internal cuneiform bone and base of the first metatarsal bone; next the extensor proprius pollicis runs forwards and inwards, along the fibular edge of the first metatarsal bone; then the tendons of the extensor longus digitorum run diverging towards the bases of the four outer toes, crossing over the tendons of the extensor brevis; and lastly, the tendon of the peroneus tertius, diverging from the extensor longus, sends its small flat tendon to the base of the fifth metatarsal bone. Each of these tendons runs in its own synovial sheath, and these are, from their superficial situation and from their proximity to the bones over which they pass, peculiarly liable to be affected by pressure, as from tight boots. The consequence of this is not unfrequently seen in a small round swelling, situated generally over the tarsal bones, and upon one of the tendons of the extensor digitorum longus. It is first discovered generally by its tenderness, and when this is relieved by taking off the pressure which was its first cause, the swelling itself still remains, soft and elastic to the touch, and having all the characters of an enlarged bursa, and which has received the name of *ganglion*. The cure may generally be accomplished easily and expeditiously: a smart blow with some hard body, as the back of a book, while the swelling is rendered tense by the forcible extension of the foot, will be all that is necessary; the cyst is thus burst, and its synovial contents, when extravasated among the adjacent cellular tissue, soon become absorbed, while the empty cyst itself shrinks and contracts to its natural size. Should, however, this plan not be approved, or, which may happen, not succeed, the introduction of a cataract needle in an oblique direction under the skin, and the puncture of the cyst, will evacuate the fluid into the surrounding cellular tissue, and thus effect a cure.*

A tumour is sometimes formed upon the instep, which is also the result of pressure, and which bears a near relation to a corn. It is met with in young men who wear tight boots, and the usual situation of it is over the articulation between the internal cuneiform bone and the metatarsal bone of the great toe. The tumour is under the skin, hard and immovable; so that it seems to a superficial observer to be an enlargement of the bone itself. The skin over it is in a natural state, except in cases of long standing, in which the cuticle becomes thickened. This swelling is described by Sir B. Brodie in a clinical lecture in the Medical Gazette, vol. xvii. He is uncertain in what precise situation this tumour exists, whether in the ligaments of the joint, or periosteum, or in the ultimate fibres of the tendon of the tibialis anticus muscle, not having had an opportunity of dissecting it.

In this view also are exposed the course and situation of the dorsal artery of the foot. This, which is merely the continuation of the anterior tibial artery, commences its course from the anterior annular ligament of the ankle, a little to the inner side of the middle of the foot; from thence it runs obliquely towards the first interosseal space of the metatarsal bones, at the commencement of which it dips into the sole of the foot, leaving only a branch to continue its course to the great toe. In the course just mentioned this artery rests upon the bones of the tarsus, separated from them and their ligaments only by a small quantity of cellular tissue. It is accompanied by its vein and a branch of a nerve, and will readily be found running along the outer or fibular edge of the tendon of the extensor proprius pollicis, which partly overlaps it. Notwithstanding the superficial situation of this artery, its close connexion with the above-mentioned tendon renders it peculiarly ineligible for the application of a ligature, and fortunately it is very rarely that we are called upon to perform an operation upon it; but its course and situation are important to the surgeon, as affording a valuable diagnostic mark, negative at

* See a paper on Ganglion by C. A. Key, Esq. in the 1st vol. of Guy's Hospital Reports.

least, if not positive, in the examination of an injury to some of the larger vessels, as the femoral or the anterior tibial. For though, owing to occasional varieties in the course and distribution of the dorsal arteries of the foot, the absence of pulsation in the situation of the arteria dorsalis pedis, just indicated, would not be a positive proof of injury to the larger vessels, (though even this might be received as valuable corroborative evidence,) yet the clear and full pulsation of this vessel would of course be undoubted evidence that the larger arteries were safe and sound. (See Tibial Arteries.)

II. *Region of the toes.*—In the natural state the toes are covered by a skin, soft and pliable, except the extreme phalanx, the dorsal surface of which is defended by the nail, for the structure and arrangement of which we refer to the article Tegumentary system. Under the skin and subcutaneous tissue we find the tendon of the long extensor, lying close upon the bone adhering to it and to the synovial membranes of the joints, by short but free cellular tissue, sufficiently loose to allow of the free movements of the subjacent joints. We observe that the length of the toes, by the construction of the bones, much shorter and smaller than the fingers, appears shorter still in the metatarsal phalanx by the greater depth of the integumental web between the toes. The operator will do well to remember this in amputating at the metatarso-phalangeal joint, or he will surely be foiled in his attempt to open it, particularly as this joint, lying deeper and being composed of smaller bones than the corresponding joint of the hand, is much less readily perceptible, even to the touch. Lastly, these organs, the toes, more universally, and in greater degree perhaps than any other part of the body, pay the penalty of hyper-refinement and civilization in the distortion and disfigurement of their entire structure from pressure. The skin suffers most acutely; it becomes entirely altered in structure. The soft cuticle which covered it is, by the irritation of pressure, increased in thickness by successive additional layers. This increase is greatest just at the point where there is most pressure, namely, at the upper and lateral parts of the projecting joints; nature thus providing a defence for the tender cutis, pressed between the bone and the shoe. The cause of irritation being still continued, the defence itself is converted into an additional enemy; the accumulated layers of hardened cuticle form a hard corn, and irritate and inflame the subjacent cutis. Another effort of nature is made to relieve the suffering parts; a small bursa is formed under the most prominent part of the corn, and this again is made an additional cause of suffering by this part also becoming inflamed, the original source of evil not being removed. The same process taking place between the toes by the pressure of one toe against the other, produces the soft corn by the moisture of this part not allowing the thickened cuticle to become hard and dry. The same process on a larger scale over the joints of the great toe occasions the bunion,* the bursal cysts of which form a beautiful illustration of the powers of nature in accommodating herself to accidental circumstances.

Nor is the mischief arising from this opposition to nature confined to the results now mentioned. The toes, from being constantly kept in a distorted position, acquire permanently an unnatural form, sometimes being bent laterally under or over each other, the ligaments become stretched, the articular cartilages absorbed, the ends of the bones altered in form, and anchylosis is not unfrequently the result. If the shoe be too short, a permanent contraction of the joint of the toe is produced, which is sometimes so distressing in walking as to be a serious impediment to this exercise, and even to demand amputation of the toe as the only means of deliverance. This, when it does occur, is almost always found in the second toe, because it projects beyond the others.

Plantar region.—The plantar region, like the dorsal, may be divided into the plantar region, strictly so called, and the region of the toes.

I. *Proper plantar region.*—The skin upon the sole of the foot is covered by a cuticle remarkable both for its general density and for the great difference of its density in different parts. In the hollow of the sole it is thinnest, next along the outer side, and thickest of all under the heel and heads of the metatarsal bones. This great thickness of the cuticle, though partly arising from pressure, is yet partly natural, being found in some degree even in the fœtus, and is one of those marks of Provident Wisdom of which every part of our structure furnishes instances. The cutis itself is still more striking for the strength and density of its structure, which we observe particularly in dissecting this part. The scalpel must be sharp indeed to cut through it with ease. This, in fact, with its horny cuticle is nature's provision against the injuries to which the important parts of the sole are exposed, and the only defence, the only sandal worn to this day by multitudes. Its structure, as shewn by removing carefully the cellular tissue from its inner surface, is composed of a number of whitish glistening fibres crossing each other in every direction, and enclosing in their meshes portions of that granular fat which forms the layer immediately subjacent to the skin. These meshes are closer and smaller as we approach the outer surface, where the cells entirely disappear. When the cuticle is separated from it, the cutis exhibits a vast number of exhalent pores, the source of that profuse perspiration which is given off from this part of the feet under exercise; these are pretty equally distributed over the sole, but the great thickness of the epidermis at the heel must impede the transpiration through it

* See an excellent paper by Mr. Key in Guy's Hospital Reports. Vide Clinical Lecture on Corns and Bunions, by Sir B. C. Brodie, Bart. in the Med. Gazette, vol. xvii.

to a considerable degree. The sensibility of this part of the integuments is not at all in relation to its apparent want of delicacy in structure; no part of the body possesses a covering more acutely sensitive. The effects of pricking, of titillation, of cold or heat applied to the sole of the foot, exemplify this. Its sympathies also are as remarkable for their liveliness as for their extent. Not even the arm-pits or sides of the ribs are at all equal to it in this respect. The bladder, the urethra, the stomach and intestines, in fact almost all the mucous membranes, together with the whole voluntary system of nerves, and through them the whole system of voluntary muscles, may be said especially to sympathize with and to be influenced by this one part. Of this no one can doubt when we see the effects of sudden cold applied to it in relaxing spasm of the urethra or bowels, in checking vomiting, or in rousing the whole nervous and muscular system during fainting, &c. The effect also of hot applications of stimulants and irritants applied to this part familiarly illustrate its extensive sympathies. The most sensitive part of the sole is the hollow, that part where the cuticle is least dense.

When the cutis is removed, we expose a stratum of cellular tissue remarkable for its density and toughness, and for the granular fat with which its cells are filled; it lies immediately under the true skin, and over the plantar fascia. We may here observe that a similar integument, and the same kind of cellular web under it, is spread over the heel, and, from the peculiarity of its texture, is probably more likely to inflame under the effects of pressure than the skin of other parts of the body; at any rate, it very frequently does inflame, and even slough, when long subjected to pressure; and inattention to this point is often the source of great misery in the treatment of fractures and dislocations of the lower extremity. The heel resting upon some hard portion of the apparatus often so torments the patient as to be a serious impediment to the successful treatment of the case.

The *fascia plantaris* demands our particular attention. It is a strong tendinous structure forming a covering to the muscles and important structures of the sole. It is very thick and dense at its posterior part, and becomes thinner, though still of the same consistence, at the anterior part. The cellular web just mentioned strongly adheres to it externally, while the muscles which it covers are not only adherent to its inner side, but many of their fibres arise directly from it. It not only forms a layer of separation between these muscles and the more external parts, but it sends processes of a similar tendinous structure between the principal muscles, which also afford origin to many of their fibres. It divides itself into three portions, one covering each of the three principal groups of muscles found here. These three portions are, however, united behind where they arise in common from the under projecting part of the os calcis, while anteriorly the layer becomes quite incomplete from the subdivision into five slips, each of these again splitting to pass to be fixed into each side of the heads of the metatarsal bones. The situation, structure, and connexions of this fascia, of the dense stratum of cellular tissue, and of the peculiar skin covering this, are highly important to the surgeon. The knowledge of these points teaches why phlegmonous inflammation must be difficult of treatment, and often dangerous in its results, whether it occurs immediately under the skin or under the fascia, but particularly in the latter situation, the dense unyielding structure of which prevents the swelling from pressing outward, thus greatly aggravating the pain and irritation, and when matter has formed, equally prevents its pointing outwards, and calls for the early application of the lancet to give it free vent, and thus prevent its spreading along the foot. The structure of the parts just described is, as far as it goes, an objection to the partial amputation of the foot recommended by Chopart, wherein the flap is formed from these parts in the sole, together with the muscles and tendons found there. But this objection is by no means fatal to operations upon these parts, which have often been successfully performed, and when they are so, often give a limb much more useful than a wooden one.

We now come to the deep-seated parts of the foot. These consist, 1. of the muscles and tendons; 2. of veins and arteries; 3. of nerves; 4. of absorbents. The muscles and tendons compose three principal groups destined to accomplish the movements of the great toe, of the three middle toes, and of the little toe, and according to their destination and use, so is their situation in the sole. On the inner side the abductor, the adductor, the flexor brevis, and tendon of the flexor longus pollicis form a pretty considerable mass, and have a separate slip of the fascia plantaris lying under them, in contact with the most superficial of them, viz. the abductor. On the outer or fibular side of the sole, a similar mass of muscles, but smaller, lie underneath the metatarsal bone of the little toe, composed also of an abductor and a short flexor, while one slip both from the long and short common flexors joins them anteriorly. The space between these two masses of muscles is occupied, most superficially, and immediately in contact with the plantar fascia, by the flexor brevis digitorum, next by the tendons of the flexor longus digitorum, accompanied by their accessories; posteriorly, the accessories or massa carnea Jacobi Sylvii; and anteriorly, the lumbricales, while deeper still than all there are the interossei interni.

Amidst this number of small muscles, the plantar arteries take their course in the following manner. The posterior tibial artery, as we have elsewhere seen (vide Ankle-joint, Regions of), passing down behind the inner malleolus, gets into the hollow of the os calcis, lying pretty close to this bone, and covered only by the integuments, cellular tissue, and fascia. It now passes between the origins of the adductor pollicis, and in doing so divides into external and internal plantar. The first of these, which is much the larger of the two, runs in a somewhat semicircular course, first forwards and outwards till it has reached the base of the metatarsal bone of the little toe, and then winds round across the other metatarsal bones, till at that of the great toe it terminates by uniting with the anterior tibial. In this course it runs first between the superficial and deep muscles, viz. first covered by the abductor pollicis, then between the flexor brevis digitorum and the long flexor tendons; it then becomes more superficial, lying between the flexor digitorum brevis and the abductor minimi digiti; then in crossing back to the inner side of the foot, it runs deep under all the muscles and tendons, except the interossei. Thus this artery forms an arch, called the plantar arch, having its convexity forwards and outwards, its concavity inwards and backwards. The branches which it supplies in this course are, first, a number of large muscular branches before it reaches the outer side of the foot; then from the convexity of the arch itself, the digital arteries, one to each metatarsal space, which, dividing at the first joint of the toes, run one on each side of the toe to its termination; and lastly, those from the upper and inner sides, being generally very insignificant muscular branches and communicating branches, these last going upwards between the metatarsal bones to anastomose with the metatarsal branches of the anterior tibial artery. It is right, however, to state that in this, as in every other part of the arterial system, great variety is occasionally found. The internal plantar artery is a comparatively small artery, merely going to supply the muscles and integuments of the great toe, and for this purpose passes forwards along the under and inner side of the tarsus, covered by the abductor pollicis as far as the first phalanx of the great toe, where it divides into several branches, supplying both sides of the great toe, and the inner side of the second. The veins which accompany the plantar arteries are, like all deep-seated veins, two in number, one on each side of the artery, and they terminate in the hollow of the os calcis by forming the posterior tibial veins. The plantar arteries are accompanied also in their course by corresponding nerves, the termination of the posterior tibial nerve, which divides in the hollow of the os calcis. The internal plantar nerve, contrary to the order of the arteries, is the larger of the two; it runs in company with the inner plantar artery, and sends branches to the three inner toes, and to the inner side of the fourth, while the external plantar nerve running the course of the corresponding artery is distributed only to the fifth toe and outer side of the fourth. The lymphatics of the sole of the foot, like the rest of this system, are composed of a superficial and a deep set, the former collecting from all parts towards the inner ankle; the latter accompanying the plantar arteries and veins, and passing up also with them behind the inner ankle, go with the tibial veins to the ham. There are several synovial bursæ in this region which it is necessary here to mention. They are surrounding the tendons as they pass into the sole along the hollow of the os calcis, viz. the flexor longus pollicis and flexor longus digitorum. Their anatomical description has been already given (see Ankle, Region of). Another synovial sheath is surrounding the tendon of the peroneus longus as it obliquely crosses the sole to its insertion. This bursal cavity is situated close upon the bone, and under the principal ligaments.

II. *Plantar region of the toes.* — Of the toes we observe that the integuments of the under part are always soft and pliable, compared with the rest of the integument of the sole, and possessing peculiarly the sense of touch; that under the skin at the extremity of the toes there is a soft elastic cushion of cellular tissue, analogous to that at the tip of the fingers, and in this and in the cutis the extremity of the digital arteries and nerves is minutely ramified. The digital arteries themselves, with their accompanying nerves and veins and absorbents, are running along the edges of this under surface of the toes. Lastly, the tendinous thecæ, in which the flexor tendons are lying, are situated along the under surface of the phalanges of the toes, and are particularly attached to the sharp edges of these bones (see Foot, Joints of). They have a smooth synovial lining which prevents the effects of friction upon the tendons, and facilitates their movements.

From the description which has now been given of the organization of the plantar region of the foot, we readily perceive, 1st, Why deep wounds of this part are both followed by considerable hæmorrhage, and why this is at the same time very difficult to stop. The arterial branches are numerous and lie deep. Before we can get at them either to press upon or to tie them, we must do so through a thick integument, a dense tendinous fascia, and deep-seated layer of muscles. If we dilate the opening in all these parts we wound many more branches, while it is impossible at such a depth, and through such part, to discover the bleeding vessel, if the opening is small. We are, therefore, compelled in such a case, if pressure will not stop the hæmorrhage, to tie the posterior tibial artery, either behind the ankle or at the lower third of the leg. But even this is sometimes not sufficient to stop the hæmorrhage, owing to the free anastomosis of the arteria dorsalis pedis with the plantar arteries; and we are then compelled also to tie the anterior tibial. 2d, We see why inflammation and suppuration in these parts, whose parietes as well as contents are in great measure tendinous, are threatening both in their present symptoms and in their consequences. Not only is the ready detection of suppuration prevented, but the efforts of nature to bring it to the surface are resisted. The inflamed parts are bound tight; if matter has formed, it is obliged to burrow laterally, in contact with nerves, arteries, tendons, &c. The inflammation spreading to the synovial sheaths either impairs or destroys the movements of the tendons in them, or, going still further, communicates the inflammation to the tendon, and occasions it to slough. Moreover, the tendinous structure which envelopes some of these bursal cavities is the cause of those violent and alarming symptoms of constitutional irritation, by no means uncommon when only a very small quantity of matter has formed within them, a state sometimes almost instantaneously relieved by a judicious opening made with the lancet, and giving exit to even so small a quantity of pus. 3d, Why severe contusions or lacerations are here so often followed by bad consequences, the power of repair in tendinous structures, which so largely enter into the composition of the parts about the foot, being small, and consequently the inflammation frequently proving the destruction either of the structure or the functions of the parts affected.

The study of the nature and position of these joints of the foot is of great interest and importance to the surgeon, and it will not be inappropriate in this article to offer some observations upon some of the operations in which they are concerned. Modern surgery, whose greatest triumphs have been in the saving of limbs, not in removing them, in discovering the least possible quantity of loss by which the disease might be eradicated, rather than the readiest method of taking off the entire limb, has taught us not to be deterred by the intricacies of the numerous joints of the foot, but fearlessly to lead the knife through any part of them, so that we may only save a serviceable portion, which may be more convenient than a wooden substitute. The removal of the toes at their joints is comparatively easy, though it should be remembered, in amputating at the metatarso-phalangeal joint, that this articulation is situated much deeper than the corresponding one of the hand, owing to the greater length of the web and greater thickness of the member itself. The metatarsal bones may be removed separately or altogether from their junction with the tarsus, as first done by Hey of Leeds, and described in his Surgical Observations. The removal of a single bone is, except it be either the first or the fifth, more difficult and even more dangerous, in regard to the liability to after inflammation, than the removal of the whole metatarsus. In performing this last operation, the guide for entering the whole row of joints is the projecting tubercle of the fifth metatarsal bone, immediately behind which the joint may be opened, and on coming to the projection of the inner cuneiform bone, (see *fig.* 167,) most surgeons recommend the cutting

Fig. 167.

off its projecting part, rather than to finish by opening the joint. The tarsal bones have been extracted, both with and without the attached metatarsal bones. Of the former kind a very remarkable instance is given by Mr. Key in the second number of Guy's Hospital Reports, in which the only bones of the tarsus left were the os calcis, astragalus, scaphoid, and internal cuneiform bones as a support to the great toe. (See *figs.* 167 and 168, in the first of which the dotted line represents the portion of the bones of the foot which was removed in *fig.* 168.)

Fig. 168.

Should disease or accident have destroyed all, or most of the bones in the front row of the tarsus, they may all be readily removed by amputation at the astragalo-scaphoid and calcaneo-cuboid joints, an operation generally known as that of Chopart, who first practised it. How far, however, such a portion of the foot preserved is preferable to the use of a short wooden leg applied to the end of the limb, amputated a little above the ankle, (a plan which we have used with perfect success,) certainly admits of a doubt. At any rate its advantages cannot be put in competition with the principle so admirably illustrated by Mr. Key in the before mentioned case, of saving, if possible, a portion of the metatarsus and toes, though at the risk of a more painful, and perhaps more dangerous operation.

Upon a general survey of the structure and form of the foot, we are struck with the difference between this organ in man and in all other animals. The most striking peculiarities consist in the great breadth of the foot, its shortness in proportion to the leg, the large size of the bones of the tarsus, the relative shortness and smallness of the four outer toes, and the great size of the inner one, the great strength of the calcaneum, and lastly, in those arches produced by the arrangement and form of the tarsal and metatarsal bones. The only animal that nearly approaches to the form of man, the monkey, yet differs from him in all these points. Its foot is narrower and longer in proportion to the leg, its tarsal bones are smaller, its four outer toes are long like the fingers, while the first is small, and separated from the rest. The calcaneum is relatively small, and inclines upwards at its posterior projection, while the peculiarities already specified necessarily occasion that the arches of the foot are much less distinct than in man. Indeed, in supporting itself erect, the monkey rests very much on the outer side of the foot, probably on this account. In all other animals these differences are still more marked. What now can be more evident or more beautiful than the design manifested in this simple arrangement of the foot! Man is physically as well as morally intended to carry himself erect. The breadth of his base was necessary for his continued support; the strength of it is called for on account of the great weight which erect progression throws upon it. Its arches were essential not only to give lodgment and defence to the vessels and nerves of the plantar region, but, by the peculiarity of their construction, to admit of a certain degree of elastic yielding, which greatly diminishes the shocks from violent efforts in leaping, running, &c. The shortness of the toes, augmented by the depth of the webs, shows that prehension forms no part of the design of the foot, while the size of the first toe, and its connexion with the others, points it out as the principal instrument of progression, to which the rest are auxiliary. The analogies between the foot and the hand are striking; they have the same general arrangement of bones and muscles, and even the arteries and nerves, the joints and ligaments, are in many respects similar, but in the particulars just mentioned the difference is strikingly obvious and important, and just in these respects it is that the feet of the Quadrumana also differ from those of man, showing a difference in their intended action, the erect position, at the utmost being only occasional, not being the natural habit, but the foot being prepared and adapted for grasping and clinging, for which the human foot is quite unfit.

The construction of the arches of the foot requires a few words. They are two in number, a transverse and a longitudinal one. The latter of these is principally found along the inner edge of the foot, and as we pass towards the outer side the longitudinal arch gradually shortens and becomes more flattened, until at the outer side the arch is entirely lost, the bones of the tarsus and metatarsus resting through their whole length upon the ground. This is to a certain degree necessary from the construction of the toes, these being weaker and shorter, as well as their metatarsal bones, as they are further from the great toe; as their strength therefore diminishes, the corresponding part of the arch is shortened and flattened, and, consequently, less strain is thrown upon them, until, at the line of the little toe, the arch is obliterated, and what weight is resting here comes at once upon the ground. But from this construction it follows that the longest and the highest line of this arch falls upon the strongest metatarsal bone and longest toe, and that whatever yielding there is occurring in the entire longitudinal arch is greatest in this part of it. This is, indeed, proved by the fact that the length of the foot in a sound state is increased in the line of the great toe to the extent of several lines, by resting the weight of the body upon the foot, whereas it is not at all increased in the line of the little toe. When, therefore, the arch yields to the superincumbent pressure, it does so chiefly along the inner side, and the foot is thus, to a certain degree, twisted, the inner malleolus approached nearer to the ground, while the outer is very little, if at all, lowered. This explains to us the reason of the scaphoid and inner cuneiform bones projecting as they do in the flat foot, and of the pain experienced on the inner side of the foot in the same deformity in all efforts to raise the heel in walking. It may also in some degree account for the fact of the more frequent occurrence of dislocation of the tibia at the ankle-joint inwards than outwards, the arch of the foot yielding first to the force of the accident on the inner side, and thus tilting the whole ankle-joint inwards. The utility in walking of the form and relation of the various parts of the foot now mentioned is readily seen when we unite the consideration of the structure of this arch with the combined action of the gastrocnemii upon the heel, and of the peroneus longus upon the outer side of the foot. The united action of these muscles throws and sustains the whole weight upon the strongest and most elastic part.

Whatever has been said of the utility of the longitudinal arch applies equally to the transverse arch, which is supplementary and auxiliary to the former in all its uses.

(A. T. S. Dodd.)

FOOT, MUSCLES OF THE.—In speaking of the muscles of the foot we necessarily understand not merely those muscles which are situated upon the foot, but those muscles peculiarly belonging to it, which are concerned in producing its motions wherever situated. The muscles of the foot, in this sense, are partly situated upon the leg and partly upon the foot, and should, in a physiological view, be considered together, that we may the better understand their separate and combined functions. We shall therefore, in this, as in other anatomical articles, first give the descriptive anatomy of the muscles situated upon the foot, and then examine their functions in connexion with those others whose action is upon the joints of the foot, and which are therefore strictly muscles of the foot, but which are anatomically described elsewhere. (See Leg, Muscles of the.)

The proper muscles of the foot are, 1. those on the dorsum; 2. those on the sole.

The muscles on the dorsum pedis are the *extensor brevis digitorum* and the *dorsal interossei.*

1. The *extensor brevis digitoram* (Fr. *pedieux*).—This is a short flat muscle, situated upon the outer side of the tarsus and metatarsus. It arises by fleshy and tendinous fibres from the upper and anterior part of the os calcis, in the hollow between that bone and the astragalus *(creux astragalo-calcanien)*, also partly from the os cuboides. It immediately forms a broad fleshy belly, the fibres of which pass forwards and inwards, and divide into four portions, from each of which proceeds a slender tendon. These four tendons, of which the two internal are the strongest, cross under those of the long extensor of the toes, opposite the heads of the metatarsal bones. Of these tendons the internal is inserted into the base of

the first phalanx of the great toe, the others are united to the outer edge of the long tendons, with which they form the aponeurosis which covers the dorsum of each toe. The obliquity of this short muscle counteracts the obliquity of the long extensor, and it serves to extend and to spread the toes, and to pull them away from the great toe.

2. *Interossei dorsales vel externi.*—These are four in number, and arise by double heads, that is, they arise from both the contiguous metatarsal bones, here occupying the whole of the interosseal space, and thus concealing the internal interossei, which are seen only in the sole. Their flat tendon unites with that of the long and short extensors, and is inserted into the side of the bases of the first phalanges of the toes in such a manner that, with internal interossei, every toe has one of these little muscles on each side of it, except the first toe, which has two distinct muscles of its own for the same action, and the little toe, which is provided with a separate abductor. Their use is to separate the toes, and perhaps to assist in extending them.

In the sole of the foot the inner side is occupied by the muscles of the great toe, constituting what some French writers call the *thenar eminence*. These muscles are as follows:—

1. *Abductor pollicis pedis.*—This commences, by a tendinous and fleshy origin, from the tubercle on the under and fore part of the os calcis, from the ligament extending between the os calcis and os naviculare, and from the fascia plantaris. Its tendon unites with the flexor brevis pollicis, and is inserted into the internal sesamoid bone, and inner side of the base of the first phalanx of the great toe. It draws the great toe from the others.

2. *Flexor brevis pollicis.*—Lies between the abductor and adductor, in contact with the metatarsal bone. It arises, by two portions, from the under and fore part of the os calcis, and from the external cuneiform bone. It is united, on each side, to the abductor and the adductor, and is inserted with these, by a union of tendons, into the two sesamoid bones and base of the first phalanx of the great toe, having the tendon of the long flexor passing between the two insertions.

3. *Adductor pollicis.*—This muscle, which is situated the most externally, or fibulad, of the muscles of the great toe, commences by a tendinous origin, from the calcaneo-cuboid ligament, and from one or two of the metatarsal bones. It is double at first, and then uniting, sends a tendon to be fixed into the external sesamoid bone and outer or fibular side of the base of the first phalanx of the great toe, in close connexion with the flexor brevis. It draws the toe towards the others. The muscles of the little toe are situated on the outer edge of the foot, and form, in that situation, a corresponding eminence, which has been called the hypothenar eminence.

1. *Abductor minimi digiti.*—This arises from the outer, under, and fore part of the os calcis, and from the fascia plantaris. It forms a long slender belly, and is fixed by its tendon into the base of the first phalanx of the little toe, and head of its metatarsal bone. It flexes and abducts the little toe, and, by its attachment to the metatarsal bone, it strengthens the arch of the foot, which indeed may be said of almost all the muscles of the foot.

2. *Flexor brevis minimi digiti* commences from the os cuboides and base of the metatarsal bone of the little toe, and lying close to this bone, it is inserted into the base of the first phalanx. It is a very small muscle, and its use is to flex the toe.

The middle of the plantar region is occupied by six muscles common to all the smaller toes.

1. *Flexor brevis digitorum*, called also *perforatus.*—This muscle arises, fleshy, from the anterior part of the protuberance of the os calcis, also from the inner surface of the plantar fascia, both from its central thick portion and from the septa, which run between this muscle and those of the great and little toes. Under the metatarsus it sends off four small tendons, which, entering the sheath on the under side of the four outer toes, are inserted into their second phalanx. Before these tendons arrive at the point of insertion each of them splits, to allow the passage of the tendon of the long flexor, in a manner similar to what takes place in the hand, and they thus have a double insertion into the toe. The action of this muscle is to flex the second joint of the four lesser toes.

2. *Flexor digitorum accessorius*, or *massa carnea Jacobi Sylvii.*—This is a short muscle, somewhat square in form, covered by the flexor brevis digitorum. It arises, fleshy, from the sinuosity of the os calcis, and tendinous from the outer side of the same part; it is attached anteriorly to the tendon of the flexor longus digitorum, just before it divides. Its use is, evidently, to assist the action of the long flexor.

3. *Lumbricales.*—These slender round muscles are found between the tendons of the long flexor of the toes; they arise from these tendons just after their division, and fix their own tendon into the inner or tibial side of the first phalanges of the four outer toes; they act by bending the first joint of these toes.

4. *Interossei plantares vel interni.*—These are three in number, smaller than the external, and having their origin each from only one metatarsal bone. Their insertion and action have been mentioned when speaking of the external interossei.

5. *Transversalis pedis.*—This little muscle is situated across the heads of the metatarsal bones, passing from the fibular side of the great toe to the tibial side of the little one, and attached to them all as it passes over them. It goes under the tendons of the long flexors and the lumbricales, or rather between them and the bones. Its action is to draw the metatarsal bones together, thus to consolidate, as it were, and strengthen that antero-posterior arch, which, were its parallel portions allowed to spread out unchecked, would be materially weakened, and be less able to encounter the violent movements to which the foot is liable in leaping, running, &c.

We shall now enumerate the muscles which are employed in the movements of the foot and its several portions, and classify them according to the joints upon which they act and the movements they produce.

The motions of the ankle-joint are	1. Flexion accomplished by	1. Tibialis anticus. 2. Peroneus tertius. 3. Extensor longus digitorum. 4. Extensor proprius pollicis.
	2. Extension performed by	1. Gastrocnemius externus. 2. Gastrocnemius internus. 3. Plantaris. 4. Flexor longus digitorum. 5. Flexor longus pollicis. 6. Tibialis posticus. 7. Peroneus longus. 8. Peroneus brevis.
The motions between the first and second row of tarsal bones* are . . .	1. Downwards and inwards accomplished by .	1. Tibialis posticus. 2. Extensor proprius pollicis. 3. Flexor longus digitorum. 4. Flexor longus pollicis.
	2. Upwards and outwards by	1. Peroneus Longus. 2. Peroneus brevis. 3. Peroneus tertius. 4. Extensor longus digitorum.
The motions of the toes are	1. Flexion performed by .	1. Flexor longus pollicis. 2. Flexor brevis pollicis. 3. Flexor longus digitorum. 4. Flexor brevis digitorum. 5. Flexor accessorius digitorum. 6. Lumbricales. 7. Flexor brevis minimi digiti.
	2. Extension by . . .	1. Extensor proprius pollicis. 2. Extensor longus digitorum. 3. Extensor brevis digitorum.
	3. Abduction by . . .	1. Abductor pollicis. 2. Abductor minimi digiti. 3. Interossei: Prior indicis. Prior medii digiti. Prior tertii digiti.
	4. Adduction by . . .	1. Adductor pollicis. 2. Transversalis. 3. Interossei: Prior minimi digiti. Posterior indicis. Posterior medii digiti. Posterior tertii digiti.

In this table we are struck with the proportion which the antagonist muscles bear to each other, both in numbers and in individual as well as collective power. This proportion is of course regulated by the demand for muscular force in the ordinary movements of the joints. The extension of the ankle, in the most ordinary mode of its performance, implies the lifting of the whole weight of the body by the elevation of the heel, the toes resting upon the ground. This, owing to the unequal length of the two levers, requires an immense power, while the shortness of the moveable lever allows of very little extent of motion. The gastrocnemii are accordingly thick short muscles, with a long and powerful tendon. These are assisted by the plantaris and five other muscles. Flexion, on the contrary, which generally implies merely the elevation of the foot, without any other force to overcome, is adequately provided for by only four muscles, and these not large, indeed one of them very small. The assistance rendered by the five auxiliary muscles, which pass behind the malleoli, though considerable on the whole, yet is small individually in proportion to their size, owing to the disadvantageous situation which their tendons occupy at so very short a distance from the centre of motion; for this reason,—when the tendo Achillis is ruptured, the patient is as incapable of walking as if all the extensor muscles were divided, yet when the body is resting the antagonism of the extensors is not entirely lost. The foot is not permanently bent upwards, and the simple act of extension can be accomplished without great difficulty. One of the most remarkable of all the extensor muscles, both as to its course and its function,

* It is remarkable that so original and accurate an observer as Dr. Barclay should attribute this motion to the ankle-joint, and should deny any motion, more than a mere yielding, to any of the tarsal bones. But it is still more surprising that he should make the same observation of the carpus, when so very considerable a part of the ordinary motion at the wrist is obviously between the two rows of carpal bones. See Barclay on Muscular Motion, pp. 404, 447.

is the peroneous externus. (See LEG, MUSCLES OF.) The tendon of this muscle passes behind the outer malleolus, then, running downwards and forwards, it enters a groove formed in the os calcis, close behind the prominence of the base of the fifth metatarsal bone. It then runs across the sole of the foot, in contact with the bones, to be fixed to the inner cuneiform bone and metatarsal bone of the great toe. The course and situation of the tendon well deserve particular attention in the dissection of the foot. Without some study, it is impossible fully to understand its office, or how essential its action is to the mechanism of progression. If we examine the general form of the foot, we see that the anterior end of it is not square, owing to the comparative length of the toes. These are not of equal length, but are each shorter than the other as we proceed outwards, the outermost of all being the shortest. This part of the foot then is like the end of an oblong, with one angle greatly rounded off. When, therefore, the weight of the body is, by the elevation of the heel, thrown forwards upon the toes, there is necessarily a tendency, in this shape of the foot, to tilt the pressing force outwards, whereas if all the toes had been of equal length, the elevation of the heel would simply have thrown the weight directly forwards, the support being equal on both sides of the foot. This tendency outwards, occasioned by the difference in length of the toes, is still further increased by the difference in strength, the largest, the most unyielding support, being on the inner side of the foot, the smallest and the most yielding being on the outer. This then being the construction of the basis of support, some means of counteracting this tendency was necessary to enable us to carry the body directly forwards, even in the simple act of walking, and still more in the more violent exertions. This is accomplished by the peroneus longus, whose tendon, like a girt, passes under the outer edge of the sole, and thus, lifting this, and in some degree turning the sole outwards, throws the weight of the body upon the great toe. This action of the muscle is particularly exemplified in the movements of skaiting.

The movements of the bones of the tarsus are so distinct and constant that we have classified the muscles which act upon them separately from those of the ankle. (See FOOT, JOINTS OF.)

The muscles of the great toe are remarkable, as might be expected, for their size and strength. The long flexor is considerably larger than that common to the other toes, and gives to this a slip of its tendon, so that the flexor longus pollicis does in fact assist in flexing all the toes.

The general arrangement of all the muscles and tendons in the sole is very curious, and has a further object than the mere flexion of the toes. The great toe is, as we see, well provided, and it needs this, since it bears the greatest share of the burden of the body in walking, &c. The muscular provision for the other toes is as considerable, and indeed more so, in proportion to the size of the toes. There is, 1st, the flexor brevis digitorum; 2d, the flexor longus

Fig. 169.

1 Flexor accessorius.
2 Flexor pollicis longus.
3 Flexor digitorum longus.
4 Slip from the flexor pollicis longus to the flexor digitorum longus.
5 Lumbricales.
6 Tendon of long flexor.

digitorum; 3d, this tendon receives an auxiliary tendon from the long flexor of the great toe; 4th, the massa carnea; 5th, the lumbricales. There can be little doubt that the use of all these muscles is to give a powerful support to the antero-posterior arch of the foot, to which purpose the mere ligaments would be little equal. But we must admire not only the number and force but the arrangement of these muscles, which are so placed as to act, almost all of them, from the same centre, and therefore with greater advantage for the object of strengthening the arch. Thus the flexor brevis digitorum lies pretty nearly central in this region, while immediately under it the flexor longus digitorum, running from within outwards, is crossed in the opposite oblique direction by the flexor longus pollicis, and these again are still further checked outwards by the flexor accessorius, so that the centre of action of all these muscles and of the lumbricales also, which arise from the long flexor tendon, is in the same line as the flexor brevis, which lies over them, and as a support to the great arch of the foot this arrangement of the muscular chords must have a peculiarly advantageous effect.

(A. T. S. Dodd.)

For the BIBLIOGRAPHY, see ANATOMY (INTRODUCTION).

FORE-ARM, (Surgical anatomy), (*Antibrachium*; Fr. *Avant-bras*; Germ. *der Vorderarm*). This term is applied to that portion of the upper extremity which is situated between the elbow and wrist-joint.

In the well-formed male all the muscles of this region, but especially the supinators, from the fascia which covers them being extremely thin, when thrown into action stand out in strong relief, giving an appearance of great power concentrated within a small space. In the female, on the contrary, the fore-arm, from the great preponderance of adipose tissue, presents a swelling outline and rounded form, not the less beautiful, perhaps, from indicating deficiency of muscular energy, and conveying the idea of softness and dependence.

The usual and least constrained position of the fore-arm is with the hand between pronation and supination, that is, with the palm of the hand inwards and the dorsum outwards; but for the purpose of anatomical description the palm of the hand is supposed to face forwards and the dorsum backwards, the fore-arm being extended. In this position the fore-arm obviously differs from the arm in being wider from side to side than from before backwards. Superiorly it presents in front a very slightly convex surface, but inferiorly there is formed by the flexor tendon a distinct central projection, which is bounded by the flexor carpi radialis on the radial side, and by the flexor carpi ulnaris on the ulnar.

The posterior surface of the fore-arm is more irregularly convex than the anterior; the greatest convexity is nearer the ulnar than the radial edge, and is formed by the olecranon above and the shaft of the ulna below, which is covered only by the skin superiorly. A considerable depression may be observed, bounded on the inner side by the olecranon, and on the outer by the supinators; in this depression the outer condyle may be felt. To the inner side of the olecranon there is a corresponding but much smaller depression, in which the inner condyle is situated. For about three inches above the wrist-joint the fore-arm posteriorly is slightly concave in the centre in consequence of the marked projection of the ulna and radius on either side. In the motions of pronation and supination the shape of the fore-arm is considerably changed; but as no practical advantage can attend a detailed account of the changes undergone, we shall not dwell upon them here.

The parts composing the fore-arm are as follow: the radius and ulna, the muscles of the hand and fingers, the radial and ulnar arteries with their branches, the venæ satellites of these arteries and the subcutaneous veins, the radial, ulnar, median, and cutaneous nerves, the absorbent vessels, a quantity of cellular and adipose tissue, various aponeuroses, and the common integuments.

The configuration, relative position, and connection of the bones of the fore-arm have been described in the article EXTREMITY. They move together in the flexion and extension of the fore-arm on the os humeri at the elbow-joint, under the influence of the biceps flexor cubiti and brachialis anticus, and the triceps extensor cubiti and anconeus.

In the motions of supination and pronation the radius is always rolled upon the ulna, the latter remaining perfectly fixed, though this fact has been disputed in consequence of the thick sacciform ligament of the wrist and the tendon of the extensor carpi ulnaris being felt to roll under the finger when placed on the inferior extremity of the ulna during the motion of rotation and supination, and thus communicating the sensation of a motion in the ulna itself.

The skin of the fore-arm differs considerably on the dorsal and anterior aspects. On the former it is coarse and comparatively rough, containing numerous small hairs; on the latter it is smooth and more delicate, and the adipose tissue being more abundant on the anterior, the whole surface is more even, while on the posterior the extensor muscles of the hand and fingers, being slightly covered, project considerably. Neither of the regions, however, contain so much fat as most other parts of the body.

The superficial veins which are subject to the greatest variety, are usually more distinct and numerous on the dorsal aspect, particularly at the lower part.

The subcutaneous nerves, which are very numerous, are derived from the following sources: 1st, the internal cutaneous nerve, which is one of the divisions of the axillary plexus; 2dly, the cutaneous branch of the radial; 3dly, the musculo-cutaneous.

The internal cutaneous nerve divides into two branches in the upper arm, in which region it accompanies the basilic vein. These two branches penetrate the fascia separately above the elbow-joint, and the one, the *anterior* branch, descends on the front of the fore-arm, the other, the *posterior*, on the back of it. The anterior branch usually passes behind the basilic vein, sending a small twig or two anterior to it. Its course is continued to the wrist-joint, supplying the skin on the anterior and inner side throughout; the posterior division accompanies the basilic vein, and may be always traced to the back part of the wrist.

The small branches of this nerve, which cross in front of the basilic or median basilic vein, are occasionally wounded in the operation of venesection; an accident which generally excites considerable inflammation, with severe constitutional irritation, symptoms which are sometimes erroneously attributed to the action of a foul lancet.

The skin on the anterior surface of the outer half of the fore-arm is supplied with nerves by the external cutaneous nerve, a division of the axillary plexus: it is a deep-seated muscular nerve in the upper arm and penetrates the fascia, becoming subcutaneous anterior and a little below the elbow-joint. In this situation it is posterior to the median cephalic vein; its branches are numerous throughout its course, which terminates at the wrist-joint in the supply of branches to the skin on the dorsum and ball of the thumb, which inosculate with the cutaneous of the radial.

This last-mentioned branch, the *cutaneous of the radial*, is derived from its trunk on the outer side of the middle of the arm; immediately after that nerve has emerged from between the triceps extensor and the bone, a series of branches is distributed to the skin of the arm. The remainder of the nerve, which is a descending branch of some size, passes down behind the elbow-joint, and becoming subcutaneous supplies the skin of the posterior surface of the outer half of the fore-arm, and corresponds to the musculo-cutaneous on the anterior. Thus it will be seen that the skin on the inner side of the fore-arm, both anteriorly and posteriorly, is supplied by the internal cutaneous, while that on the outer side is supplied in front by the musculo-cutaneous, and behind by the radial nerve.

The superficial veins of the fore-arm, though subject to the greatest variety, are usually distinguished by the names of the cephalic, basilic, and median. The two first commence on the back of the hand; the cephalic on the external, and the basilic on the internal side. They freely anastomose at the lower part of the fore-arm, after which they separate, and reaching the anterior surface below the elbow, are joined by the median vein, as described in the article ELBOW.

The superficial absorbents take nearly the same course as the veins, though they are far more numerous, and on the whole pursue a straighter direction. The course of these vessels is occasionally demonstrated in the living subject by active inflammation of their coats following the absorption of irritating matter.

Aponeurosis.—The aponeurosis of the fore-arm is simply a continuation of the same structure, which surrounds and supports the muscles of the upper arm; it varies very much in density and appearance in different situations; this difference arises from the fact that both the triceps extensor and biceps flexor cubiti send to it many fibres, which not merely give additional strength to its texture, but also act as a medium through which these muscles possess the power of making tense the fascia. This provision for tightening and supporting the fascia of the fore-arm is analogous to those arrangements which we meet with in the thigh and leg.

The fascia of the fore-arm is strongest at the posterior part of the limb, on each side of the olecranon. The fibres derived from the tendon of the triceps on the external side pass transversely outwards to be inserted into the outer condyle, intermingling with the radial extensors at their origin, at the same time firmly connected to the olecranon process, posterior and internal edge of the ulna, thus forming a dense and firm covering to the anconeus, between which muscle and the extensor carpi ulnaris a process of fascia is met with which forms a dense septum between the two. The fibres from the internal edge of the triceps at the upper part also pass transversely, reaching the inner condyle, intermingle with the origin of the flexor muscles; others again, descending at the back part of the arm, form an aponeurosis over the flexor carpi ulnaris; while those which pass forwards intermingle with the aponeurotic fibres of the biceps. These fibres from the biceps are uniformly strong and distinct, and give a great firmness and density to the fascia on the inner side of the arm covering the flexor muscles, which is not met with on the outer side of the arm supporting the supinators. The fascia in front of the fore-arm which covers the supinators receives its last fibrous connexion from the tendon of the deltoid. The fascia of the fore-arm on reaching the posterior part of the wrist-joint has interwoven with its texture many beautifully distinct fibres, taking a slightly oblique course from without to within, and from above to below; these fibres, which are firmly attached to the radius on the outer side and the ulna on the inner, become insensibly lost in the fascia on the back part of the hand, which resembles in its homogeneous appearance the fascia on the lower part of the fore-arm; these supplementary fibres to the fascia, though presenting a distinct edge neither above nor below, act as a ligament to the extensor tendons in their passage behind the wrist-joint, which has been called by some anatomists the posterior annular ligament; between these tendons and the ligament there is a large and distinct bursa, not unfrequently the seat of inflammation. The fascia on the lower and fore part of the fore-arm, consisting principally of transverse fibres, becomes gradually thinner, and in front of the wrist-joint is inseparably interwoven with the fibres of the annular ligament.

The aponeurosis of the fore-arm forms many septa between the muscles. Commencing with the description of the septa in the back part of the arm, we find a dense and strong one separating the anconeus from the extensor carpi ulnaris, and from which the latter muscle takes part of its origin. A second dips between the extensor carpi ulnaris and extensor communis digitorum, giving origin to both. A third is found between the common extensors of the fingers and radial extensors. The radial extensors and supinators are not thus separated from each other. A fourth process, distinct though comparatively thin, separates the supinator radii longus from the brachialis anticus, the tendon of the biceps, pronator radii teres, and flexor carpi radialis. There is also another process which unites the tendon of the supinator radii longus on the outer side to the flexor carpi ulnaris on the inner side, and forms a firm and dense covering to the radial artery. The pronator radii teres is scarcely separated from the flexor carpi radialis by a distinct septum, though the last-mentioned muscle is completely separated from the palmaris longus by a dipping in of the fascia. Between the flexor communis digitorum sublimis and flexor carpi ulnaris there is a very perfect and distinct septum.

Of the different morbid growths which arise in the cellular tissue of the fore-arm, those which are superficial and those which are beneath the fascia require careful distinction, the removal of the former being easily effected, while all operations on the latter require great consideration and care.

The superficial tumour projects under the skin, creating some deformity; it may be moved with facility, for its attachments are loose; while, on the other hand, the deep-seated or sub-fascial tumour has frequently a flattened surface, and often appears, on superficial examination, insignificant and of small extent, while in fact its mass is considerable, burrowing deeply between the muscles. It is to be distinguished from the supra-fascial tumour by its comparative immobility, by the various effects produced upon it by the fascia when in a state of tension or relaxation, by the pain produced by pressure on nerves, or impediment to the circulation from pressure on the vessels. In the removal of the sub-fascial tumour the operator must call to mind the direction and relative position of the muscles in the neighbourhood of it, as the roots or under surface of these generally follow the interspace between the muscles, and are thus guided to a great depth among the vessels and nerves of the fore-arm.

The same principles apply to the diagnosis and treatment of superficial and deep-seated abscesses. The superficial abscess is less circumscribed; the matter is diffused without limit through the subcutaneous tissue; from its position the absorption of the superincumbent tissues takes place rapidly, the skin either giving way entirely without the aid of the surgeon, or else pointing at some particular spot indicates where the abscess lancet may be employed with advantage.

The sub-fascial abscess, on the contrary, proceeds slowly in many cases, and even insidiously, bound down by the unyielding fascia; it tells us of its presence, in the first instance, rather by the constitutional disturbance which it rouses than any striking indications of local mischief. These abscesses are occasionally the consequence of inflammation commencing in the theca of the flexor tendons, and the burrowing of the matter upwards in the course of the tendons. The septa of the fascia, which have been described passing down between the muscles to the bone, limit the passage of the pus in different directions.

The fascia itself is not much subject to disease, though it seems peculiarly disposed to slough as a consequence of phlegmonous erysipelas.

Vessels.—The main arteries of the fore-arm are the radial and ulnar, into which the brachial artery divides just below the bend of the elbow. The brachial artery at this spot has on its outer side the tendon of the biceps; on its inner side, one of the venæ comites, the median nerve, and the pronator radii teres muscle. Behind the brachial artery is the brachialis anticus muscle, and in front of it the fascial insertion of the biceps muscle.

The radial artery, which is the smaller of the two divisions, pursues nearly the same direction as the brachial, and in the lower part of the upper third of the fore-arm is found exactly midway between the radial and ulnar surfaces, overlapped by the supinator radii longus, and lying upon the tendon of the pronator radii teres muscle, with the radial nerve about a quarter of an inch to its outer side, and separated by fat and cellular membrane. From this point the radial artery descends towards the wrist-joint, and at the lower part of the upper half of the fore-arm quits the pronator radii teres, and passes on to the anterior surface of the flexor longus pollicis, having the flexor carpi radialis to its inner side. A little lower down, that is, at the upper part of the lower third, the vessel emerges from beneath the supinator radii longus muscle, and is covered only by the fascia. In its further course to the wrist-joint the flexor carpi radialis maintains its position on the inner side, to which the tendon of the supinator radii longus corresponds on the outer. The radial nerve no longer accompanies the vessel, for it has now slid under the supinator radii longus, and reached the posterior face of the arm. As the radial artery just above the wrist-joint is covered only by the fascia, and lies upon the bone, its pulsations are easily felt, and in consequence of its convenient situation is generally selected by the medical practitioner to ascertain the general state of the circulation. We should, however, always bear in mind the great variety both in size and distribution to which this vessel is liable, and take the precaution of at least examining the radial artery in both arms.

The inner edge of the supinator radii muscle is a certain guide to the situation of this artery should the surgeon be required to secure it, and this should always be effected by two ligatures, as its free anastomosis below will certainly produce secondary hemorrhage if this precaution is neglected. As the nerve lies on the outer side of the artery, the needle must be passed from without inwards.

The ulnar artery has a deep course, first passing beneath the median nerve, which separates it from the pronator radii teres muscle, next beneath the flexor digitorum sublimis, the two last muscles separating it from the flexor carpi radialis and palmaris longus, and upon the flexor digitorum profundus, and when it reaches the tendon of this muscle midway between the wrist and elbow-joints, it comes into contact with the ulnar nerve, by which it is separated from the flexor carpi ulnaris muscle on its inner side. In its further descent to the wrist-joint it is situated between the flexor communis digitorum sublimis and flexor carpi ulnaris. Gradually sliding behind, the tendon of the latter remains covered by it for about two inches above the annular ligament of the wrist, in front of which it passes into the palm of the hand. The third branch worthy of mention in this division of the fore-arm is the anterior interosseal. This vessel is a branch of the ulnar artery, and not unfrequently is of large size, though usually of a calibre about intermediate to the two last mentioned. It arises from the ulnar artery where that vessel is covered by the pronator radii teres, and descending towards the interosseal ligament reaches that structure a little below the tendon of the biceps. It is accompanied by a branch of the median nerve in its course downwards; lies between the interosseous ligaments and the external edge of the flexor communis digitorum profundus; it terminates by dividing into two branches, of which one passes backwards through the interosseal ligament, anastomosing with the posterior interosseal, and the other, a small branch, descends over the wrist-joint into the palm of the hand, where it anastomoses with the deep palmar arch.

In the posterior region of the fore-arm we meet with only one vessel of any size; this is the *posterior interosseal artery*, a branch from the anterior interosseal, which passes through the interosseal ligament opposite the tubercle of the radius; its course is not so straight and uniform as the anterior, its distribuent branches are larger and more numerous, and it may be said to ramble down between the extensor muscles and the interosseal ligament, though it does not lie so immediately in contact with the ligament as the anterior interosseal. It terminates by anastomosis with the vessels about the wrist-joint.

Such is the usual distribution of these vessels; they are, nevertheless, subject to every kind of variety, and the operator previously to the commencement of an operation ought always carefully to examine the course of these vessels in order to detect any anormal arrangement either in relation to their size or distribution.

The arteries of the fore-arm are more exposed to accidents from cutting instruments than most other vessels in the body; and the usual plan of securing the vessel in these cases is to apply two ligatures on the wounded trunk, one above and the other below the orifice, the latter being required in consequence of the free anastomosis of the vessels in the hand.

But the fore-arm is occasionally wounded by sharp penetrating instruments, which passing deeply into the fleshy mass, the vessel which has been wounded is not immediately indicated, and the surgeon is consequently at a loss to discover which of the three main trunks requires the application of a ligature.

An examination through the wound would tend to aggravate the mischief, and besides, the search is often attended with difficulty, and often unsatisfactory.

In such cases it will be found far more advantageous to arrest the hemorrhage by pressure on the brachial artery, at the same time allaying the local inflammation by due attention to the position of the arm, and the usual antiphlogistic remedies, a plan which I have seen adopted with great success by Mr. Tyrrell, at St. Thomas's Hospital.*

* See St. Thomas's Hospital Reports, edited by John F. South, No. i. p. 25.

There are some cases, however, which imperatively require the application of ligatures, as for instance, when either of these vessels is opened by sloughing of the tissues from phlegmonous inflammation, or from aneurism in the fore-arm or hand. In the first of these cases, patients have frequently been lost from the temporary suspension of the hemorrhage by the use of cold applications or accidental circumstance, and its occurring again suddenly during the absence of the surgeon.

In the performance of the operation of tying the radial artery the supinator radii longus muscle affords an unerring guide throughout the fore-arm, but the surgeon must remember that the inner edge of this muscle is not on the outer side of the fore-arm, but as nearly in the centre as possible. The needle must be passed from without inwards, in order to avoid wounding the nerve.

The ulnar artery cannot be secured in the upper third of the arm, it lies so completely covered by most of the flexors arising from the inner condyle; as soon as the vessel has gained its position between the flexor carpi ulnaris and the flexor digitorum communis, it may be easily reached, the former muscle overlapping it, and therefore forming an excellent guide. The needle in this operation must be passed from within outwards, as the nerve lies to the ulnar side of the artery.

The bones of the fore-arm are not unfrequently fractured, either singly or together, but the radius, from its external position and strong connection with the bones of the hand, is more frequently fractured than the ulna. The injury generally takes place a little above the middle of the bone.

When both bones are fractured, the accident is frequently occasioned by the passage of a heavy weight over the limb, the violence acting immediately on the injured portions. In childhood these bones are sometimes bent instead of being broken, and as the deformity is slight, though the effect altogether very serious, the nature of the accident is not very readily detected.

"When these bones are fractured near their inferior extremities," says M. Boyer,* "the inflammatory swelling might render the diagnosis difficult, and cause the fracture to be mistaken for a luxation of the hand. But the two cases may be distinguished by simply moving the hand; by the motion, if there be luxation without fracture, the styloid processes of the radius and ulna will not change their situation; but if a fracture do exist, these processes will follow the motion of the hand."

If the radius be fractured a little below the head and above the tubercle, that is, through the neck, and the annular ligament remain entire, the deformity is so slight that there is great difficulty in detecting the nature of the injury, especially if there be much swelling and effu-

* Lectures of Boyer upon Diseases of the Bones, arranged by M. Richerand, translated by M. Farrell, vol. i. p. 161.

sion. Unless the surgeon can distinctly feel the head of the radius, so that he can clearly ascertain on rotating the lower portion with the hand, that the upper does follow but remains perfectly unmoved, he has no equivocal guide as to the real nature of the injury.

If the ulna is fractured separately from the radius, which seldom occurs, the injury generally happens to the lower third of the bone, which is much smaller and more exposed than the upper; the accident is easily detected by running the finger down the posterior edge of the bone. When the radius is fractured near its centre, the pronator quadratus muscle obtains entire power over the bone, and drawing the lower portion across towards the ulna, causes a considerable projection in the anterior interosseous space. If this be not corrected by the use of a pad, as recommended a little further on, the two bones will unite, and all motion of pronation and supination be entirely lost.

In all these cases of fracture of the bones of the fore-arm, nearly the same plan of treatment is required, namely, 1st, two pads, increasing in thickness from the elbow to the wrist, and not wider in any place than the arm itself, sufficiently soft to be pushed well into the interosseal spaces, applied anteriorly and posteriorly; a long linen roller enveloping the hand and the whole of the fore-arm, and pressing the pads between the two bones, so as to counteract the action of the two pronator muscles which have a tendency to bring them together. Splints extending from the elbow to the hand.

When the radius alone is fractured, it is advisable not to support the hand, but to allow it to hang down, and by this plan the hand acting as a weight, will draw the lower fractured portion, which has a tendency to overlap the upper, downwards, and thus bring them into apposition.

(Samuel Solly.)

FORE-ARM, MUSCLES OF THE.— When we consider how varied and complex are the motions of the arm and hand, it is no matter of surprize that so many as nineteen muscles should be found composing the fleshy mass of the fore-arm.

These muscles may be classified in reference to their action, and are briefly enumerated as follows:—

In the first place there is one muscle physiologically belonging to the upper arm, the anconeus; the rest are connected with the hand; for instance, there are three flexors of the hand; *flexor carpi radialis, flexor carpi ulnaris, palmaris longus.* Three extensors of the hand, *extensor carpi radialis longior, extensor carpi radialis brevior, extensor carpi ulnaris.* Three long flexors of the thumb and fingers; *flexor communis digitorum sublimis, flexor communis digitorum profundus, flexor longus proprius pollicis.* Five extensors of the thumb and fingers, *extensor ossis metacarpi pollicis, extensor primi internodii, extensor secundi internodii, extensor communis digitorum, extensor indicis.* Two supinators, *supinator radii longus, supinator radii brevis.* Two pronators, *pronator radii teres, pronator quadratus.*

In proceeding to describe the attachments and relations of the foregoing muscles, it will be found convenient to examine them as they are met with in the following regions of the fore-arm. 1. The anterior region, which contains a superficial and a deep set of muscles. 2. The posterior region, which likewise has its superficial and its deep layers of muscles. These regions again may be conveniently subdivided into radial and ulnar sections, between which a very natural line of demarcation is observable after the skin and adipose tissue have been removed.

Exactly on this line, and one-third from the elbow and two-thirds from the wrist-joint, two long muscles will be found in contact, the *supinator radii longus* in the radial section, the *flexor carpi radialis* in the ulnar. Above and below this point these muscles diverge. The flexor carpi radialis, at its origin from the internal condyle, is distant, from the boundary line referred to, at least one-third of the transverse diameter of the arm, and the space thus left, triangular in its figure, contains a large portion of the pronator radii teres. The radial edge of the pronator radii teres is in contact with the supinator radii longus to the extent of about an inch and a half; this muscle descending in like manner obliquely from its origin in the ulnar section towards the radial leaves above a similar though small triangular space, in which the tendon of the biceps flexor cubiti is lodged. Below the point referred to above, between the elbow and wrist, the flexor carpi radialis runs in contact with and on the ulnar side of the boundary line till within an inch and a half of the wrist-joint, where it gradually slides into the radial section, so that at the annular ligament the tendon of the flexor carpi radialis will be found entirely in the radial region with its internal edge in contact with the boundary line.

Thus it will be seen that a line drawn from the elbow to the wrist and dividing the fore-arm into two portions, of which the internal or ulnar section is exactly two-thirds, while the external or radial section is only one-third of the transverse width, not merely forms an artificial division into radial and ulnar sections, but also points out the exact situation of the tendon of the biceps, the outer edge of the pronator radii teres, and the flexor carpi radialis, and in addition, as we shall presently see, the supinator radii longus. The fleshy belly of this muscle lies exactly parallel with this boundary line in the upper half of the arm.

In consequence of the supinator radii longus becoming tendinous about the middle of the fore-arm, and the tendon being narrower in its transverse diameter than the muscle, a space is left at the lower part of the arm between it and the flexor carpi radialis, and the supinator radii longus is no longer met in contact with the boundary line. In this space is lodged the radial artery, lying midway between these two tendons, separated from the flexor longus pollicis by a deep layer of fascia, which is united to the edge of the supinator radii longus on the outer side, and the flexor carpi ulnaris on the inner side

Muscles in the anterior region of the fore-arm.—*a. Superficial layer of muscles.*—On the radial side we observe two, *supinator radii longus* and *extensor carpi radialis longior.*

1. *Supinator radii longus, (grand supinateur,* Cloq., *brachio-radialis,* Soëmm.,) arises by a broad, flat, fleshy origin from the rough ridge, on the outer side of the lower extremity of the os humeri, which gradually terminates in the outer condyle; it is connected at the apex of its origin with the deltoid : it arises likewise from the intermuscular ligaments of the upper arm ; passing over the elbow-joint, its surfaces, which in the upper arm face outwards and inwards, are converted into anterior and posterior in the fore-arm ; opposite the tubercle of the radius it becomes tendinous on its under surface, and the fleshy fibres on its anterior face entirely disappear about the middle of the fore-arm in a flat tendon, which, narrowing as it descends, is inserted into the external edge of the base of the radius.

This muscle at its origin has to the inner side of it the brachialis anticus muscle and the radial nerve and superior profunda artery; to its outer side and posteriorly the triceps extensor cubiti ; a little lower down and just above the elbow-joint it has the extensor carpi radialis longior to its outer side, which maintains a uniform relation to it in its whole course; in passing over the elbow-joint the tendon of the biceps flexor cubiti separates it from the brachialis anticus; below the tendon of the biceps muscle, we meet with, first, the pronator radii teres in apposition with its internal edge ; and, next, the flexor carpi radialis. In contact with its posterior face superiorly is the supinator radii brevis ; below this muscle the tendon of the pronator radii teres; and still lower down the flexor longus pollicis.

The supinator radii longus, in addition to its action as a supinator of the hand, is a flexor of the fore-arm upon the arm.

2. *Extensor carpi radialis longior, (radialis externus longior,* Soëmm., *humero sus-metacarpien,* Chauss., Dumas,) arises from the lower extremity of the ridge above referred to, and from the outer condyle. Advancing forward it passes over the front of the elbow-joint, and soon becoming tendinous on its anterior surface descends on the anterior part of the fore-arm, partly overlapped by the tendon of the supinator radii longus—its tendon gradually seeks the posterior part of the arm, and running through a broad shallow depression appropriated to it and the second radial extensor, finishes its course by being inserted into the back part of the metacarpal bone supporting the index finger. This muscle, as its name implies, is an extensor of the hand, possessing also a slight power in effecting its abduction.

In the ulnar section of the anterior superficial antibrachial region we find five muscles.

1. *Pronator radii teres* arises tendinous, above the elbow-joint from the intermuscular ligament of the upper arm, from the front part of the internal condyle of the os humeri, from the process of fascia separating it from the flexor carpi radialis, and from the ulna close to the insertion of the brachialis anticus. This muscle, though tendinous at its origin, soon becomes fleshy, and from its rounded form, which causes a distinct projection beneath the skin at the front and upper part of the fore-arm, derives its name. Its fleshy fibres terminate in a tendon as it enters the radial section, which gradually becomes wider as it descends, and sliding behind the supinator radii longus and extensor carpi radialis and in front of the radius, is inserted into the outer and back part of that bone. The *pronator radii teres* has to its outer side, superiorly, the tendon of the biceps muscle; below the tubercle of the radius it has the internal edge of the supinator radii longus in apposition with it, and as it slides in a spiral direction round the radius, and behind this muscle, it has the supinator radii brevis superior and external to it ; to its inner side it has throughout its course the flexor carpi radialis.

In the ulnar section the anterior surface of this muscle is in contact with the fascia; in the radial it is covered by the supinator radii longus, the two radial extensors, and crossed by the radial artery and nerve. The posterior surface of this muscle is in contact with the anterior ligament of the elbow-joint, the brachialis anticus, the median nerve, ulnar artery, the flexor communis digitorum sublimis and radius. This muscle, while presenting a smooth and tendinous face to the under surface of the supinator longus and radial extensors, continues fleshy on its under surface to the very point of its connexion with the radius, the muscle beneath, whose surface is in contact with its fleshy fibres, being clothed in a similar manner with tendon ; this admirable contrivance for preventing friction is by no means peculiar to this situation, though its utility is frequently overlooked.

The name of this muscle indicates its action as a pronator of the hand, and when that effect has been produced, if its contractile power be still further excited, it will flex the fore-arm upon the upper. In case of fracture of the radius, this power is excited injuriously in bringing the radius across the ulna, and thus obliterating the interosseal space, and if not corrected by the surgeon, causing unnatural union of the two bones.

2. *Flexor carpi radialis (M. radialis internus,* Winslow, Albinus, Lieutaud, Sabatier, Soëmm.; *grand palmaire,* or *radial anterieur,* Cloquet;) arises from the internal condyle of the humerus in common with the last-mentioned muscle; at the point where these two muscles are connected with the humerus there exists no natural separation between them. About an inch and a half from their origin a separation is effected by the dipping in of the fascia forming

one of the muscular septa previously referred to. At the lower part of the upper third of the fore-arm their separation is complete. The flexor carpi radialis first changes its muscular fibres for tendinous on its anterior face, and a rounded tendon is the result at the upper part of the lower third of the arm. This tendon passes in front of the wrist-joint and through a groove in the os trapezium, is ultimately inserted into the base of the metacarpal bone supporting the fore-finger.

This muscle has on its outer edge, in the superior third of the fore-arm, the pronator radii teres, in the two inferior thirds the supinator radii longus; the palmaris longus to its inner edge, both at its origin and throughout its whole course in the fore-arm. Anterior to it there is simply the fascia, its posterior face is in contact with the superficial flexor of the fingers above and the long flexor of the thumb below. The tendon of this muscle projects distinctly through the skin at the lower part of the arm.

The flexor carpi radialis, besides flexing the whole hand on the fore-arm, bends the second row of carpal bones upon the first. It will also act as an abductor of the hand, in consequence of its being fixed on the outer side of the hand in the pulley-like groove of the trapezium through which it passes. It slightly assists the pronator muscles in their influence over the hand.

3. The *palmaris longus*, Soëmm., *epitrochlo-palmaire*, Chauss. The origin of this muscle, which is in common with the other flexors, is from the inner condyle, also from a tendinous intermuscular septum which separates it from the flexor carpi radialis on the outer side and the flexor communis digitorum on the inner. This muscle, the smallest of those situated in the fore-arm, becomes tendinous midway between the elbow and wrist-joint. This tendon, which is narrow and slender, descends to the annular ligament, and is ultimately connected with the palmar fascia. This fascia has sometimes been considered as a mere expansion of the tendon of the palmaris longus, but as the muscle is occasionally wanting and the fascia never, we regard it rather as another instance of that useful connexion of muscles with fasciæ which we have already had occasion to admire. This muscle, except at its origin where it has the flexor carpi radialis to its inner side and the flexor communis to the outer, maintains a position completely superficial to the other muscles, its posterior face lying upon the flexor communis sublimis.

This muscle flexes the hand, and makes tense the palmar fascia and annular ligament, and thus takes off from the palmar vessels and nerves and the tendons of the digital flexors the pressure to which they are exposed when the hand grasps a solid body firmly; as, for instance, when the whole weight of the body is sustained, as in the case of the sailor climbing the rigging of a vessel, by the power of the flexors of the fingers and hand.

4. *Flexor communis digitorum sublimis perforatus*. (*Musculus perforatus*, Soëmm., *epitrochlo-phalanginien commun*, Chauss.) This muscle also arises from the inner condyle in common with the other muscles, and from a strong tendinous septum separating it from the flexor carpi ulnaris. About the middle of the fore-arm this portion of the muscle is joined by muscular fibres which arise from the radius immediately below the insertion of the supinator radii brevis, and on the inner side of the pronator radii teres. Between these two origins of the flexor communis digitorum is placed the median nerve. The tendinous fibres, into which the muscle is gradually transformed, become first apparent on the anterior surface, and next being collected ultimately split into four cords, which passing behind the annular ligament of the wrist, enter the palm of the hand; opposite the first phalanx of the four fingers these cords, splitting into two portions and allowing the passage of the deep flexors, terminate by being inserted in the rough edge on the sides of the second phalanges. The tendons of this muscle as well as the deep flexor are bound down to the phalanges by smooth tendinous sheaths or thecæ which are dense and firm between the articulations, but insensibly disappearing opposite the joint, where their presence would interfere with the motion of the parts; they are lined by synovial membrane to prevent unnecessary friction.

Although the lateral width of this muscle is considerable, only a very narrow edge is in contact with the fascia, the remainder being covered by the last-mentioned muscles, so that some anatomists have described it as constituting a middle layer.

On the internal edge is placed the flexor carpi ulnaris, which maintains the same relative position to it throughout the fore-arm. In contact with its posterior face we have the flexor digitorum profundus, the flexor longus pollicis, and the ulnar artery, vein, and nerve.

This muscle flexes the second phalanx on the first, and the first on the metacarpus, and the whole hand on the fore-arm.

5. *Flexor carpi ulnaris*, (*musculus ulnaris internus*, Soëmm, *cubital interne*, Portal, *cubito-carpien*, Chauss.) This muscle arises from the internal extremity of the internal condyle of the humerus from the tendinous intermuscular septum, between it and the flexor carpi digitorum sublimis, and from the olecranon process of the ulna; between these two heads the ulnar nerve is situated; its origin from the ulna is not limited to the olecranon process, for it continues its connexion with that bone nearly as low down as the origin of the pronator quadratus. This muscle, which arises tendinous and fleshy, merges into tendinous fibres on its anterior surface at the upper part of the lower third of the fore-arm. The tendon by degrees becomes more rounded, but does not cease to receive fleshy fibres until it terminates by becoming inserted into the annular ligament and os pisiforme.

The flexor carpi ulnaris, forming the inner margin of the muscles of the fore-arm, is in contact with the fascia: its external edge touches the flexor communis digitorum sublimis. The relation of this muscle to the ulnar artery has induced some anatomists to denominate it *muscle satellite de l'artère cubitole.*

In addition to its power as a flexor of the hand on the fore-arm, this muscle adducts the hand, drawing it towards the mesial line.

b. The deep layer of muscles.—These are three in number, the *flexor longus proprius pollicis, flexor communis digitorum profundus perforans,* and the *pronator quadratus.* A portion of the supinator radii brevis is also found in it.

1. *The flexor longus proprius pollicis,* Sœmm. (*Radio-phalangettien du pouce,* Chauss.) This muscle, situated most externally, arises by two heads; one, narrow, rounded, tendinous, and fleshy, from the inner condyle of the humerus; the other, broad and fleshy, from the front of the radius, below the insertion of the biceps and supinator radii brevis, and from the interosseal ligament, extending as low down as the insertion of the pronator quadratus. Its tendon, first formed on its internal and anterior edge, descends behind the annular ligament of the wrist-joint, and taking its course between the two heads of the flexor brevis pollicis, is inserted into the last phalanx of the thumb.

This muscle is covered anteriorly by the supinator radii longus and extensor carpi radialis longior, except at the lower part, where it is simply covered by the deep fascia on which the radial artery lies. To its inner side is the flexor digitorum profundus.

This muscle is a flexor of the last phalanx of the thumb, a powerful and important muscle in grasping objects.

2. *Flexor communis digitorum profundus perforans.* (*M. perforans,* Sœmm. *M. cubito-phalangettien commun,* Chauss.) arises tendinous from the front of the ulna immediately below the insertion of the brachialis anticus into the tubercle of that bone, and from the same as low down as the pronator quadratus; also from the interosseous ligament. It becomes tendinous on its anterior face about the middle of the fore-arm, thus presenting a smooth and polished surface to the muscles in front of it: like the superficial flexor, it forms its four tendons, which, after traversing the palm of the hand and piercing the split tendons of the superficial flexor, are ultimately inserted into the third phalanx of each of the fingers.

This muscle has the flexor longus pollicis to its outer side; the flexor carpi ulnaris to its inner; and the flexor carpi radialis, flexor communis digitorum sublimis and palmaris longus, anterior to it.

To flex the fingers on the hand, commencing with the flexion of the last phalanx on the others, and the whole hand on the fore-arm, constitutes the principal action of this muscle.

3. *Pronator quadratus,* Sœmm. (*Cubito-radial,* Chauss.) This muscle, entirely covered by those mentioned above, presents a beautiful appearance on their removal, from the tendinous surface admitting by its transparency the colour of the muscle to shine, as it were, through it.

It arises from the ulna about an inch and a half above the wrist-joint, occupying exactly that extent of the surface of the bone with its attachments: it is inserted fleshy into the lower part of the radius.

This muscle, simple as its action appears, that of rolling the radius over the ulna, performs a most important part in those easy motions of the hand which the artist unconsciously produces when he is engaged sketching in bold and flowing lines the subject of his picture.

To the surgeon a knowledge of the attachments of this muscle is peculiarly important, for in those cases in which the radius is fractured near its lower extremity it draws the injured bone into the field of the flexor tendons, and by bringing it into close contact with the ulna, produces a deformity which great care will alone obviate.

Posterior antibrachial region.—If we now look to the posterior part of the fore-arm, we shall find that though it may be divided into radial and ulnar sections like the anterior, the proportions between them will be very different; for one-fifth of the transverse diameter of the arm alone can be correctly allotted to the radial region in the upper part, and two-fifths close to the wrist-joint. The line of demarcation between these two regions is accurately formed in the dissected arm by the radial edge of the extensor communis digitorum. This muscle, like those on the anterior surface of the arm, is wide and muscular above, tendinous and comparatively narrow below; and hence we find the radial section wider below than it is above. In the ulnar section, we have the extensor communis digitorum to the outer side; in contact with this muscle, on its ulnar side, is the extensor carpi ulnaris. This muscle, at its origin at the upper part of the arm, is narrow, and the space, thus yielded as it were by its form, is occupied by the anconeus, which forms the boundary of this region on the ulnar side. The space left at the lower part of the arm, from the divergence of the tendons of the extensor carpi ulnaris and extensor communis digitorum, permits a view of the indicator. The radial section contains at its upper part solely the extensor carpi radialis brevior; but at the upper part of the middle of the arm, we have sliding into it from behind the extensor communis digitorum, the extensor ossis metacarpi pollicis, and extensor primi internodii pollicis. These pursue their course obliquely across the radial section till they reach the outer edge of the arm. Lower down than these muscles and scarcely in contact with their inferior edges, we discover the tendon of the extensor secundi internodii pollicis likewise emerging from beneath the extensor communis digitorum.

a. Superficial muscles of the posterior antibrachial region. — 1. *Anconeus* (*epicondylo-cubital,* Chauss.) though usually described as a distinct muscle, is, in reality, a continuation of the triceps extensor cubiti: the fibres of each are perfectly continuous, and there is no line of demarcation between them. An artificial boundary may be made by drawing a line horizontally inwards when the fore-arm is extended on the upper arm, between the outer condyle of the os humeri and the olecranon process of the ulna. With this view of the limit of the upper edge of the anconeus, it may be described as a triangular muscle, the base above and the apex below. This muscle arises tendinous from the back part of the outer condyle, its external and anterior edge continuing tendinous almost to its insertion; its superior fleshy fibres pass transversely inwards and backwards, to be inserted into the fascia of the fore-arm and also into the olecranon; the middle and inferior fibres pass backwards to the ulna with various degrees of obliquity, and occupy by their insertion about one-third of the bone from its superior extremity.

This muscle is a simple extensor of the fore-arm.

2. *Extensor carpi ulnaris, (ulnaris externus*, Sœmm.; *cubito sus-metacarpien*, Chauss.) arises from the back part of the outer condyle between the anconeus and the extensor communis digitorum, with which latter muscle it is so intimately connected that, more strictly speaking, it ought to be said to arise in a common tendon. Connected by a narrow origin to the humerus it gradually expands, and about the middle of the fore-arm, a tendon being formed in the centre, it exhibits in its further course a well-marked specimen of the double penniform muscle. The tendon of this muscle, in its passage towards the wrist-joint, runs in an especial groove appropriated for its reception in the back part of the ulna; it terminates by being inserted in the metacarpal bone supporting the little finger. The extensor carpi ulnaris is more or less connected with the fascia throughout the whole of the upper arm.

This muscle extends the first row of carpal bones on the second and the whole hand on the fore-arm; it is likewise an adductor of the hand.

3. *Extensor communis digitorum (epicondylo sus-phalangettien commun*, Chauss. Dumas) arises from the back part of the outer condyle in common with the extensor carpi ulnaris on its outer side, and the extensor carpi radialis brevior on its inner side. The connexion of this muscle to the os humeri is extremely narrow in comparison with the width of the muscle in the centre of the fore-arm. In its ample attachment to the fascia it resembles the flexor ulnaris, and, like it, is a penniform muscle. We not unfrequenly find a portion of this muscle so entirely distinct from the rest that anatomists have occasionally described it as a separate muscle, under the name of the extensor proprius minimi digiti; for being inserted into the little finger, it possesses the power of extending that portion of the hand. It passes behind the posterior annular ligament of the wrist-joint, splits into four tendons, which, expanding on the back part of the phalanges of the four fingers, convey the power of the muscle to each phalanx in an equal degree. The tendons of this muscle in their passage behind the annular ligament of the wrist-joint are clothed by a synovial membrane (reflected like all other synovial membranes) so as to form a perfect purse or bursa. Both these muscles are intimately connected upon their under surface at the upper part of the arm, with the aponeurosis covering the supinator radii brevis.

This muscle is an extensor of the fingers and the hand on the fore-arm.

4. *Extensor carpi radialis brevior, (radialis externus brevior*, Sœmm. *Epicondylo sus-metacarpien*, Chauss. Dumas), with a small portion of the extensor carpi radialis longior, occupies the radial division of the posterior superficial antibrachial region. This muscle arises from the outer condyle by a flattened narrow origin, in common with the extensor communis digitorum, being overlapped on its outer side by the extensor carpi radialis longior. This muscle, like most we have described in the fore-arm, swells out towards the centre, where, gradually becoming tendinous, it again diminishes in size. It passes the same groove in the radius as the extensor carpi radialis longior, and terminates by an insertion into the metacarpal bone of the middle finger. The under surface of this muscle is tendinous at the upper part of the arm, which permits it to play without friction upon the smooth and tendinous face of the supinator radii brevis with which it is in contact.

This muscle acts as an extensor of the hand on the fore-arm and an abductor.

b. Deep muscles of the posterior antibrachial region.—The muscles in this region commencing above, are the *supinator radii brevis, the extensor ossis metacarpi pollicis, the extensor primi internodii pollicis, the extensor secundi internodii*, and *the indicator*.

1. *Supinator radii brevis, (epicondylo-radial*, Chauss.) arises tendinous from that portion of the outer and back part of the ulna, unoccupied by the insertion of the anconeus; it arises also from the back part of the outer condyle, covered at its origin from the outer condyle by the extensor communis digitorum and by the extensor carpi radialis brevior. Its posterior and external surface is tendinous, its internal fleshy, and it embraces so much of the upper extremity of the radius, as to form an imperfect tube. Anteriorly we find it partly overlapping the tubercle of that bone, with the tendon of the biceps which is inserted into it. Between these and the under surface of the muscle is a large and distinct bursa mucosa; it covers rather more than the upper third of the radius by its insertion, extending as low down as the pronator radii teres.

This muscle is the main agent in effecting the supination of the hand.

2. *Extensor ossis metacarpi pollicis, (abductor longus pollicis manus*, Sœmm. *cubito-radi sus-metacarpien*, Dumas,) arises from the ulna, interosseous ligament, and the back part of the radius, opposite the insertion of the pronator radii teres, having to its outer side the supi-

nator radii brevis, to its inner the extensor primi internodii pollicis. It is covered posteriorly by the extensor communis digitorum and extensor carpi ulnaris. Gliding downwards and outwards from beneath these muscles and becoming tendinous on its under surface, it slips over the lower third of the posterior face of the radius, and then running in a groove on the outer side of that bone, common to it and the next mentioned muscle, is ultimately inserted into the metacarpal bone of the thumb.

The action of this muscle is to extend the metacarpal bone of the thumb, which corresponds as regards its capacity for motion, with the phalanges of the fingers.

3. *Extensor primi internodii (extensor minor pollicis manus*, Sœmm.; *cubito sus-phalangettien du pouce*, Chauss.) is a very small muscle compared with the last, though varying much in size in different subjects. It lies between the extensor ossis metacarpi pollicis and the extensor secundi internodii, passing through the same groove in the radius as the extensor ossis metacarpi pollicis, it becomes inserted into the first phalanx of the thumb.

4. *The extensor secundi internodii pollicis (extensor major pollicis manus*, Sœmm.; *cubito sus-phalangettien du pouce*, Chauss.)—This muscle is usually larger than the former; it arises fleshy from the ulna and interosseous ligament; becoming tendinous in its centre, it presents the same penniform appearance referred to above. The groove in the radius which is narrow and deep, this tendon alone being lodged in it. It is situated between that for the two radial extensors and the broad and hollow one for the common extensors and indicator. Crossing on the back of the wrist the radial extensors it is finally inserted into the second phalanx of the thumb. This muscle is entirely covered in the fore-arm by the common extensors of the fingers.

5. *The indicator (cubito sus-phalangettien de l'index)* occupies the remaining portion of the posterior interosseal space. Like the three last described muscles it is penniform, and arises fleshy from the ulna and interosseous ligament, it descends to the hand and passes through the same groove at the back of the radius as that of the extensor communis digitorum, it is inserted into the posterior surface of the three phalanges of the index finger. This muscle is entirely concealed by the extensor carpi ulnaris and extensor communis digitorum.

The names of this and the two preceding muscles indicate their actions.

For BIBLIOGRAPHY, see ANATOMY, (INTRODUCTION.)

(*Samuel Solly.*)

FOURTH PAIR OF NERVES (*nervus trochlearis*, s. *patheticus*).—The fourth pair is the most slender of the encephalic nerves. They are intermediate in the order of succession to the third or motor oculi and the fifth nerves, and hence the name. Each nerve is attached at its encephalic extremity to the lateral part of the superior surface of the anterior medullary velum or valve of Vieussens, immediately behind the testes or the posterior of the tubercula quadrigemina. It is divided at its attachment, for the most part, into two roots, inserted at a little distance from each other, one close to the testes, the other posterior to it. Occasionally it has but one root and sometimes even three. Gall and Spurzheim* are of opinion that the nerve might be traced to a more remote point, and according to Mayo† "its fibrils appear to pass through the filaments of the pillar of the valve, and in part to arise from the back part of the medulla oblongata."

The nerve is concealed at its insertion by the superior vermiform process of the cerebellum, and it is not immediately provided with neurilemma, and hence, as also because of its delicacy, it is very easily broken off.

Its course within the cranium is circuitous and long, longer than that of the other nerves. It passes outward, downward, and forward: it first descends external to the superior peduncle of the cerebellum (the processus a cerebello ad testes), between it and the vermiform process, then becomes invested with arachnoid membrane and free, and runs round the lateral part of the crus cerebri, above the superior margin of the pons Varolii, and beneath the free edge of the tentorium cerebelli, until it reaches the posterior clinoid process of the sphenoid bone; it then enters the outer wall of the cavernous sinus between the points of attachment of the tentorium, and is transmitted through a canal in the dura mater, by which the wall is formed, forward to the foramen lacerum of the orbit. It does not enter the sinus, being contained in a canal in its outer wall.

At the posterior part of the sinus the nerve is situate beneath the third, between it and the first division of the fifth nerve; but at the anterior, and as they are about to pass into the orbit, the fourth and frontal branch of the fifth are both above the third, the fourth internal and a little superior to the frontal.

The nerve lastly enters the orbit through the superior part of the foramen lacerum in company with the frontal, above the levator palpebræ muscle, and immediately beneath the roof of the region. Having entered, it runs forward and inward, gains the surface of the superior oblique muscle, and attaching itself to it upon its superior aspect, about its middle, it divides into filaments, which are all distributed to the muscle.

The fourth nerve does not give off any branch during its course to the oblique muscle, unless, at times, first a filament described by Cruveilhier, and, according to him, distributed to the tentorium cerebelli. This filament arises from the nerve while traversing the wall of the cavernous sinus, runs backward into the substance of the tentorium, and divides into two or three branches: Cruveilhier calls it "the branch of the tentorium." Secondly, according to both Swan and Cruveilhier, the fourth nerve gives off a fila-

* Anatomie du Systeme nerveux.

† Physiology.

ment to the lachrymal branch of the fifth. Before its entrance into the orbit the nerve receives a filament from the sympathetic,* and at or immediately after entering, it receives one also from the frontal branch of the fifth, by the accession of which it is sensibly increased in size. It is very closely connected to the frontal itself at the back of the orbit.

Upon the fourth nerve the power of the superior oblique muscle is considered to depend. It is remarkable that this muscle should be provided with an especial nerve, differing, apparently, so much in its encephalic relations from those by which the others are supplied; but the theories which have been advanced upon the subject are as yet so unsubstantial, that we think it better to leave them untouched. (See Orbit, muscles of the).

The nerve exists with similar relations in all the vertebrata.

For the Bibliography, see Nerve.

(B. Alcock.)

GANGLION, (Gr. γαγγλιον; Germ. *Nerven Knoten.*)—This term is applied to several distinct structures: to the nodules placed on certain nerves, to the lymphatic glands or ganglions, to certain bodies, as the thyroid, the thymus, &c., which have been called by some anatomists vascular ganglions, and lastly, in surgical language, to the enlargement of the synovial bursæ. It is, however, most generally applied to the ganglions of the nerves; but of late years many anatomists, who conceive that the various masses of grey matter met with in the encephalon and spinal chord are, together with the ganglia of the nerves, sources of nervous power, have extended to those masses the general term of ganglion. Although there can be no doubt that the analogy has a real foundation, and that this application of the word is both convenient and correct, it is nevertheless proposed, in obedience to custom, to retain the old and more limited sense of the term ganglion, and to devote the present article to the structure of the ganglions of the spinal and sympathetic nerves, referring the reader for an account of the functions of these bodies to the articles Nervous System and Sympathetic Nerve.

The nervous ganglions consist of a number of oval or roundish organs connected with certain nerves, and placed deeply in the trunk of the body, to which they are confined, being situated, with the exception of those of the head, in the immediate vicinity of the vertebral column. Their number and size are subject to variation, not only in different persons, but even on the two sides of the same individual; the following is the enumeration which approaches nearest to the truth: thirty on each side of the body, placed on the posterior roots of the spinal nerves; one on each side, situated on the larger origin of the fifth pair; the ganglions of the great sympathetic consisting of the following, connected on each side of the body with what is regarded as the trunk of this nerve, viz. three cervical, twelve dorsal, three to four or five lumbar, three to five sacral; to these we must add some large masses placed near the mesial plane, viz. two semilunar, three or four cœliac ganglions, and one cardiac ganglion, first described by Wrisberg, but which is occasionally deficient; and lastly, forming a part of the great sympathetic, the ophthalmic, the spheno-palatine, the otic, and the submaxillary ganglions, and a small body usually met with in the cavernous sinus, the cavernous ganglion. M. Hip. Cloquet has described in rather vague terms a small reddish mass placed in the anterior palatine canal, which he calls the *naso-palatine* ganglion; but Arnold, Cruveilhier, and others deny, and with good reason, the existence of this body. A gangliform enlargement is constantly seen on the commencement of the nervus vagus, and a second lower down; a similar swelling is also placed on the glosso-pharyngeal nerve (g. petrosum).

Professor Müller of Berlin has discovered above this enlargement a *true ganglion on the the glosso-pharyngeal* (ganglion jugulare nervi glosso-pharyngei), occupying half or two-thirds of the trunk of the nerve, and being precisely to that nerve what the intervertebral ganglion and the Gasserian are to the spinal nerves and the fifth pair. My colleague Mr. Walker has shown me this ganglion, which is placed in the upper part of the foramen lacerum basis cranii posterius, and corresponds to the above description.*

Arnold has further noticed that at the junction of the superior twig of the Vidian nerve, or nervus innominatus, with the facial nerve, there is a gangliform swelling.†

Mayer has discovered a minute posterior root of the sublingual nerve, with a ganglion on it, in some mammalia (ox, dog, pig), and *in one instance in man.*

Thus the total number of ganglions in the human body amounts to about one hundred and twenty-seven, exclusive of the gangliform enlargements on the pneumo-gastric, glosso-pharyngeal, and the facial nerves.

These bodies have been variously arranged by writers on this subject; thus by Weber‡ they are divided into ganglions of reinforcement, such as those on the spinal nerves, and into ganglions of origin, of which those of the sympathetic, the ophthalmic, and the spheno-palatine are examples; whilst Wutzer,§ classing them according to their situation and relations, considers that there are three orders, 1. the cerebral; 2. the spinal; 3. the vegetative: the first comprises the Gasserian ganglion, the ophthalmic, and the ganglion of Meckel, to which must be added the otic ganglion of Ar-

* See Pauli in Müller's Archiv. for 1834.

* This very interesting discovery confirms the opinion that the glosso-pharyngeal is, like the spinal and the fifth, a compound nerve of motion and sensation. See Medizinische Vereins-Zeitung, Berlin, 1833.

† Icones Nerv. Corp. p. 2. tab. ii. and vii.

‡ Anat. Compar. nervi sympath.

§ De corp. hum. ganglior. fabrica atque usu, p. 52.

nold; in the second order are enumerated the thirty spinal ganglions and the ganglionic enlargement of the nervus vagus and glosso-pharyngeus; in the third division are included the ganglions of the sympathetic nerve.

The former of these arrangements is objectionable, because offices are assigned to the ganglions the existence of which has not been ascertained; and the latter is so far erroneous that in this classification the ganglion of the fifth pair is separated from the spinal, to which it is undoubtedly similar; whilst the ophthalmic and spheno-palatine are as incorrectly divided from the system of the sympathetic.*

In endeavouring to detect that which constitutes the essential difference among these numerous bodies, we ought to pay special attention to the character of the nerves which are attached to the ganglions. Taking this as the only rational guide, I should refer them to two classes. 1. Those which are placed on sentient nerves, comprising the Gasserian, the ganglion of the glosso-pharyngeus, and the spinal ganglions The gangliform enlargement of the nervus vagus should be referred to this order, inasmuch as there can be little doubt, although this at present is not proved, that this nerve is compounded, like the spinal nerves, of motor and sentient fibrils, a surmise supported by the distribution of the vagus, and still more by the interesting discovery of my friend Mr. Solly, of the existence of certain motor fibrils in the exact part of the medulla oblongata, whence this nerve arises.†

2. Those which have connected with them both motor and sentient nerves, and are, as I believe, always in relation with contractile and sensitive structures:‡ those, namely, of the great sympathetic nerve, comprising the cervical, the dorsal, lumbar, and sacral, together with the cardiac, the semilunar and cœliac, also the ophthalmic, the spheno-palatine, the otic, submaxillary, and cavernous.

These classes nearly correspond with the *simple* and *compound* ganglions of Scarpa* and Meckel.†

There are occasionally found ganglia on other nerves; thus, Mr. Swan‡ has noticed one on the posterior spinal nerve, where it is placed under the extensor tendons of the wrist. My friend Mr. Pilcher has also found in two subjects a gangliform enlargement on the internal nasal nerve, where it is lodged on the æthmoidal bone.

It is necessary to remark that although the ganglia of the first class are placed on certain of those nerves which are commonly regarded as being subordinate simply to sensation, yet the highly important observations of Dr. M. Hall,§ which have, I conceive, opened an entirely new field in physiology, render it doubtful that those bodies are essential to the exercise of sensation.

Organization.—Although the cerebro-spinal and sympathetic ganglia present some important peculiarities when contrasted with each other, particularly as regards the proportions of the grey and fibrous substances, still as both classes possess essentially the same structure, they may with propriety be considered in a collective manner.

Every ganglion contains two totally distinct substances which have a close relation to, and are, I believe, identical with the grey and fibrous matters, constituting the encephalon and other parts of the nervous system. It is true that the appearance of these bodies is in many respects dissimilar to that of the brain; but at length it is universally admitted that differences in mere physical properties are unimportant, and do not constitute any test as to the essential structure of an organ. In the present instance the diversity may very readily be understood when the difference of situation is considered. The cerebral organ is enclosed in a cavity, the cranium, formed of some of the strongest bones of the skeleton, and hence, being effectually defended from the effects of motion and external pressure, all its parts are soft and delicate; whilst the ganglia, placed on bones which move on each other, slightly it is true, are exposed to external compression, and consequently a much firmer texture is required. It is for this reason that these bodies are invested in a dense fibrous capsule, which is to them what the cranium is to the encephalon, and which furnishes in addition a number of internal processes surrounding each fibril, and sustaining the spherical masses of grey matter. The difficulty of detecting the intimate texture is by these means greatly increased; but as it is so similar to that of the cerebrum, it is desirable to examine the constituent parts according to the order observed in investigating that organ.

I. *Reddish grey matter.*—The quantity of this substance, often called the peculiar matter of the ganglions, but which, as I have stated,

* The following is the classification of Müller: 1. Ganglia of the posterior roots of the spinal nerves, of the larger portion of the nervus trigeminus, of the nervus vagus, and ganglion jugulare nervi glosso-pharyngei. 2. Ganglia of the great sympathetic. 3. Ganglia which occur at the points of junction of the cerebro-spinal nerves with the branches of the sympathetic, comprising ganglion petrosum nervi glosso-pharyngei, intumescentia gangliformis nervi facialis, ganglion spheno-palatinum, ciliare, oticum (probably). To which should be added ganglion submaxillare. Handbuch der Physiol. der Menschen. Erster Band. p. 588.

† According to the present opinion, the whole of the fibres belonging to the nervus vagus enter into the ganglion; and Bischoff imagines that this nerve derives its motor portion from the spinal accessory. The intimate relations between these two nerves require further investigation.

‡ It cannot be too often repeated that sensibility, or, to speak more correctly, the capability of being excited by the contact of a physical agent, may exist without being accompanied with consciousness: the inner surface of the heart, of the blood-vessels, and intestine are as capable of being excited as the skin or the retina; but the impressions which they receive are not *usually* perceived by the mind.

* Anat. Annotat. liber primus. De nerv. gang. et plex. p. 9.

† Man. d'Anat. t. i. p. 231.

‡ On the Nerves, pl. xxii. fig. 3.

§ Lect. on the Nerv. Sys. 1836.

is possessed by those bodies in common with the brain and spinal chord, is very considerable, constituting apparently the largest, and certainly the most essential part of the ganglion. It is so intimately connected with the fibres that these latter appear as if they were incrusted, being surrounded in every direction by this greyish matter; but although this intimate intermixture is very evident, no fibrils can be perceived actually terminating in or arising from the grey matter. A section of one of the sympathetic ganglia, the first cervical for example, displays this incrustation of the fibres and the interposition between them of rounded masses of the grey matter; but the Gasserian is in many respects the most favourable for examination.

Much difference of opinion exists concerning the true nature of this substance. Scarpa contends that it is not analogous with the grey matter of the brain, but that it consists of a flocculent tissue loaded with a mucilaginous fluid, which becomes oily in obesity, and watery and abundant in anasarca. The accumulation of fat in the true ganglionic tissue has, however, been denied by Béclard, Wutzer, and others. According to Bichat, whose opinions must always command our respect, "the ganglions have a colour very different from that of the nerves. They present a soft spongy tissue, somewhat similar to the lymphatic glands, but which has nothing in common either with the cerebral substance or with that of the nerves." It is stated by Lobstein, who has published one of the latest and most minute accounts of the structure and diseases of the sympathetic nerve,* that he has observed lying contiguous to the white and filamentous tissue another substance presenting a flocculent appearance, with globules interspersed *(materies vel substantia orbicularis tomentosa)*, and which he regards as the second material of the ganglia.

Fig. 170.

Semilunar ganglion, twice the natural size.

a, a, Fasciculi of splanchnic nerve.
b, b, Fibres running through the ganglion.
c, c, Branches collected from the former, and emerging.
d, d, Flocculent or orbicular substance placed between and applied to fibres.
e, e, Foramina perforating the ganglion.

This juicy or gelatinous substance, which is met with in the spinal as well as in the sympathetic ganglia, does not, however, according to Lobstein, appear to be an essential part of the organization, as it varies in its proportion in different ganglia, and may even be absent; nor, it is said, can it be assimilated with the grey matter of the brain.

Ehrenberg also controverts the opinion that the ganglia resemble the grey part of the brain; but although he has found by microscopical inspection, that these bodies contain an overwhelming proportion of large varicose tubes, similar to those of the fibrous portion of the brain, yet he has also shewn that they possess *minute varicose fibres like those of the grey substance;* and what particularly is deserving of notice, he has detected in the muscles of the fibres *granules similar to those which are found in the cervical portion of the brain.*†

* De Nervi Sympath. Humani, fabrica, usu, et morbis, p. 66.

† Structur des Seelenorgans bei Menschen und Thieren, Berlin, 1836, p. 31.

Notwithstanding these and other high authorities, the researches of many recent writers, which have thrown so much new and valuable light on the mutual relations of the component parts of the nervous system, leave little room for doubting the identity of these two substances. The analogy of the whole nervous system tends to prove that this peculiar matter is nothing else than the grey substance; in the Gasserian ganglion, indeed, the resemblance is so striking that no doubt of their identity can be entertained. This view of the subject was taken by Winslow, Johnstone, and others; and lately the existence of grey matter has been admitted by Dr. Fletcher, an assumption, indeed, which is the basis of his hypothesis, that the ganglionic system of nerves is the immediate seat of irritability.*

II. *Fibres.*—This is a most important branch of the present inquiry, because a knowledge of the connexions of these bodies with the other parts of the nervous system and with each other, as well as of the internal disposition of their fibres, is indispensable to the investigation of their functions. The subject may be resolved into two questions. *a. What is the arrangement of the fibres in the ganglia? b. What is the nature of the fibres which are connected with the ganglia?*

a. The internal disposition of the nervous filaments, owing to the very intimate relations subsisting between them and the grey matter, is difficult to determine; and hence it has happened that great difference of opinion prevails on this point. I shall in the first place describe the arrangement in the most simple of these organs, and for that purpose shall select that of the portio major of the fifth pair. On inspection it is seen that the large coarse fibrils of the nerve on approaching the ganglion begin to spread out from each other, and although in its interior they are, as we have already observed, encrusted by the grey matter, yet, on scraping this away, the fibres may be seen still passing on uninterruptedly, but becoming more and more separated from each other. It is this disposition which Scarpa has aptly enough compared to a rope the two ends of which remain twisted, whilst in the middle the component threads are unfolded and pulled asunder. A similar, but less distinct arrangement exists in the spinal ganglia.

Although the continuity of the fibres through the ganglion is easily demonstrated, yet it would be wrong to conclude that this passage is all that happens; for in the first place the three branches of the trigeminal nerve which emerge from, are decidedly larger than the trunk of the same nerve which passes into the ganglion. Their physical qualities are also altered, especially as relates to their colour, which, instead of having the whitish aspect common to the proper fibres of the cerebro-spinal axis, is for some distance of the reddish hue proper to the ganglionic system; and again it would be in opposition to all our notions of the properties of the grey matter to imagine that the fibres do not maintain intimate connexions with that substance, by which means its influence, whatever it may be, is communicated to those threads.

In the sympathetic ganglions the internal formation is much more intricate; and it is especially in reference to these bodies that so much diversity of opinion prevails among anatomists. The researches of Monro,* Scarpa,† and Lobstein,‡ as well as ocular inspection, prove that *some* fibres undoubtedly pass without interruption through the ganglion.

On making a section of the first cervical ganglion, previously hardened by alcohol, fibres will be perceived, which, although separated from each other by irregular interstices filled with grey matter, are still continued uninterruptedly from one to the other extremity. There are, however, besides these, other fibres, which are so complex that it is almost impossible to demonstrate their exact disposition. I believe, however, that, independently of those fibrils which run through the ganglion, there are some which terminate in, and others which arise from the grey matter in its interior.

Fig. 171.

Superior cervical ganglion of the great intercostal nerve of the right side.

a, Trunk of the great intercostal nerve a little below the foramen caroticum. *b*, Trunk of the nerve below the superior cervical ganglion. c, *c*, c, c, The branches which from the three superior cervico-spinal nerves run to join the superior cervical ganglion of the great intercostal nerve. *d*, *d*, *d*, Nerves issuing from the superior cervical ganglion. *e*, Nervous fibriform stratum of the ganglion. *f*, Reticulated plexus produced by the mingling of the nervous fibres. *g*, Reticulated or plexiform nervous filaments. *h*, Nervous filaments variously mingled with others connected with the neighbouring cerebral and spinal nerves. *i*, The nervous filaments of which the trunk of the intercostal nerve below the superior cervical ganglion is composed.

* Rudiments of Physiol. st. ii. a. p. 87.

* Obs. on Nerv. Sys. p. 54.
† L. c. p. 14, Tab. 1. fig. 1, 2, 3, 4.
‡ L. c. Tab. tertia.

b. What is the nature of the fibres which are connected with the ganglia? The very interesting inquiries of Brown, Darwall, Teale, Stanley, and others into the nature of those frequent affections now generally known under the term of neuralgic diseases, by which a new and unexpected light has been thrown on a most obscure branch of pathology, render this part of the present investigation of pre-eminent importance. The mutual influence exerted by the cerebro-spinal axis and the great sympathetic on each other, in consequence of which disease of the brain and spinal chord may cause morbid actions and conditions of the organs of digestion, circulation, and secretion, and vice versa, can only be experienced by a reference to the relations which exist between these two great divisions of the nervous system. Unfortunately, however, this question, so important both as regards physiology and pathology, is not easily resolved on account of the difficulty in the present state of our knowledge of distinguishing from each other the different species of fibres which enter into these organs. I shall in the first place speak of the fibres which are perceptible to the naked eye, and afterwards point out the information that has been afforded by microscopical examination.

The intervertebral ganglia (and these observations may be applied to those of the fifth pair, of the glosso-pharyngeal, and of the pneumo-gastric) receive fibres only from the posterior roots of the spinal nerves, which, since the researches of Bell, Magendie, and Mayo, have been regarded as being subordinate to sensation. But if the important principles announced by Dr. M. Hall be susceptible, as I believe they are, of that confirmation from anatomical examination of which at present they stand in need, then to the true sensiferous fibrils which enter these ganglia we must add what are called by Dr. Hall *incident* filaments. It is also a question which yet remains to be decided, whether the twigs that are known to run between the posterior roots of the spinal nerves and the sympathetic ganglions pass in reality from the former to the latter or from the latter to the former; if, as appears most probable, these threads are furnished by the sympathetic, then it is to be presumed they are subsequently continued to the intervertebral ganglions.

With respect to the sympathetic ganglions, the following are the only facts that are at this time established.

1. There are longitudinal commissural filaments by which the ganglia are joined to each other, and by which they are formed, however remote they may be from one another, into one great and extensive system.

2. There are fibrils which extend between the motiferous part of the cerebro-spinal axis and the sympathetic, but whether they are derived from the former or the latter is not decided.

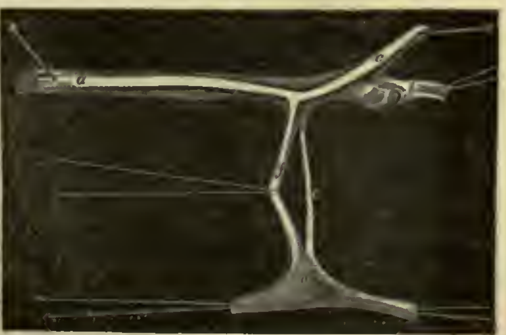
3. There are sentient fibrils observing a similar disposition.

As the anatomical facts by which these facts are established will be found under the head Sympathetic Nerve, only a few remarks are required in this place.

1. With respect to the longitudinal commissural fibres, they are as necessary here as in other parts of the nervous system; and although Bichat speaks of this connexion of the ganglions being occasionally absent, such deficiencies are extremely rare, and if they do really exist, must be regarded as an abnormal state. The importance of this connexion is rendered apparent by the union of the several nodules placed on the trunk of the sympathetic, which is so constant that anatomists were for a long time so far misled by it as to compare this gangliated cord with the common nerves of the body; but it is perhaps still more striking in the commissural fibres, which are so invariably noticed passing from the sympathetic to the small ganglia of the head.

2 and 3. In consequence of the motor and sentient nerves of the head usually forming distinct trunks, the ophthalmic ganglion offers a natural analysis, as it were, of the connexion between the great sympathetic and the cerebro-spinal axis. One twig passes between this small body and the nasal nerve of the fifth pair (sentient); a second extends between it and the lower division of the third pair (motor). The dissections of Arnold prove that a similar connexion exists in the spheno-palatine, the otic, and the submaxillary ganglia.* Mayo has also ascertained that the branches placed between the ganglia of the great sympathetic and the compound nerves of the spine are of a twofold character, one set being attached to the sentient and the other to the motor root. The adjoining figure (*fig.* 172), copied from a dissection I made for this purpose, shows the mode of communication in the thorax.

Fig. 172.



a, Anterior root. *c*, Ditto. *b*, Posterior root entering the ganglion. *d*, Sympathetic ganglion. *e*, Filament of communication to posterior root. *f*, Filament of communication to anterior root.

* These connexions are very beautifully represented in his work, Icones Nerv Capit. Tab. 5, 6, 7, and 8. On some points relative to the otic ganglion it has been proved by the dissections of Schlemm that Arnold was in error, especially as relates to the branch supposed to be furnished from the ganglion to the tarsor tympani.

Notwithstanding so many important points have been established, it must be confessed that much remains to be decided. Thus, for example, we perceive that the ganglion of Meckel, like the ganglions of the sympathetic in the neck, has connected with it a motor fibril; but this fibril, as Arnold has observed, presents the whitish character and firm texture common to the cerebro-spinal nerves, and therefore, it must be presumed, passes from the portio dura to the ganglion, whilst the twigs uniting the cervical nerves and the sympathetic are reddish and soft, rendering it probable, as Fletcher supposes, that they are furnished by the ganglia.

Such being the imperfect results of ocular inspection, we are naturally anxious to obtain more exact information, especially in reference to the character of the different orders of fibres which are connected with the ganglia. The microscopical observations which are being carried on at this time with so much zeal in Germany, and from the prosecution of which the most valuable evidence may be anticipated respecting the undecided points of minute anatomy, have already thrown some light on this interesting question. Thus Ehrenberg* has detected in the sympathetic not only the varicose fibres which some imagine are proper to that system, but also some of the cylindrical fibres of which the cerebro-spinal nerves are principally composed. According to Lauth and Remark, the nerves of organic life (i. e. of the sympathetic) consist for the most part of varicose fibres mixed up with a small proportion of cylindrical; whilst those of animal life consist principally of cylindrical mingled with a few varicose fibres. This is the exact appearance which must have been anticipated, if the mutual interchange of fibres described by Bichat,† W. Philip,‡ Mayo,§ Fletcher,‖ and others, really exist.

It may here be remarked that although the accuracy of Ehrenberg's researches, confirmed as they have been by Müller, Purkinje, Valentin and others, is called in question by Krause, Berres, and Treviranus, yet the essential fact of there being a decided difference in the physical character of different orders of nervous fibres, and, consequently, a test for their successful analysis, is universally admitted.¶

Lastly, it is a question of great interest whether there are not, independently of the relations which exist between the sympathetic and the cerebro-spinal axis, fibres proper to the former,

* L. c. p. 31.

† An. Gén. i. p. 220. "The ganglions (of the sympathetic) like the brain *furnish* and *receive* their particular nerves."

‡ On Vital Functions, and Gulstonian Lect.

§ Out. of Phy. 4th edit. p. 259.

‖ Rud. of Phy. part ii. a. p. 76.

¶ Since the above was written I have learnt that the doubts expressed by Treviranus, Arnold, and others, as to the correctness of the views of Ehrenberg, have been confirmed. Professor Müller attributes the appearance of the varicose fibres to artificial causes; and it is said that Ehrenberg himself doubts if such fibres exist in the normal condition.

which establish between them and the organs they supply with nerves most important connexions. Our present knowledge does not afford the means of solving this question; and, although my attention has been particularly directed to this subject, still, as my observations are as yet incomplete, I shall satisfy myself by expressing my conviction that such a system of nervous fibres does exist.

Covering.—Every ganglion possesses two coverings: the outer one in the spinal ganglions is very firm, being derived from the vertebral dura mater, whilst in the sympathetic ganglions it is composed of condensed cellular tissue. On raising very carefully the external capsule, a more delicate tunic is exposed, which adheres to the proper ganglionic tissue.

Bloodvessels.—These bodies, like all other parts of the nervous system, are amply supplied with arterial blood. After a successful injection, two, three, or more arteries, derived from the neighbouring vessels, may be readily observed running to the ganglion. Each vessel, having perforated the coverings of the ganglion, forms according to Wutzer a plexus on the inner surface of the capsule, and at length sends delicate branches into the pulpy matter, which, with the aid of the microscope, may be observed to run in the same direction with the nervous filaments. The exact mode in which these vessels terminate is unknown, but it is probable, as in the cerebro-spinal system, that each nervous fibre is accompanied by a minute artery and vein. No lymphatics have been demonstrated, but analogy tends to prove their existence, and Lobstein states that he has often seen them forming networks around the ganglions.

Chemical composition.—The experiments performed by Bichat* and Wutzer† would tend to show that the substance of the ganglions is distinct in its qualities from the cerebral matter and also from that of the nerves. By boiling, it is at first hardened, but soon becomes softened; maceration in cold water renders it more soft and pulpy, and if sufficiently prolonged, the water being frequently changed, it is converted into adipocire. It is liquefied by the alkalies, and is rendered crisp and hard by the acids and alcohol.

BIBLIOGRAPHY.—*Haase*, De gangliis nervor. *Scarpa*, Anat. Annot. Liber i. de nerv. gang. et plexibus. *Monro*, Obs. on nerv. system. *Soemmering*, De corp. hum. fabric. t. iv. *Bichat*, Anat. gén. *Wutzer*, De corp. hum. ganglior. fabrica atque usu. This work contains an elaborate list of the various authors who have treated of the ganglions, and an epitome of their opinions. *Lobstein*, De nervi sympath. humani, fabrica, usu et morbis. *F. Arnold*, Kopfthiel des Vegetativen nervensystem, beim Menschen. *J. Müller*, Handbuch der Physiol. des Menschen, 1834. *C. J. Ehrenberg*, Structur des Seelenorgans bei Menschen und Thieren, Berlin, 1836; Anat. der Microskopischen Gebilde der Menschlichen Körpers. Wien. 1836.

(R. D. Grainger.)

* Anat. Gén. t. i. p. 226.

† De Corp. Hum. Gang. Fabrica atque Usu, § 55. The reader will find in this work many details relative to the above subject.

GASTEROPODA, (*γαστηρ, venter, πους, pes;* Eng. *Gasteropods;* Fr. *Gastéropodes;* Germ. *Bauchfüsser; Mollusca Repentia,* Poli.)

Definition.—An extensive class of the Molluscous division of the animal kingdom distinguished by the structure and position of their locomotive apparatus, which consists of a muscular disc attached to the ventral surface of the body, serving either as an instrument by means of which the animal can crawl, or in rarer instances compressed into a muscular membrane useful in swimming.

Characters of the class.—*Body* soft, enclosed in a muscular covering, which, from its contractility in every direction, produces great variety in the external form of the animal: the back is covered with a mantle of greater or less extent, which in most of the genera secretes a shell either enclosed within its substance, or, as is more frequently the case, external and sufficiently large to conceal and protect the whole body, in which case it is often provided with an operculum capable of closing its orifice when the animal is lodged within it. The *head* is anterior, distinct, and generally furnished with two, four, or six tentacles, which are placed above the oral aperture, and merely serve as instruments of touch. The *eyes* are two in number, and are placed sometimes on the head itself, but more generally at the base, at the side or at the extremity of the tentacles; they are always very small, and not unfrequently wanting. The muscular disc which is subservient to locomotion is called the *foot*, and is generally broad and fleshy, forming a powerful sucker, but in some instances it takes the shape of a deep furrow, or is compressed into a vertical lamella. The *respiratory apparatus* varies in structure; in some genera it is composed of vascular ramifications which line a cavity into which the respired medium is freely admitted. Others are provided with branchiæ, adapted to the respiration of water, variously disposed upon the exterior of the body, or concealed internally. The *heart* generally consists of an auricle and ventricle, and is systemic, or, in other words, receives the blood from the organs of respiration, and propels it through the body. The *sexual organs* vary in their structure in different orders; in the greater number each individual is possessed both of an ovigerous and impregnating apparatus, but copulation is essential to fecundity: in many the sexes are distinct, and some are hermaphrodite and self-impregnating. Some species are terrestrial and others aquatic.

In separating the Gasteropoda into orders, the naturalist finds in the position and structure of the branchial apparatus a character sufficiently obvious; and as the arrangement of these organs is modified by the circumstances of each individual, and is generally in relation with the peculiarities met with in the internal organization of the animal, the branchiæ are at present universally referred to as affording a convenient basis of classification. We shall in this article follow the arrangement adopted by Ferussac, of which, as well as of the systems of other zoologists, an outline is contained in the following table.

Order I. *NUDIBRANCHIATA,** (Cuv.)
Syn. Polybranchiata,† and genus *Doris,* Blainville; *Gasteropodes Dermobranches,‡* Dumeril; *Gasteropodes Tritoniens,* Lamarck.

In these the branchiæ are symmetrical, assuming a variety of forms, but always placed upon some part of the back, where they are unprotected by any covering; the animals may be provided with a shell or naked, but they are all hermaphrodite with mutual copulation, and marine.

1st Sub-order, *Anthobranchiata,§* Goldfuss; *Cyclobranchiata,‖* Blainville.
1st Fam. *Doris.*
2d Sub-order, *Polybranchiota,* Blainville.
2d Fam. *Tritonia, fig.* 173.
3d Fam. *Glaucus, fig.* 174.

Fig. 173.

Fig. 174.

Order II. *INFEROBRANCHIATA,* (Cuv. and Blain.)
Syn. Gast. Dermobranches, Dumeril; *Gast. Phyllidiens,* Lamarck.

In the Inferobranchiate Gasteropods the branchiæ are arranged under the inferior border of the mantle on both sides of the body, or upon one side only: the mantle sometimes contains a calcareous lamella. All the genera

* *Nudus,* naked; *branchiæ,* gills.
† Πολυς, *many;* branchiæ.
‡ Δερμα, *skin.*
§ Ανθος, *a flower.*
‖ Κυκλος, *a circle.*

are hermaphrodite with reciprocal impregnation, and marine.

1st Sub-order, *Phyllidiadæ*, Cuv.
 1st Fam. *Phyllidia*, *fig.* 175.
2d Sub-order, *Semi-phyllidiadæ*, Lam.
 2d Fam. *Gastroplax*, Blainville.
 3d Fam. *Pleurobranchus*, Cuv.

Fig. 175.

Order III. *TECTIBRANCHIATA*,* (Cuv.)

Syn. Chismobranches, Blainville; *Gast. Adelobranches*,† Dumeril; *Gast. Phyllidiens* and *Laplysiens*, Lamarck.

In this order the branchiæ are placed upon the dorsal aspect of the body, but are protected by a fold of the mantle which almost always contains a shell presenting a rudimentary spire. They are all hermaphrodite like the preceding, and marine.

1st Fam. *Dikera*.
2d Fam. *Akera*.

Order IV. *PULMONALIA INOPERCULATA*, (Ferussac)

Syn. Pulmones, Cuv.;‡ *Pulmobranches*, Blainville; *Gast. Trachelipodes*,§ Lamarck.

The respiratory apparatus is here adapted to the respiration of atmospheric air, and instead of being composed of branchial tufts or laminæ, consists of a cavity lined by the ramifications of the pulmonary vessels, the entrance to which can be opened or closed at the pleasure of the animal. Almost all the species are provided with a shell either turbinated or concealed within the mantle, but are never furnished with a calcareous operculum. Every individual is hermaphrodite, but mutual copulation is essential to fertility. Some are terrestrial, others inhabit fresh water, and some are marine.

1st Sub-order, *Geophilidæ*,* Ferussac.
 1st Fam. *Limax*.
 2d Fam. *Helix*.
2d Sub-order, *Gehydrophilidæ*,† Ferussac.
 3d Fam. *Auricula*.
3d Sub-order, *Hygrophilidæ*,‡ Ferussac.
 4th Fam. *Limnæus*.

Order V. *PULMONALIA OPERCULATA*, (Ferussac.)

Syn. Pectinibranchiata,§ Cuv.; *Siphonibranchiata*,|| Blain.

The respiratory organs of the animals forming this order are similar in structure to those found in the last, but they differ materially in other points. In all the operculated division the shell is closed by a calcareous operculum not found in the last, and instead of that hermaphrodite condition of the sexual organs common to the inoperculated order, the sexes are distinct, the male and female parts existing in different individuals. They are all terrestrial.

1st Fam. *Helicina*.
2d Fam. *Turbicina*.

Order VI. *PECTINIBRANCHIATA*, (Cuv.)

Syn. Trachelipodes, Lamarck; *Monopleuribranches*, Blain.; *Gast. Adelobranches* and *Siphonibranches*, Dumeril.

This extensive order, which comprises most of the univalve mollusks whose shells enrich our cabinets, is characterized by a respiratory apparatus adapted to an aquatic medium. The branchiæ are pectinated, consisting of ranges of fringes disposed like the teeth of a comb, and generally enclosed in a dorsal cavity which opens externally at the side of the body or above the head. The shell is always turbinated, and sometimes provided with an operculum. The sexes are separate, and the animals fluviatile or marine.

1st Sub-order, *Pomastomidæ*,¶ Ferussac; *Chismobranches*, Blainville.
 1st Fam. *Turbo*, Lin.
 2d Fam. *Trochus*, Lin.
2d Sub-order, *Hemipomastomidæ*, Ferussac.
 3d Fam. *Cerithium*, Adanson.
 4th Fam. *Buccinum*, Lin.
 5th Fam. *Murex*, Lin.
 6th Fam. *Strombus*, Lin.
 7th Fam. *Conus*, Lin.
3d Sub-order, *Apomastomidæ*, Ferussac.
 8th Fam.
 9th Fam. *Voluta*, Lin.
 10th Fam.
4th Sub-order, *Adelodermidæ*, Ferussac.
 11th Fam. *Sigaretus*, Adanson.

* *Tectus*, covered.
† Αδηλος, *concealed*.
‡ Pulmo, *lungs*.
§ Τραχηλος, *the neck*; πους, *foot*.

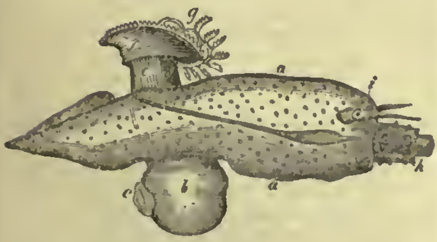
* Γη, *the earth*; φιλεω, *to love*.
† Γη, *the earth*; υδωρ, *the water*; φιλεω.
‡ Υγρος, *moist*; φιλεω.
§ Pecten, -inis, *a comb*.
|| Σιφων, *a canal*.
¶ Πωμα, *operculum*; στομα, *mouth*.

Order VII. *SCUTIBRANCHIATA,** (Cuv.)

Syn. Cervicobranches, Blain.; *Chismobranches,* Blain.; *Gast. Dermobranches,* Dum.; *G. Trachelipodes,* Lam.

Fig. 176.

Fig. 177.



In this order the structure of the branchiæ is analogous to what has been described in the Pectinibranchiata; but the shell, which in the latter was always turbinated, in the Scutibranchiata is a mere shield, in which the indications of a spire are very slight or totally deficient. There is never an operculum. The organs of both sexes are united in every individual, but there is no necessity for copulation, each animal being self-impregnating. The species are all aquatic.

1st Sub-order, *Anthophora.*†

1st Fam. *Haliotis, fig.* 176.

2d Sub-order, *Calyptracidæ,*‡ Lam.

2d Fam. *Capulus.**

3d Sub-order, *Heteropoda*† *Nucleobranches,* Blainville.

3d Fam. *Pterotrachea, fig.* 177.

Order VIII. *CYCLOBRANCHIATA,* (Cuv.)

Syn. Dermobranches, Dum.; *Gast. Phyllidiens,* Lam.; *Gast. Chismobranches,* Blain.

In this order the branchiæ are arranged under the margin of the mantle around the circumference of the body; the shell is a simple shield, either composed of one piece, which is never turbinated, or else made up of several divisions. They are all hermaphrodite and self-impregnating.

1st Sub-order, *Chismobranchiata,* Blain.; *Cyclobranchiata,* Goldfuss.

1st Fam. *Patella.*

2d Sub-order, *Polyplaxiphora,*‡ Blain.

2d Fam. *Oscabrion.*

Cuvier detaches the genera *Vermetus, Magilus,* and *Siliquaria* from the Pectinibranchiata on account of the irregular form of their shell, which is only spiral at its commencement, and is usually firmly attached to some foreign body, a circumstance which involves as a necessary consequence the hermaphrodite type of the sexual organs, so that these genera are self-impregnating. He has, therefore, arranged them in a separate order, to which he applies the name of *Tubulibranchiata.*

Tegumentary system.—The skin which invests the Gasteropoda varies exceedingly in texture, not only in different species but in different parts of the same animal; its structure being modified by a variety of circumstances connected with the habits of the creature, the presence or absence of a calcareous covering, or the mode of respiration. In the naked Gasteropods, especially in the terrestrial species, it is thick and rugose, serving as a protection against the vicissitudes consequent upon the changeable medium which they inhabit. In such as are aquatic the integument is proportionably thinner, and its surface more smooth and even; in both, however, it differs much in texture in different parts of the body; thus in the dermobranchiate species it becomes attenuated into a thin film, where it invests the vascular appendages subservient to respiration, and such portions as cover the organs of sense assume a transparency and delicacy adapted to the sensibility of the parts beneath. In those orders which are provided with shells, the integument which protects such parts of the body as are exposed when the animal partially emerges from its abode, is thick and spongy, and very different from the thin fibrous membrane which invests the mass of viscera contained within the shell. We are led by various circumstances to presume that the skin of all the Gasteropods is in structure essentially analogous to that of higher animals, and in de-

* *Scutum,* a shield.

† Ανθος, *a flower*; φερω, *to carry.*

‡ Καλυπτρα, *a covering.*

* Many of the Capuloid Gasteropods are thought by Cuvier to be diœcious.

† Ετερος, *different*; πους, *foot.*

‡ Πολυς, *many*; πλαξ, *a scale*; φερω, *to carry.*

scribing it we shall avoid obscurity by applying to its different parts the names ordinarily made use of by anatomists to distinguish the tissues enumerated as composing the human integument.

The *dermis* is an extremely lax and cellular texture, eminently elastic, and so intimately blended with the contractile layers beneath it, that it is difficult to recognise it as a distinct structure: its great peculiarity consists in the power which it possesses of secreting calcareous matter, which being deposited either in a cavity within its substance, or as is more frequently the case, upon its outer surface, forms a concealed or external shell: from this circumstance, and from the abundant quantity of mucus which it constantly furnishes, we may infer its great vascularity, while the high degree of sensibility which it evidently possesses unequivocally demonstrates that it is plentifully supplied with nerves, although the existence of a true papillary structure cannot be satisfactorily distinguished. *The colouring pigment* likewise exists, as is evident from the brilliant markings which are often met with in some of the more highly coloured species; but there is a circumstance in connection with this rete mucosum which requires particular mention, as it will enable us afterwards more clearly to explain the formation of shells; the pigment is not merely a layer which serves to paint the surface of the body generally, but appears rather to be an infiltration of the lax tissue of the cutis with coloured fluid, which is poured out in great abundance at particular points, especially around the margin of the shell, and there being mixed up with the calcareous matter secreted by the collar, its tints are transferred to the exterior of the shell itself, tinging it with similar hues. *The epidermis* is evidently deficient, its place being supplied by the viscid matter with which the surface of the body is continually lubricated. The muciparous crypts destined to furnish the copious supply of glairy fluid with which the skin is so largely moistened, have not been detected, but the pores through which it exudes are sufficiently distinct. It is in connexion with the needful diffusion of this secretion over the entire animal, that the skin of the terrestrial species, as the Slugs and Snails, is observed to be deeply furrowed by large anastomosing channels, formed by the rugæ of the surface, and serving as canals for its conveyance by a species of irrigation to every point. No pilous system, properly so called, exists in any of the Gasteropods, the hairy covering of many shells being, as we shall presently see, of a widely different nature.

From the modifications observable in the structure of the integument, it is not to be wondered at that names have been applied to different portions, which it will be useful to notice, especially as they are not unfrequently used in a confused and unprecise manner. That portion of the skin which is more immediately connected with the secretion of the shell, in such Gasteropoda as are provided with a defence of that description, has been termed the *mantle*, and in certain instances, from the mode in which it seems to form a special covering to a part of the body, it has some claim to the name; the mantle is, however, extremely variable, both in position and arrangement. In the Nudibranchiata, which have no shell, it cannot be said to exist, as no fold of the integument or defined margin indicating a portion deserving of a distinct appellation can be detected. In the *Tectibranchiata* the mantle is a small triangular fold of the integument on the right side of the body, inclosing a rudimentary shell, and serving as a covering to the subjacent branchiæ. In the Inferobranchiata it invests the whole of the back, and forms a fold around the margins of the body, beneath which the branchiæ are found; whilst in all the conchiferous Gasteropods it lines the interior of the shell, whatever its shape, forming a distinct fold or thickened rim around its aperture, to which when much developed, as in Helix, the name of *collar* is not improperly applied.

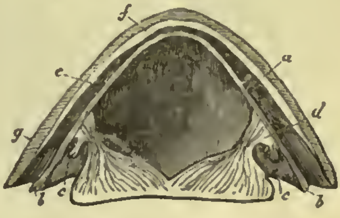
In the naked terrestrial species the mantle consists of a thickened portion, occupying a variable position on the back, and more or less defined by a distinct margin; it is here not unfrequently termed the corselet, and generally contains a calcareous plate. In *Vaginula* it covers the whole of the back; in *Limax* it occupies only its anterior portion; in Parmacella it is found in the middle of the dorsal region, whilst in Testacella it is placed quite posteriorly in the vicinity of the tail; yet whatever its situation, shape, or size, it is the immediate agent in the formation of the shell, and as such we have deemed it necessary to be thus precise in describing the different aspects which it assumes.

Growth of shell.—The varied and beautiful shells that form so important a part of the integument of many individuals belonging to this order, however they may differ in external form and apparent complication, are essentially similar in composition and in the manner of their growth. These calcareous defences, although serving in many cases as a support to the animal, from which important muscles take their origin, differ widely from the internal skeletons of vertebrate animals, being mere excretions from the surface of the body, absolutely extra-vital and extra-vascular, their growth being entirely carried on by the addition of calcareous particles deposited in consecutive layers. The dermis or vascular portion of the integument is the secreting organ which furnishes the earthy matter, pouring it out apparently from any part of the surface of the body, although the thicker portion, distinguished by the appellation of the mantle, is more especially adapted to its production. The calcareous matter is never deposited in the areolæ of the dermis itself, but exudes from the surface, suspended in the mucus which is so copiously poured out from the muciparous pores, and gradually hardening by exposure; this calciferous fluid forms a layer of shell, coating the inner surface of the pre-existent layers to increase the size of the original shell, or else is furnished at particular points for the reparation of injuries which accident may have occasioned. It is to the investigations of Reaumur that we are indebted for our knowledge concerning this interesting process, and subsequent writers have added little to the information derived from his researches; in order, however, to lay before the reader the principal facts connected with this subject, we shall commence with the simplest forms of the process, and gradually advance towards such as are more complicated and less easily understood.

The shells of the Gasteropoda are of two kinds, some being entirely concealed within the substance of the mantle, and consequently internal, whilst others are placed upon the surface of the body external to the soft integument. In the former case the shell is uniform in texture and colourless; in the latter, its developement is much more elaborate, and it is not unfrequently moulded into a great diversity of forms, and painted with various tints, which are sometimes of great brilliancy. The internal or dermic shells are found in many of the *pulmonary* and *tectibranchiate* orders, and possess but little solidity; although inclosed in the substance of the mantle, they are so little adherent, that when exposed by an incision they readily fall out of the cavity in which they are lodged, and from which they are apparently quite detached. Their substance is generally calcareous, but in many instances, as in *Aplysia*, the shell is of a horny texture, being transparent, flexible, and elastic, as is the gladius of many of the Cephalopod Mollusca. In all cases horny or calcareous plates of this description are found to be composed of superposed lamellæ, which are successively secreted by the floor of the cavity in which they are contained, the inferior layer being always the largest and most recent. These shells, therefore, may be considered as merely formed by the deposition of successive coats of varnish, which become indurated, and the simple manner of their growth will best exemplify the mode in which more complicated shells, whatever be their form, are constructed. External shells present an endless diversity of figure, and some classification of their principal forms will facilitate our contemplation of the peculiarity observable in each. The concealed shells, which are merely the rudiments of what we are now considering, are so small in comparison with the size of the body, that they can only be looked upon as serving for the protection of the more important organs, namely, the heart and respiratory apparatus, which are placed beneath them, but the external shells, from their great developement, are not merely a partial protection to the animal, but in most cases constitute an abode into which the creature can retract its whole body. The external shell consists generally of one piece, the form of which may be symmetrical, in which case it is a cone or disc simply covering the back of the animal; or, as is generally the case, the shell may be more or less twisted around a central axis, forming a convoluted, turbinated, or spirivalve shell. In one genus only, *Chiton*, Lin., the shell is formed of several pieces articulated with each other, and covering the surface of the back.

The shell of the Patella, a section of which is represented in *fig.* 178, is a simple cone placed upon the back of the creature, which it completely covers, and upon which it is evidently moulded. On making a section of the animal, as in the figure, the shell is found to be entirely lined by the mantle *a*, *b*, by which it is secreted.

Fig. 178.

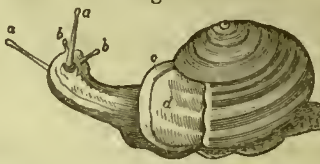


That the whole surface of the mantle is capable of secreting the calcifying fluid from which the shell is formed, is distinctly proved by the manner in which a fracture or perforation in any part is speedily repaired by the deposition of a patch of calcareous matter beneath it, but in the ordinary growth of the animal the different portions of the mantle execute different functions. It is obvious that the enlargement of the body of the patella, as its age increases, must necessitate a corresponding enlargement of its habitation, and this is principally effected by additions of calcareous matter in successively larger rings around the mouth of the shell only; the great agent therefore in forming the shell is the margin of the mantle, *b*, *b*. This hangs loosely as a fringe near the mouth of the shell, and being moveable at the will of the animal, the calcareous matter which it pre-eminently furnishes may be laid on in successive layers to extend the mouth of its abode; and these consecutive additions are indicated externally by concentric lines running parallel with the circumference of the shell, the number of which necessarily increases with age. Whilst the abode of the creature is thus enlarged by the deposition of shell from the vascular and spongy margins of the mantle, the office of the rest of that membrane is reduced to the increase of its thickness, depositing successive coatings of calcareous particles, which are laid on to its inner surface, and when a section of the shell is made *(f)*, these last-formed strata are readily distinguishable by their whiteness and different arrangement. So far the production of an external shell is entirely similar to what we have met with in the formation of the internal defences of the naked Gasteropoda, yet in other respects the former are much more elaborately organised. In the first place many of them are adorned externally with colours, not unfrequently arranged with great regularity and beauty; these tints belong exclusively to the outer layers of the shell, that is, to those formed by the margins of the mantle, and are produced by a glandular structure appropriated to the secretion of the colouring matter, which only exists in the vascular circumference of the calciferous membrane. The colouring matter becomes thus incorporated at definite points, with the cement by which the shell is extended, and is arranged in various manners according to the position of the secreting organs which furnish it. Another peculiarity which distinguishes external shells is that their outer surface is often invested with a membranous layer, called the epidermis, which having been regarded by some authors as a part of the true integument of the body, has given rise to the supposition that all shells being placed between two layers of the skin were in fact internal, the difference between the one and the other consisting merely in the extent of development. In support of this opinion reference has been made to the great thickness of this epidermic coat, which not unfrequently is such as to give to the surface of the shell a felted or pilous appearance; but if such an idea were correct, it is evident that the epidermis must be formed prior to the deposit of calcareous matter beneath it, which observation has disproved, inasmuch as those shells in which the epidermic covering is most dense and shaggy are found whilst in ovo to be without such an investment. The so-called epidermis, therefore, whatever may be the aspect which it presents, whether it be, as is usually the case, a brittle lamella encrusting the shell, or a flocculent and pilous covering, is evidently inorganic, being merely a crust of inspissated mucus, originally secreted with the calcareous particles, and forming when dry a layer encrusting the surface of the shell.

There is yet another structure common to shells of this class, of which it remains to speak, namely, the enamel or pearl, which lines such portions of them as are immediately in contact with the body of the animal; this polished material may be likened to the glazing of an earthenware vessel, and is a varnish produced from the general surface of the mantle, by some modification of its secretion the nature of which is unknown, and spread in successive coatings over the more coarse calcareous matter, wherever such a polish becomes needful.

Having thus briefly described the origin of the different parts of a shell in the simple form which we have chosen as an example, we shall now proceed to examine the structure and mode of growth in others of a more complicated aspect. The majority of the Gasteropoda are furnished with a shell which has been denominated spirivalve. Let the reader imagine the shell of the Patella to be lengthened into a long cone, which, instead of preserving its symmetrical form, is twisted around a central axis, and he will immediately understand the general arrangement of the parts in shells of this description. The cause of such an arrangement is owing to the shape of the body of the animal inhabiting the shell, which, as it grows, principally enlarges its shell in one direction, thus of course making it form a spire modified in shape according to the degree in which each successive turn surpasses in bulk that which preceded it. The axis around which the spire revolves is called the *columella*, and the mode of revolution around this centre gives rise to endless diversity in the external form. In the spirivalve-shelled Gasteropoda, as in those last described, we find a difference in structure between that part of the mantle which envelopes the viscera, and is always concealed within the cavity of the shell, and the more vascular portion placed around its aperture: the former is thin and membranous, its office being merely that of thickening the shell by the deposition of successive calcareous strata applied to its inner side, and of producing the pearly lining which smooths and polishes the interior; the latter part of the mantle is thick, spongy, and coloured, secreting largely the calcareous particles with which the progressive amplification of the shell is effected: this portion (*fig.* 179, *c*,) from its thickness, and the

Fig. 179.



manner in which it usually surrounds the entrance to the shell, is generally termed the collar. In such species as inhabit coloured shells we may observe upon the surface of the collar (*fig.* 179, *d*,) patches of different colours corresponding in tint with the various hues seen upon the exterior. These spots supply the pigment, which being mixed up with the earthy cement serving for the enlargement of the shell stains it with a corresponding tint. In many instances, as in the figure, the colours are continually secreted by the dark spaces, *d*, causing the painted bands which they produce to wind uninterruptedly in the direction of the convolutions of the spire, and they may be seen gradually to increase in breadth as the size of the animal enlarges: but more frequently it happens that the colouring matter is only furnished at stated periods, and in such cases of course the shell will be marked with spots, the intervals between which will be regulated by the frequency of the supply. It will be seen that by a combination of these circumstances it is easy to explain how every variety of marking may be produced.

The most conspicuous exception to the general process by which shells are painted, is met with in the porcellaneous Couries (*Cypræa*), which at various periods of their growth could scarcely be recognised as belonging to the same genus. In the young animal the enlargement of the shell is effected in the ordinary manner, and its colours are supplied from the surface of the collar: in the mature state, however, these shells are coloured in a very different manner, and acquire at the same time a great increase of thickness; this is effected by the enormous development of the alæ of the mantle, which in the full-grown animal become so much extended, that when the creature is in motion they are laid over the external surface of the shell so as entirely to conceal it. These alæ contain patches of pigment which secrete colours entirely different from those contained in the collar, and from their whole surface exudes a calcareous varnish, which being laid over the exterior of the old shell completely conceals the original markings; these, however, may be again exposed on removing with a file the outer crust: a line, which is generally very distinctly seen running longitudinally along the back of the shell, indicates the spot where the edges of the two alæ of the mantle met during the completion of this singular process. Such shells are therefore remarkable from the circumstance of having their thickness increased by additions to the outer as well as to the internal surface.

In terrestrial shells it is only when they have arrived at their full growth that a rim or margin is formed around the aperture, which serves to strengthen the whole fabric; but in marine shells, which attain to much larger dimensions, the growth is effected at distinct periods, each of which is indicated by a well-defined margin, and these ridges remaining permanent, the successive stages of increase may be readily seen. At each suspension of development, it is not unusual to find spines or fringes, sometimes differently coloured from the rest of the shell, and not unfrequently of considerable length. In *fig.* 180, which represents the shell of *Murex*

Fig. 180.

cornutus, the nature and arrangement of such spines is well exemplified. They are all formed by the margin of the mantle which shoots out into long fringes, encrusting themselves with a shelly covering; each spine therefore is at first hollow, and if in many species they are found solid, it is because the original cavity has been gradually filled up by the deposition of earthy matter within it. The syphon with which many Conchiferous Gasteropoda are provided is produced in precisely the same manner, and its identity in form with the other spines covering the surface of the shell is in the annexed figure sufficiently obvious. In many species, as in the beautiful *Turbo scalaris*, (*fig.* 181,) the epocha of growth are only indicated by ridges surrounding the shell at regular intervals, each of which originally terminated a fresh augmentation of its size. It is difficult to imagine by what influence these creatures are induced to enlarge their habitations at such regular intervals, terminating each operation by a similar margin; some authors imagine that each time the creature emerges from its abode a fresh addition is made; others that it is dependent upon the temperature or state of the seasons, but without sufficient grounds for either of these assertions; it seems more probable therefore that the growth of the body gradually rendering the former dimensions of the shell incommodious from time to time renders these periodical enlargements necessary.

Fig. 181.

Although shells are evidently inorganic and extra-vascular structures, it is now universally conceded that their inhabitants have the power of removing portions which may obstruct their growth, or needlessly infringe upon the limits of their abode. In the Murices we have indisputable evidence of this fact in the removal of such spines as would interfere with the revolutions of the shell around the columella, and in Conus and similar genera a like faculty enables the animals to thin the walls which bound the inner whirls when their original thickness is rendered unnecessary by the accession of new turns. Such a solvent power indeed is not only exercised upon their own habitations, but many Gasteropods are able gradually to bore holes in other shells, or perforate the rocks upon which they reside to a considerable depth. The mode in which this is effected is, however, still a mystery; some authors ascribe it to a power of absorbing their shells, an expression the vagueness of which is sufficiently evident; others ascribe it to some acid secretion at the disposal of the animal; yet although this explanation is certainly plausible, when we reflect that the very structure which secretes this supposed acid is itself the matrix of such abundant alkaline products, it is not easy to imagine how the same structure can at the same time furnish such opposite materials.

As we should expect from the mode of its growth, the shell throughout all the Conchiferous class is composed of earthy matter, cemented together by an animal substance easily separable by the action of acids. In the porcellaneous shells the animal matter exists in much less quantity than in those of a fibrous texture; in the former, indeed, Mr. Hatchett found that when the carbonate of lime, of which the earthy portion is almost entirely formed, is dissolved even by very feeble acids, little or no vestige of any membranous structure could be perceived, nor indeed could any be detected, but by the small portion of animal coal which was formed when these shells had been exposed for a short time to a low red heat; in others however, as the Patellæ, a substance was left untouched by the acids which had the appearance of a yellowish transparent jelly, by means of which the earthy matter had been, as it were, cemented together.

On examining minutely the mechanical arrangement of the layers of which these shells are composed, it is found to vary in different kinds, and from this circumstance the fossil conchologist may derive important information in examining mutilated remnants sometimes so plentifully met with in calcareous strata. The simpler shells (Patella, Fissurella) are formed of very thin, compact, and parallel layers, whilst in others three distinct strata of fibres, each of which assumes a different direction, may be observed. The fibres composing the external layer are disposed perpendicularly to the axis of the shell. In the middle stratum the fibres are placed obliquely and are slightly twisted, but so arranged that each meets at an obtuse angle the extremity of one of the fibres composing the outer layer, and in the internal stratum they again assume a perpendicular direction. Such a disposition of the fibres, which is met with in all Siphonibranchiate shells, is eminently calculated to resist external violence in whatever direction it may act, and greatly contributes to the solidity of the whole fabric.

Operculum.—Many of the spirivalve Gasteropoda, especially such as are aquatic, are provided with a calcareous plate, which is placed upon the posterior surface of the body, and closes accurately the mouth of the shell, when the animal is retracted within it. The texture of the operculum is sometimes horny, but it is more frequently calcareous and of a stony hardness, its contour being accurately adapted to the orifice. It is composed of parallel fibres disposed perpendicularly to the base of the shell, and deposited in successive layers around an axis, so as to give to the whole structure the appearance of a solid spirivalve, as may readily be seen on removing it from the animal and examining its inner surface. This has been looked upon by some zoologists as analogous to the second valve of bivalve Mollusca, to which, but for its want of a ligamentous attachment, it certainly bears a distant resemblance.

The deciduous operculum of terrestrial Gasteropoda, or *epiphragma*, as it is usually called, is a widely different structure, being merely an inspissated secretion, with which, during the period of hybernation, the entrance to the shell is closed; and on removing the outer plate, not unfrequently a second or even a third similar membrane will be found within, forming additional safeguards against intrusion or the vicissitudes of temperature.

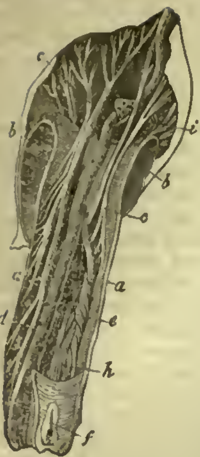
During the progressive growth of the shell the animal contained within it necessarily changes its original position, advancing gradually as the body enlarges from the earliest formed spires towards the aperture, as may easily be proved by sawing off the apex of a spirivalve shell containing the living animal. This circumstance is remarkably conspicuous in some of the Bulimi (*Bulimus decollatus*), enabling the occupant, as it grows, to break off the turns of its spire which first contained it, so that at the latter period of its life it does not retain any part of its original shell. The mode in which this advancement is effected is a subject of much curiosity, as it involves a power of detaching the muscles connecting the creature with its abode, from the place where they were originally fixed, and forming a new connexion with the shell; but whether this is effected by the removal of the original fibres and the production of others more anteriorly, as is believed by some, or whether, as is more probably the case, the creature has a power of changing the attachment of its retractor muscle at pleasure, is still a matter of uncertainty.

Organs of digestion.—We shall not be surprised to find that in a class so extensive, and composed of individuals living in such diversified circumstances, the alimentary organs are much modified in form in different species, according to the nature of the food with which they are nourished.

Mouth.—In most instances the mouth presents the appearance of a retractile proboscis, which can be protruded or shortened at the will of the animal, but unprovided with jaws or any apparatus for mastication; it is in such cases a muscular tube, formed of longitudinal fibres prolonged from the common parietes of the body, and of circular muscles, the former serving for the retraction of the organ, the latter causing its elongation by their successive action; by means of this simple structure every movement requisite for the prehension of food is effected. At the bottom of the tube is a narrow vertical aperture, the edges of which are slightly cartilaginous, and behind this is the tongue armed with spines variously disposed; the aliment therefore, having been forced by the contractions of the proboscis through the aperture at its termination, is received by the tongue, and by the aid of the latter organ is propelled into the œsophagus without mastication or any preparatory change.

In *Buccinum* and other syphoniferous genera, the structure of the proboscis is much more complicated and curious, (*fig.* 182.) " The proboscis, which carries with it the œsophagus in its different states of protrusion, is organised with wonderful artifice, being not only capable of flexion in every direction combined with limited power of retraction or elongation, but it can be entirely lodged in the interior of the body, folded within itself, so that that half which is nearest the base encloses the other portion: from this position it is protruded by unfolding itself like the finger of a glove or the tentacle of a snail, only it is never completely inverted. We may represent it as composed of two flexible cylinders (*fig.* 182, *a*, *b*,) one inclosed within the other, the upper borders of which join, so that by drawing outwards the inner cylinder, it is elongated at the expense of the other, and on the contrary, by pushing it back, the internal cylinder becomes lengthened by its shortening. These cylinders are acted upon by a number of longitudinal muscles (*c*, *c*), all very much divided at each extremity, the internal or superior divisions being fixed to the parietes of the body, whilst at the other end they are attached to the inner wall of the internal tube (*a*) of the proboscis, along its whole length, extending even to its extremity; their action is obviously to draw the inner cylinder, and con-

Fig. 182.



sequently the entire proboscis inward. This being done, a great part of the inner surface of the inner cylinder becomes a part of the external surface of the outer cylinder, whilst the contrary occurs when the proboscis is elongated and protruded.

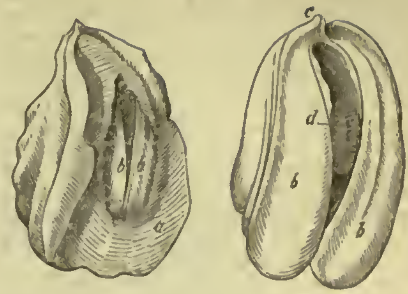
The elongation of the inner cylinder by the unfolding of the outer, or what is the same thing, the protrusion of the proboscis, is effected by the intrinsic annular muscles which assist in forming the organ; they surround it throughout its whole length, and by their successive contractions force it outwards; one especially, seen at *b*, placed near the junction of the extremity of the outer cylinder with the integuments of the head, which is stronger than the rest. When the proboscis is protruded, its retractor muscles acting separately, bend it in every direction, being in this case antagonists to each other. The internal cylinder incloses the tongue *(f)*, the salivary canals (*e*), and the greater part of the œsophagus (*d*), but its principal use is to apply the extremity of the tongue to such objects as the animal would suck or erode by its armed surface.

In Aplysia, Akera, and others, the mouth consists of a fleshy mass of considerable strength, to which are attached muscular bands proceeding from the sides of the body, serving for its movements, some drawing it forwards whilst others retract it, but there are no jaws nor anything equivalent to them, except the cartilaginous hardness of the lips.

But in such of the Gasteropoda as devour vegetable matter, the mouth, instead of being a proboscis, consists of a strong muscular cavity, inclosing a dental apparatus adapted to the division of the food. In the Snail, Slug, Limnæus, Planorbis, &c., this is a single crescent-shaped horny tooth, attached to the upper surface, and furnished along its opposite edge with sharp points, separated by semicircular cutting spaces, admirably adapted for the division of vegetable food.

The dental organs of Tritonia and Scyllœa are, however, still more perfectly contrived for such a purpose. The muscular mass of the mouth is strong and powerful, but instead of the single tooth of the Snail, it is armed with two cutting blades (*fig.* 183, *b*, *b*), horny in their texture and exceedingly sharp, resembling in every respect a pair of strong curved shears, from which in fact they only differ in the mode of their union, the spring of the one being replaced by an articulation (*c*) inclosed in a synovial capsule. These blades are approximated by strong muscular fibres, and few

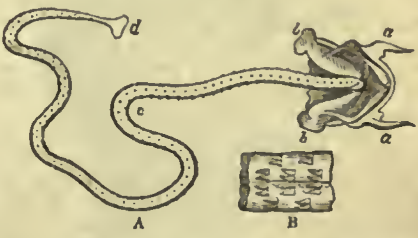
Fig. 183.



animal structures can resist their edge. The lips (*h*), which are placed in front of these teeth, are strong and very flexible, forming a muscular tube, by means of which the food is seized and brought within the power of its formidable jaws, and then the divided morsels, being seized by the horny teeth which invest the tongue (*d*), are conveyed into the œsophagus.

Tongue.—The tongue in these Mollusca is generally a very important organ, serving not only as a necessary auxiliary in deglutition, but often as a means of eroding the food: in fact, in one tribe only, *Thethys*, is it found to be deficient. In most of the proboscidean species the tongue is short, and covered with sharp, horny, and recurved spines, which, seizing the morsels of food taken into the mouth by a sort of peristaltic motion, push it backwards into the œsophagus. In some genera which have no proboscis, the tongue is of extraordinary length; thus in Haliotis it is half as long as the body, and in Patella, Turbo, Pica, and others, it much exceeds in length the entire animal. The tongue of Patella, which is three times the length of the body, is represented at *fig.* 184; it is supported by two cartilaginous pieces (*b*, *b*) placed on each

Fig. 184.



side of its root; from these arise strong and short muscular bands, which wield the organ. The surface of this singular tongue, a magnified view of which is given at B, is armed with minute though strong teeth, placed in transverse rows and arranged in three series; each central group consists of four spines, while those on the sides contain but two a-piece. It is only at its anterior extremity, however, that the tongue so armed presents that horny hardness needful for the performance of its functions, the posterior part being comparatively soft; it would seem, therefore, that in proportion as the anterior part is worn away, the parts behind it assume gradually the necessary firmness and advance to supply its place. The action of this curious instrument is as follows:—in the upper part of the circumference of the mouth we find a semicircular horny plate, resembling an upper jaw, and the tongue, by triturating the food against this, gradually reduces substances however hard. On opening the Patella, the tongue is found doubled upon itself, and folded in a spiral manner beneath the viscera.

The tongue of *Oscabrio* resembles that of the Patella, except in its armature, being furnished on each side with a series of hooked and three-pointed scales, and another set of long, sharp, and recurved spines, whilst its centre is simply studded with tubercles. In Turbo pica the scales, which are cutting and denticulated, are arranged transversely along its surface.

The tongue of Buccinum (*fig.* 182, *f*), is placed at the extremity of the proboscis, forming a most extraordinary apparatus, capable of destroying by its constant action the hardest shells; externally it resembles rather a mouth than a tongue, being divided into two lips, each of which is studded with sharp horny teeth. These lips are supported upon two cartilages which occupy the anterior half of the proboscis, and are moved upon each other by strong muscular fasciculi (*h*) in such a manner that the spines which arm the surface of the organ are alternately erected and depressed by their action, a movement the constant repetition of which soon wears away the substances upon which it is made to act. This spiny tongue is situated just within the entrance to the œsophagus (*d*), and besides acting upon foreign bodies will materially assist in propelling the food into that tube.

In other Gasteropods the tongue is short and merely an organ of deglutition: thus, in *Aplysia* it is broad, heart-shaped, and studded with sharp points. In Onchidium and Doris, the surface is marked with transverse grooves, which are crossed at right angles by others of great fineness. And in the Snail and Slug, in which the surface of the tongue is similarly marked, the striæ are so delicate that they can only be seen with a microscope.

Alimentary canal.—We shall commence our description of the intestinal canal of the Gasteropod Mollusca by the examination of the simpler forms which it presents. In the Snail (*fig.* 190), the whole alimentary tube (*e, f, g, k*) is thin and membranous. The stomach, which is merely a dilatation of the œsophagus, is semitransparent, but studded with opaque points and internally folded into delicate longitudinal plicæ. From this arises an intestine, of considerable length, without cœca, valves, or remarkable appearance internally, except near its termination, where the orifices of minute follicles may be detected; the intestine having performed several convolutions enveloped in the masses of the liver, with which it is connected by cellulosity and numerous vessels, at last runs along the margin of the pulmonary cavity, close to the orifice of which it terminates. In Vaginulus the arrangement is nearly similar (*fig.* 189, *g, h, i.*) In *Tritonia* and *Doris* the structure of the digestive tube is equally simple, and in these as well as in the majority of the Gasteropoda the only remarkable differences are found in the proportional size of the stomach and the length of the intestinal convolutions. In *Doris* we find near the orifices by which the bile is poured into the stomach, an aperture communicating with a round vesicle or cœcum, the inner surface of which is evidently glandular, and from its large supply of blood derived from one of the hepatic arteries, probably furnishing an abundant secretion analogous to that of the pancreas. In *Phasianella* the stomach is very voluminous and sacculated internally. In *Buccinum* the digestive apparatus is more complicated in its structure. The œsophagus commences, as we have already seen, at the extremity of the proboscis, and of course follows all the motions of that organ; when the proboscis is protruded in search of prey, the gullet is straight and adapted to the reception of food; but when the proboscis is retracted within the body, the œsophagus is bent upon itself, so as to be partially contained within the proboscis, whilst the greater portion is folded beneath that organ in its retroverted state. After making another fold it dilates into a small crop, the lining of which is plicated in the direction of its axis, and to this succeeds the stomach, which is a moderately sized round cavity, irregularly rugose internally. The intestine is very short, and has a small cœcum appended to its side; it terminates in a capacious rectum, placed, as is invariably the case, in the vicinity of the respiratory cavity, and having its lining membrane gathered into prominent longitudinal rugæ. Many of the Gasteropoda are provided with several digestive cavities, resembling in some degree the stomachs of ruminating Mammalia. In *Janthina*, which is furnished with a proboscis like that of the *Buccinum*, the œsophagus arising from this terminates by a narrow slit in a membranous cavity or first stomach, to which succeeds a second, having thicker walls and plicated internally. The intestine is extremely short, terminating as usual in the neighbourhood of the respiratory cavity. In *Pleurobranchus* the resemblance of the stomachs to those of a ruminating quadruped is very striking. The first stomach (*fig.* 185, *a*), which is membranous, receives the bile by a large orifice (*b*) placed near its communication with the second digestive cavity (*c*), which is smaller and more muscular; to this succeeds a third (*d*), the sides of which are gathered into broad longitudinal lamellæ, precisely similar to those of a ruminant; and to render the analogy still more perfect, a groove is found running along the walls of the second cavity from one orifice to the other, apparently subservient to rumination. The fourth stomach (*e*) is thin, and its walls smooth. This animal lives on Alcyonia and small Zoophytes.

Fig. 185.

Many Gasteropoda which devour shell-fish and other hard materials have a true gizzard adapted to break in pieces such food; this is the case with *Thethys*, an animal whose mouth is totally destitute of dental organs, but their want is supplied by a fleshy gizzard resembling that of a bird, having its interior lined with a dense cartilaginous membrane, like that which lines the gizzard of graminivorous fowls, and in its cavity shells of Mollusca and Crustaceans are found comminuted by its action. In *Limnæus* we find a gizzard strictly analogous in structure to that of a granivorous bird: it presents two dilatations, one at the cardiac, the other at the pyloric extremity, whilst the middle portion is occupied by two strong muscles, united at the sides by tendinous bands. The gizzard of *Planorbis* is precisely similar to that of Limnæus. In Onchidium the muscular gizzard is followed by two other stomachs, the lining membrane of that which immediately succeeds it being gathered into large folds, which must greatly retard the passage of the aliment; while the third cavity, which is short and cylindrical, is likewise lined with a membrane folded into more delicate plicæ, affecting a longitudinal direction.

There are some families in this class which are provided with a still more elaborate apparatus for the preparation of their food, their stomachs being armed internally with teeth variously disposed, and on many accounts extremely curious. In all the Bullæ (Akera) the gizzard contains three plates of stony hardness attached to its walls, and so disposed that they are evidently powerful agents in the trituration of the food. In *Bulla lignaria (fig.* 186)

Fig. 186.

two of these teeth are placed on either side of the gizzard, into the cavity of which they project, and are united to each other by strong muscular bands; the third piece is smaller than the other two, but similarly imbedded in radiating muscles, whose action must powerfully grind down the substances which come under the influence of this singular mill. In the other *Bullæ* the structure of the gizzard is the same, but the bony plates differ slightly in form and arrangement. In all, however, the fragments of shells and other hard substances found in it attest the efficacy of the apparatus.

The gizzard of *Scyllæa (fig.* 187, *e)* is, externally, a strong fleshy cylinder, and when this is opened there are found, firmly imbedded in its muscular walls, twelve horny plates, which are extremely hard and as sharp as the blades of a knife; their edges are dis-

Fig. 187.

posed in the direction of the axis of the organ, and as they project considerably into its cavity, their action upon the contents of the gizzard must be sufficiently evident.

Aplysia, however, furnishes us with the most curious form of these stomachal teeth. The œsophagus, which is comparatively narrow at its commencement, soon dilates into a capacious crop, which is generally found filled with pieces of fucus and the fragments of shells. To this crop succeeds a short cylindrical gizzard with strong and muscular walls, and after the gizzard we find a third stomach which leads to the intestine. On opening the gizzard and third stomach *(fig.* 188) they are found to have their

Fig. 188.

interior armed in a manner which is probably unique. The sides of the gizzard (*b*) are covered with pyramidal plates of a rhomboidal figure, the apices of which resemble the tubercles found upon the grinding surfaces of the human molar teeth. Of these there are twelve larger plates arranged in quincunx, besides several smaller ones placed near the entrance of the organ. These teeth are of a horny nature and formed of laminæ parallel to their bases: their adhesion to the surface of the lining membrane is so slight that they are detached by the slightest effort, without leaving any trace of membrane or other bond of union, the place of their attachment being only indicated by a smooth and prominent surface, corresponding in shape to the base of each tooth. The apices of all these teeth meet in the centre of the gizzard, and whatever passes through that cavity must be bruised by their action.

The third stomach (*d*) is armed with teeth of a totally different nature. These are little conical hooks (*c*) attached to one side of the organ only, and as little adherent in the dead animal as are the pyramids of the gizzard towards which their points are directed. In the figure many have fallen off, leaving slightly elevated spots indicative of the place of their attachment. Near the pylorus is a large aperture communicating with a cœcum of considerable size (*f*), evidently identical with the spiral cœcum of the Cephalopoda both in its position and relation to the insertion of the biliary canals (*e*), forming, as in Fishes, the rudiment of a pancreas. From the orifice of the cœcum a ridge is prolonged into the commencement of the intestine (*g*).

Accessory glands.—The auxiliary chylopoietic secretions found in the Gasteropoda are generally only two, the salivary and the hepatic. In some rare instances already adverted to, as in Doris and Aplysia, we may likewise add the pancreatic furnished by the cœca, which in those genera terminate in close vicinity with the ducts issuing from the liver, and which, from every analogy, represent the pancreas of vertebrate animals.

The salivary glands are constantly present and seem to present a size and importance corresponding with the mode in which the mastication of the food is accomplished. In those genera which are provided with a cutting apparatus placed in the mouth, they are very largely developed, as also in most of the proboscidean species, and it is only in the Cyclobranchiate order, where the long spiral tongue is used rather for the abrasion than the mastication of the food, that they become small, and, in a very few instances, undistinguishable. In *fig.* 190, which represents the viscera of the Snail, these glands are marked with the letters *á á*, and this engraving will give a good idea of the general structure which they present, and of the ordinary termination of the ducts which pour the saliva into the oral cavity. The glands are placed along the sides of the stomach, which they partially invest, and sometimes those of the opposite sides are intimately united with each other; their colour is whitish and semi-transparent, and they are formed of small lobes, which, in many species where their texture is less compact, may be distinctly seen to be formed of the ramifications of their arborescent ducts, each ultimate division of which is terminated by a secreting granule. In Vaginulus (*fig.* 189) the salivary glands are small, but in addition to the ordinary structure (*f*) we find an additional tube or slender cœcum (**f*), which, lying at first upon the stomach, passes through the nervous collar to join the duct by which the saliva is discharged. The secondary divisions of the ducts gradually unite to form an excretory canal for each of the two glands, which invariably pour the salivary secretion into the mouth in the vicinity of the tongue. When very small, as in Testacella, Onchidium, and Haliotis, they are found to be merely arborescent tufts placed on each side of the oral mass. In all the Pectinibranchiate order, where the mouth is converted into a protrusible proboscis, the glands themselves (*fig.* 182, *i*) are found within the visceral cavity, and their ducts (*e, e*) are very long and tortuous so as to follow the movements of the proboscis in which they are lodged, running in contact with the œsophagus to open at the extremity of that tube on each side of the spiny tongue; it is even probable that the secretion which they furnish at that point may assist, in some measure, in the destruction of the shells and other hard bodies, which are submitted to the continued action of this organ.

In *Doris* and *Pleurobranchus* a glandular structure of considerable size is found near the commencement of the œsophagus, which is of a brownish colour and plentifully furnished with bloodvessels. This has been looked upon as an auxiliary salivary organ, but as its duct has not been as yet satisfactorily traced, its real nature is unknown: but in *Janthina* there are distinctly four salivary glands, each furnishing a distinct duct; two of these run, as in Buccinum, to the extremity of the proboscis, whilst the other pair empties the secretion of the corresponding glands into the commencement of the œsophagus.

Biliary system.—The liver throughout the whole class is of great comparative size, enveloping the convolutions of the intestines and filling a large portion of the visceral cavity. That of the Snail consists of four large lobes (*fig.* 190, *h*), each divisible into lobules, and these again into secreting granules, from each of which issues an excretory duct. The ducts gradually unite into larger trunks, so that the whole organ, when unfolded, accurately represents a bunch of grapes, the stem of which would be the common biliary duct. In the same animal the excretory ducts from each of the divisions of the liver unite into one canal, which opens into the pyloric extremity of the stomach (*g*) in such a manner that as much bile must be poured into the stomach itself as into the commencement of the intestine. In the Slug the liver consists of five lobes, and from these are derived two distinct biliary canals, which open separately into the intestine, one on each side of the pylorus. A similar disposition occurs in *Vaginulus (fig.* 189, *l, h').*

Fig. 189.

In *Scyllæa* the liver *(fig.* 187, *d)* is divided into six small and detached round masses, the excretory ducts of which open above the point where the œsophagus joins the singularly armed gizzard (*c*). The liver of *Aplysia* is very large and forms three principal masses, among which are seen the convolutions of the intestine. The biliary canals are very wide and open into the third stomach near the aperture communicating with the rudimentary pancreas *(fig.* 188, *c).* In *Testacella Haliotoidea* there are two livers perfectly distinct from each other, and from each arises a proper duct, which opens separately into the commencement of the intestine near its origin. *Onchidium* furnishes us with a still more curious arrangement, being provided with three distinct livers, pouring their secretions by separate canals into different parts of the alimentary tube. Each portion perfectly resembles the others in external appearance, and in structure as well as in the nature of their respective secretions. The excretory canal which proceeds from the largest mass enters the œsophagus, discharging itself near to its cardiac termination; the duct of the second terminates near the same point, whilst the bile produced by the third is poured into the gizzard itself. The insertion of the two former above the gizzard would seem intended for the same purpose as the abundant secretion which is poured into the ventriculus succenturiatus of Birds, namely, to moisten the food before its introduction into the gizzard; it is, however, singular to find the biliary fluid employed for this purpose; nor is the insertion of the third duct into the first of the three stomachs of this animal less extraordinary, a similar arrangement occurring only in a few fishes, as in the *Diodon Mola.*

The liver of *Doris* is very large, and not only is the bile which it secretes discharged by large and numerous ducts into the stomach, so wide, indeed, that it is difficult to conceive how the food is prevented from entering them, but moreover the liver furnishes a second duct of large calibre, which opens externally in the vicinity of the anus. A part of the bile in this case is evidently excrementitious, as there is no doubt that the second canal takes its origin from the substance of the liver. "This," says Cuvier speaking upon this subject, "is the first instance of the kind which I have met with, and the fact was sufficiently singular to make me hesitate long and examine the matter with all possible precaution before admitting it. It is only by one supposition that it can be explained otherwise,—namely, that the lobes of two different glands are so interwoven that they are not to be distinguished from each other, one portion producing bile used in the process of digestion, and the other secreting a fluid which escapes by the canal in question." Before its termination externally, the secondary duct communicates by a short canal with a lateral receptacle, which forms a kind of gall-bladder, having its lining membrane much corrugated and its walls apparently muscular; this is probably a reservoir for the excrementitious fluid, in which it may be retained until the animal feels its discharge necessary. There is reason to suspect that the fluid thus furnished is a colouring matter, used as a means of defence, and expelled like the ink of the cuttle-fish on the approach of danger, but the matter is undecided.

The bile is in all cases produced from arterial blood, and the liver is provided with but one system of veins answering to the hepatic.

Organs of respiration.—The respiratory organs of the Gasteropoda are found to be constructed upon very various principles, adapted to the medium which they inhabit, or the peculiar exigencies of the individuals composing each order. Nevertheless in different groups allied by the generalities of their organization, the respiratory system is, in most instances, found to be constructed upon the same plan, and this circumstance more than any other has rendered the position and nature of the respiratory organs the most eligible basis of classification. On looking over the table which we have given at the commencement of this article, the reader will perceive at once that the names by which the different orders are designated indicate the general disposition of the pulmonary or branchial appendages, and we shall therefore follow the arrangement there adopted in considering more minutely the peculiarities belonging to each.

The first or *Nudibranchiate order* is distinguished by having the breathing apparatus perfectly exposed to the influence of the surrounding medium, which in all the genera belonging to this division is the water of the ocean; the branchiæ constantly assume the shape of arborescent tufts, placed in different situations upon the dorsal aspect of the animal. In Doris (see article Circulation, *fig*. 321, vol. i. p. 649,) they form a circle around the anus. In *Tritonia* they are disposed in two rows along the sides of the animal, extending from one extremity of the body to the other. In *Scyllæa* they consist of little tufts irregularly disseminated over the surface of the back and upon the fleshy alæ projecting therefrom. In *Glaucus* they form on each side three large and palmated fins, being used as agents of progression as well as instruments for the purification of the blood. In *Œolis* the branchiæ assume the shape of long riband-like lamellæ disposed in imbricated rows; but whatever their form their structure is essentially the same, each tuft or lamella containing the ramifications of the branchial vessels, and effecting the oxygenisation of the blood by the extent of surface which they expose to the action of the surrounding water.

In the *Infero-branchiata* the respiratory tufts or plates are arranged around the circumference of the body, lodged in a deep groove between the margin of the foot and the edge of the mantle which covers the back. The *Tectibranchiata* have the branchiæ covered by a little fold or operculum formed by a duplicature of the skin, and generally containing a horny or calcareous plate; beneath this are seen the respiratory leaflets arranged in rows upon the two sides of a semi-crescentic membrane: their structure in Aplysia is represented in *fig*. 191. Each branchial lamella (*a*, *a*) divides dichotomously into smaller plates until the divisions become extremely minute; the ramifications of the arteries and veins within them being distributed to each are spread over an extent of surface adequate to the efficient aeration of the circulating fluid which they contain. The principal trunk of the branchial artery (*c*) runs along the concave margin of the crescentic membrane, while the large venous trunk occupies the opposite or convex border; the veins from the branchiæ all terminate in this great vein, their orifices being disposed in circles, as seen at *d*.

The *Pectinibranchiate* order includes that large family of aquatic Gasteropods which are enclosed in shells, and the arrangement of the whole of their breathing apparatus is adapted to the respiration of water. The branchiæ resemble in structure those of fishes, and are pectinated or composed of parallel laminæ disposed like the beards of a feather, and attached in two or three rows to the roof of a large cavity placed under the integuments of the back; or else in some rare cases, as in the Valvata cristata, the branchia is single, resembling a pen, and floats externally.* A very material difference is observable between the truly aquatic species and the pulmonary Gasteropods which inhabit the water, but breathe air; in the latter, which are compelled to come to the surface to respire, the aperture leading into the pulmonary cavity is small and furnished with a powerful sphincter, so that the air taken in is retained at the pleasure of the animal; but in those which are provided with pectinated branchiæ, the entrance to the branchial chamber is a wide fissure, always allowing free ingress and egress to the circumambient fluid. Many genera of this order are provided with a special apparatus called the syphon, for conveying the water freely into the respiratory chamber; this is a semi-canal formed by a fold of the right side of the mantle, and lodged in a groove projecting from the mouth of the shell; through this channel the water at all times has free admission to the gills. The respiratory organs of the *Scutibranchiata* resemble those of the last order, and are contained in a similar cavity, to which the water is constantly admitted; but in the *Cyclobranchiata* the branchiæ consist of a series of lamellæ placed external to the body, around the border of the mantle, by the edge of which they are overlapped.

Respiration is effected in the *Pulmonary Gasteropoda*, whether they be terrestrial or aquatic, by an apparatus fitted for breathing the air of the atmosphere; the lung or pulmo-branchia, as we may call this singular organ, consists of a large cavity placed beneath the mantle, over the surface of which the vessels returning the blood from the system spread in beautiful ramifications, and from these the pulmonary veins take their origin, collecting the blood which has been exposed to the action of the air, and conveying it to the heart. A large orifice admits the air freely into this chamber, the walls of which alternately contracting, draw in and expel it at regular intervals by an action precisely similar to that of the human diaphragm. In the Slugs (Limax) the cavity is small, but the network of the vessels spreads over its whole surface. In the Snail (Helix), on the contrary, the organ is much larger, but its floor only is covered with the respiratory ramifications. In *fig*. 322, of the article Circulation, vol. i. p. 649, a diagram is given of this structure, and in *fig*. 190, (*m*, *n*,) the details of its arrangement are more minutely shewn; yet even in the beautiful drawing of Cuvier, from which our plate is copied, the minute divisions of this superb plexus are but inadequately shewn. The order which has been established by Ferussac, under the name of *Pulmonalia operculata*, is composed of individuals classed by Cuvier among the *Pectinibranchiata*, to which in every circumstance, with the exception of the structure of the respiratory system, they are closely allied; these, however, breathe the air in a cavity analogous to that which we have just described, only differing in the position and nature of the aperture leading to it, which here, instead of being a rounded orifice in the margin of the collar, opened and closed at the will of the animal, is a large fissure placed above the head, exactly as in the Pectinibranchiate order.

Organs of circulation.—Having thus described the different arrangements of the branchiæ, we shall be enabled more readily to investigate those modifications in the disposition of the organs subservient to the circulation of the blood which are dependent thereupon. Throughout the whole class, with

* For a figure of the branchial chamber of the Buccinum undatum, and an account of the ciliary movements which have been observed in many orders of Gasteropoda to be connected with respiration, the reader is referred to the article Cilia.

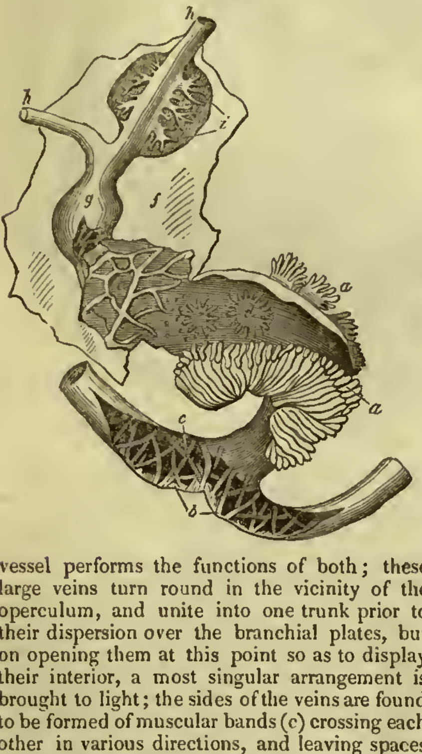
Fig. 190.

the exception of the Scutibranchiate and some of the Cyclobranchiate orders, the heart is single, consisting of an auricular and ventricular cavity, and is interposed between the branchial or pulmonary vessels and the system, receiving the aerated blood from the respiratory organs, and propelling it through the body. The heart of Aplysia (*fig.* 191, *e, g*) or of the Snail, (*fig.* 190, *o, p*) will exemplify its ordinary structure. The auricle varies slightly in shape in different genera, but is always extremely thin and pellucid, containing in its coats muscular bands of great delicacy. The ventricle is provided with stronger walls, and is generally separated from the auricle by a valve, formed of two pieces. The heart is enclosed in a pericardium, but its position is regulated by that of the branchiæ; and from the great diversity of arrangement which we have found the latter to present, a corresponding want of uniformity in the locality which the heart occupies may be readily expected. We shall select two forms of the respiratory organ as examples of the variable position of the heart, and as illustrations of the usual distribution of the bloodvessels, viz. the Snail, (vide Circulation, *fig.* 322, and the Doris, *fig.* 321,) and afterwards notice the principal aberrations from the ordinary disposition. In the Snail, the blood derived from the whole body is brought by great veins, performing the functions both of the vena cava and of a pulmonary artery, to the plexus of vessels lining the floor of the respiratory cavity; after here undergoing the needful aeration, it enters the heart, from whence it is driven into the aorta. The aorta immediately divides into two trunks, one distributed to the liver, the intestine, and the ovary; the other supplying the stomach, the oral apparatus, the organs of generation, and the foot. In the Slug the arteries are perfectly white and opaque, and their ramifications, which may be traced with great readiness, are extremely beautiful.

In *Doris* (*fig.* 321) the heart is, in consequence of the position of the branchiæ around the anus, removed quite to the posterior extremity of the body. The blood derived from all parts of the body is conducted by large veins to the respiratory organs; the pulmonary arteries which return it from thence unite into a circular vessel (*b, b*), surrounding the anus, and from this arise two vessels, emptying themselves into the auricle. The aorta, on issuing from the heart, divides into two large vessels, the first supplying the intestinal canal, stomach, and duodenum, the organs of generation, the foot, and the mouth; whilst the other large trunk is entirely distributed to the liver.

In *Tritonia* the heart is placed near the centre of the body, and the auricle itself resembles a cylindrical vessel placed transversely across the other viscera, and communicating with the ventricle near its middle. The blood arrives at the heart through four vessels from the long fringe of branchiæ, two coming from the anterior and two from the posterior parts. We have already described the disposition of the branchiæ in the Tectibranchiate order, but in following the course of the circulating fluid, we shall find in some of the individuals included in this division circumstances requiring special notice, as being of extreme interest to the physiologist. In Aplysia, the blood returned from the system is brought by two large venous trunks to the vena cava or pulmonary artery (*fig.* 191, *b*); for in this case the same

Fig. 191.



vessel performs the functions of both; these large veins turn round in the vicinity of the operculum, and unite into one trunk prior to their dispersion over the branchial plates, but on opening them at this point so as to display their interior, a most singular arrangement is brought to light; the sides of the veins are found to be formed of muscular bands (c) crossing each other in various directions, and leaving spaces between them; these intervals are seen even by the naked eye to be apertures establishing a free communication between the interior of the vein and the abdominal cavity, and allowing injection to pass with facility from the vein into the visceral cavity, or from the abdomen into the vein: the anterior portion of each of these vessels may indeed be said to be literally confounded with the general cavity of the the body, a few muscular bands, forming no obstacle to a perfect communication, being the only separation between the two. It is therefore evident that the fluids contained in the abdominal cavity may in this manner have free access to the mass of the blood as it approaches the respiratory organ, and that the veins can thus perform the office of the absorbent system; but in what manner the blood is prevented from escaping through the same channels is not at all obvious, although probably during life the contraction of the fasciculi which bound these apertures may in some measure obstruct the intercourse. It is from this circumstance, and the analogous communication which exists in the Cephalopoda by the intervention of the spongy appendages to the venæ cavæ found in those Mollusks, that Cuvier was led to the conclusion that in all the class the veins are the immediate agents of absorption, and that an absorbent system does not exist in any but the vertebrate division of the animal kingdom. We meet, moreover, in Aplysia with another peculiarity in the circulating vessels; the aorta, shortly after its commencement, divides into two large arteries (*h h'*), one of which presents nothing peculiar in its distribution; but to the larger of the two, whilst still enclosed in the pericardium, we find appended a remarkable structure, the use of which has been hitherto perfectly inexplicable: projecting from the opposite sides of the vessel are two vascular crests, represented in *i*, formed of a plexus of vessels issuing from the aorta itself, and ramifying in an exceedingly beautiful manner through the substance of these extraordinary organs; in other respects the arteries are distributed in the usual manner. The Cyclobranchiate and Scutibranchiate Gasteropods approximate the testaceous class in many points of their organization, but in none more so than in the position which the heart is found to occupy, and the arrangement of its cavities. In Patella, indeed, the heart is placed in the anterior part of the body, and still conforms in its general structure to the description which we have given above; but in Oscabrio the auricle is divided into two distinct portions, one receiving the blood from each range of branchial plates; and in *Haliotis, Fissurella, Emargenula*, and *Parmophorus*, not only is this division of the auricle met with, but the ventricle, as in many of the testaceous Mollusks, is perforated by the rectum, and the similarity of arrangement which is here presented with what is met with in the Conchifera will be readily appreciated by a reference to the article which treats of the anatomy of that division of the Mollusca.

Nervous system.—The nervous system of the Gasteropoda furnishes us with the most perfect form of the heterogangliate, or as it has been less happily denominated, cyclo-gangliated type. It consists of a variable number of ganglia or nervous centres disposed in different parts of the body, but connected with each other by cords of communication, and from these ganglia the nerves appropriated to different parts proceed. Each ganglion, therefore, is a distinct brain; and were the preponderance in size to be regarded as the criterion of relative importance, it would not unfrequently be hard to say to which the pre-eminence is due. There is, however, as we shall soon perceive, an uniformity in the arrangement of certain masses, and a regularity in the appropriation of the nerves proceeding from them to particular organs, which leave us little room for hesitation upon this point; before, however, entering upon a more detailed account, we will offer a few general observations upon this system, applicable to the whole class. The nervous centres are obviously of a different nature from the cords by means of which they are connected into one system, and from the nerves arising from them; the nervous mass of the ganglion itself is generally granular in its appearance, whilst the texture of the nerves is homogeneous and smooth; the distinction is, however, in a few instances, rendered still more remarkable by a striking difference in colour; thus in Aplysia, whilst the nerves are of a pure white, the ganglionic centres are of a beautiful red tint; the same circumstance is met with in the Bulimus Stagnalis, and has also been remarked in many of the conchiferous Mollusca. A second peculiarity may be noticed in the mode in which the nerves and ganglia are invested with a neurilema or sheath, so loosely connected with them that it may be inflated or injected with great facility, and for this reason the nerves have been mistaken for vessels by some authors.

As an example of the most perfectly dispersed arrangement of the nervous centres we shall select Aplysia, in which the ganglia are more numerous than in the generality of the Gasteropod Mollusks. In this animal we find a ganglion placed above the œsophagus to which the name of the brain is universally allowed, not so much on account of its size as because throughout the class it constantly occupies the same position, and as invariably supplies those nerves which are distributed to the most important organs of sense; in this case its branches run to the muscles of the head and to the male organ of generation; it likewise sends on either side a large branch to each of the great tentacles, which as they approach those organs give origin to the optic nerves.

On each side of the œsophagus is found another ganglion equalling the brain in size, and constituting two other nervous centres, which are united to each other and to the brain by cords so disposed as to form a collar around the œsophagus; each of these gives off a number of nervous filaments, which are lost in the muscular envelope of the body; a fourth ganglion joined to the brain by two cords is found under the fleshy mass of the mouth; this supplies the œsophagus, the muscles of the mouth, and the salivary glands. At a considerable distance from these, and placed near the posterior portion of the body in the vicinity of the female generative organs and the respiratory apparatus, is a fifth ganglion communicating with the second and third by means of two long nerves, and giving branches to the liver, the alimentary canal, the female generative system, as also to the branchiæ and the muscles of the operculum. From this account it will be seen that none of these ganglia can be said to preside exclusively over any particular apparatus, branches from each being distributed to very different structures; but yet, speaking generally, there appears to be some reason for classifying their functions. Thus the brain is exclusively the centre of the principal senses: the two great lateral ganglia supply the bulk of the muscular system; the sub-oral ganglion is particularly subservient to mastication and deglutition, and the fifth or posterior nucleus being almost entirely appropriated to the supply of the digestive, respiratory, circulatory, and generative viscera, might be regarded as analogous to the sympathetic. There are, however, but few of the Gasteropoda in which the ganglia are so distinct in position and function as in Aplysia. In the inoperculate pulmonary Gasteropods, as in the Snail and Slug, the nervous centres are only two in number, namely, the brain, placed in its usual position above the œsophagus, and a large sub-œsophageal ganglion connected with it by two cords embracing the œsophageal tube. The brain in this case supplies nerves to the muscles of the mouth and lips, as well as to the skin in their vicinity; it likewise furnishes the nerves of touch and of vision, besides those distributed to the generative organs, and from the sub-œsophageal ganglion, which fully equals the brain in size, arise those nerves which supply the muscles of the body and the viscera. There is, however, placed under the œsophagus a very minute nervous mass, which from the constancy of its occurrence is worthy of notice; it is formed by the union of two minute nerves arising from the brain, and the little filaments which it gives off are lost in the œsophagus itself.

One remarkable circumstance may be mentioned as being probably peculiar to the class under consideration, namely, the changes of position to which their nervous centres are subject; obeying the movements of the mass of the mouth, with which they are intimately connected, they are pulled backwards and forwards by the muscles serving for the protrusion and retraction of the oral apparatus, and are thus constantly changing their relations with the surrounding parts. In the Snail it would seem that the great size of the nervous collar which embraces the œsophagus will in some circumstances permit the mass of the mouth to pass entirely through it, so that sometimes the brain rests upon the œsophagus, and at others is placed upon the inverted lips.

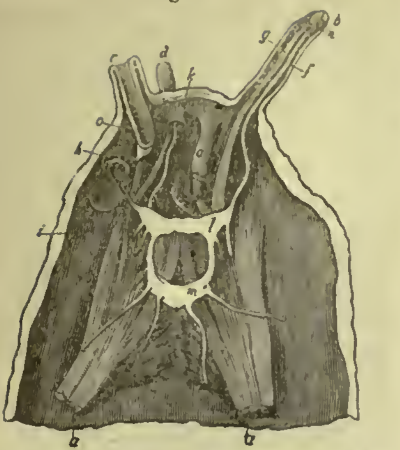
In most of the *Pectinibranchiata*, the brain consists of two ganglia united by a transverse cord; from these two centres arise the principal nerves, two of which unite to form a small ganglion beneath the œsophagus, from which that tube derives its peculiar supply.

It is in the Nudibranchiate division, however, that the nervous centres exist in their most concentrated form, and in these it is doubtful whether there are any ganglia, except the large supra-œsophageal brain. We may take Tritonia as an example of this form of the nervous system. In this beautiful Gasteropod the brain consists of four tubercles placed across the commencement of the œsophagus, the nervous collar being completed by a simple cord; all the nerves which supply the skin, the muscular integument, the tentacles, the eye, and the muscles of the mouth arise from the brain, and anatomists have not hitherto detected any other source of nervous supply, although Cuvier suspected two minute bodies, which he found beneath the œsophagus apparently connected with the brain, to be of a ganglionic nature.

The slow-moving and repent tribes of which we are now speaking have their powers of sense almost entirely limited to the perception of objects in actual contact with their bodies, and instruments adapted to touch and vision are the only organs of sense which the anatomist has been able to distinguish. The utter want of an internal skeleton or of an external articulated crust forbids us to expect that any of them are provided with an apparatus specially calculated to appreciate sonorous undulations. Their tongue, coated as it is with horny plates, studded with spines, or absolutely corneous in texture, is obviously rather an instrument of deglutition than an organ of taste. No researches have hitherto detected any part of the body which could be looked upon as devoted to smell; the eye is generally a mere point, rather inferred to be such by analogy than clearly adapted to vision; and the sense of touch in fact is the only one which anatomical evidence would intimate to be perfectly developed. Yet in spite of these apparent deficiencies, observation teaches us that many genera are not utterly deprived of the power of appreciating intimations from without connected with the perception of odours; it has been found by direct experiment that some of them are peculiarly sensible of the approach of scented bodies; thus the snail, although at rest within the shelly covering which forms its habitation, will with great quickness perceive the proximity of scented plants which are agreeable articles of food, and promptly issue from its concealment to devour them. Some anatomists have supposed that it is at the entrance of the respiratory cavity that we are to look for the special seat of smell, where, as the air alternately enters and is expelled by the movements of respiration, the odorous particles with which it may be impregnated are rendered sensible. Others with scarcely less probability conceive that the whole surface of the body which is exposed to the atmosphere may be endowed with a power of smelling, the quantity of nerves which are distributed to the integument, and the moisture with which it is constantly lubricated, seeming to adapt it perfectly to the performance of this function, giving it all the characters of a Schneiderian membrane. It is not impossible that sounds may be perceived in a somewhat analogous manner, although no proof has yet been adduced that any of the Gasteropoda are sensible to impressions of this nature. The sense of touch is exquisitely delicate over the whole surface of the animal, but more especially so in the foot, which is extremely vascular and abundantly supplied with nerves; yet in spite of this delicacy in the organisation of the skin which makes it so sensible of contact, it appears to have been beneficently ordered that animals so helpless and exposed to injury from every quarter, are but little sensible to pain, and that such is the case, M. Ferussac, a diligent observer of their economy, bears ample testimony. "I have seen," says he, "the terrestrial gasteropods allow their skin to be eaten by others, and in spite of large wounds thus produced, shew no sign of pain." But besides the sensation generally distributed over the skin, we may observe in most instances organs of variable form which seem peculiarly appropriated to touch. These are the tentacles, or horns as they are usually termed, which occupy a variable position upon the anterior part of the animal.

The tentacles vary in number in different genera: thus in *Planorbis* we find two, in the generality of cases four; in a few, as some species of *Œolis*, six; and in *Polycera* even eight of these appendages are met with. The structure of the tentacles is by no means the same in all the individuals belonging to this class. In the aquatic species they are to a greater or less extent retractile, but can in no case be entirely concealed within the body, as is usual in the terrestrial division; they are therefore not hollow, but composed of various strata of circular, oblique, and longitudinal muscular fibres, by means of which they are moved in every direction, and applied with facility to the objects submitted to their examination. In all instances they are plentifully supplied with nerves arising immediately from the brain. Their shape is subject to great variation; they are usually simple processes from the surface of the body more or less elongated, and in some cases even filiform, as in *Planorbis*. In *Murex* (*fig.* 193) each tentacle is a thick and fleshy stem, near the extremity of which a smaller one is appended. In *Tritonia* each tentacle is composed of five feathery leaflets, and is enclosed in a kind of sheath which surrounds its base. In *Doris* the two inferior are broad, flat, and fleshy, while the superior are thick and club-shaped. In *Scyllæa* they consist of broad fleshy expansions attached by thin pedicles to the anterior part of the body. In *Thethys* they are placed at the base of the veil which characterises the animal, but in all cases they are solid and incapable of entire retraction. In the terrestrial Gasteropoda, in which from many causes the tentacles are more exposed to injury, a much more complicated structure is needed, by which these important organs are not only moved with facility in different directions, but which allows them to be perfectly withdrawn into the interior of the body, from which position they may be made to emerge at the will of the animal: the mechanism by which this is effected will be understood by referring to *fig.* 192, representing a dissection of the common snail, and exhibiting the tentacles in different states of protrusion. Each tentacle (*c*, *d*,) is here seen to be a hollow tube, the walls of which are composed of circular bands of muscle, and capable of being inverted like the finger of a glove; it is in fact, when not in use, drawn within itself by an extremely simple arrangement.

Fig. 192.



Structure of the tentacles in the Garden-Snail (Helix Pomatia).

From the common retractor muscles of the foot four long muscular slips are detached, one for each horn; these run in company with the nerve to each tentacle, passing within its tube when protruded, quite to the extremity *(g)*. The contraction of this muscle dragging the apex of the organ inwards, as seen at *c*, of course causes its complete inversion, whilst its protrusion is effected by the alternate contractions of the circular bands of muscle of which the walls of each tentacle are composed. There is, however, another peculiarity rendered necessary by this singular mechanism, by which the nerves supplying the sense of touch may be enabled to accommodate themselves to such sudden and extensive changes of position; for this purpose the nerves supplying these organs are of great length, reaching with facility to the end of the tubes when protruded, and in their retracted state the nerves are seen folded up within the body in large convolutions. In the figure, *a a* indicates the origins of the retractor muscles of the foot from the columella; *b*, the right superior tentacle fully protruded; *c*, the left superior tentacle partially retracted; *d*, the left inferior tentacle extended, and *e*, the right inferior tentacle fully retracted and concealed within the body; *f*, the nerve supplying the superior tentacle elongated by its extension; *g*, the retractor muscle of the same tentacle arising from the common retractor muscle of the foot and inserted into the extremity of the tube; *h*, the nerve of the opposite side thrown into folds; *i*, the retractor muscle of the same tentacle contracted; *k*, the aperture through which the nerve and retractor muscle enter the tentacle *d*; *l*, the brain; *m*, the subœsophageal ganglion; *n*, the eye.

Vision.—The eyes of Gasteropoda are extremely small in comparison with the bulk of the animals, and seem more to represent the rudiments of an organ of sight than to be adapted to distinct vision. In many species indeed they appear to be absolutely wanting. When found, they resemble minute black points, by far too small to admit of any satisfactory examination of their internal structure; and even in the largest forms of the organ which are met with in the more bulky marine genera, it is with difficulty that their organisation can be explored. In *fig.* 193 we have delineated the position and structure of the eye in a large Murex.

Fig. 193.

Tentacles and eye of Murex.

The natural size of the organ is seen in the upper figure, in which on the right side the organ is represented untouched, while on the left a section has been made to exhibit its interior. This section when magnified, as in the lower figure, shews us that it consists of a spherical cavity lined posteriorly with a dark choroidal membrane, and containing a large spherical lens; the position and structure of the retina we have been unable satisfactorily to determine, although the visual nerve may be readily traced to the back of the choroid, where it seems to expand; but whether, as in the Cephalopods, its sentient portion is spread out behind the pigment which lines the eye-ball, or whether, as in the forms of the organ common to the vertebrate orders, the retina is placed anterior to the choroid, is a question which we are at present unable to solve. But however this may be, we see anteriorly a distinct pupil surrounded by a dark radiating zone, apparently an iris, to which it corresponds at least in position, although that it is really capable of contracting or enlarging the pupillary aperture is more than our observations warrant us in affirming. Finding, therefore, the eye of the Murex to offer a structure which indubitably entitles it to be regarded as an organ of sight, we are justified in considering the more minute specks of smaller Gasteropoda as similarly formed and subservient to the same office. In the aquatic species the eyes are generally placed at the base of the superior or larger tentacles, although not unfrequently they are supported upon short pedicles appropriated to them, as is the case in *Haliotis* and others. In *Murex* we have seen that the tentacles which support them are large and fleshy, and by the position of the eyes at the extremity of so long a stem these can be readily directed to different objects. In no case, however, can they be retracted within the body so as to be quite enclosed in the visceral cavity. In the terrestrial Gasteropods the eyes are generally placed at the extremity of the superior horns, a position which manifestly extends the range of vision, and moreover, in consequence of the structure which we have described when speaking of the organs of touch, may be completely drawn within the body. In *fig.* 189, *b*, the eye of Vaginulus is seen at the extremity of the upper tentacle, and the origin of the optic nerve *(c)* from the brain *(d)*, as well as the convolutions which it makes to allow of its adaptation to the varying length of the tentacle, and the bulb in which it terminates behind the eyeball *(b*)*, are sufficiently displayed. In *fig.* 192, *b*, the eye of the snail exhibiting the same circumstances has been represented, and the apparatus by which the movements of the whole organ are effected is so clearly shewn as to render further description superfluous.

Generative system.—The description of the generative apparatus of the Gasteropoda forms one of the most remarkable parts of their history, and the complication which it presents in some orders is probably unique in the animal kingdom. The class may be divided, as far as relates to this function, into three great divisions: — 1st. Hermaphrodite and self-impregnating; 2d. Hermaphrodite, but reciprocally impregnating each other by mutual copulation; 3d. Sexes distinct, the female being impregnated by copulation with the male. We shall consider each of these divisions in the order in which they have been enumerated. The lowest orders approximate the Conchifera in most parts of their organisation, and in the arrangement of their generative system we need not be surprised to see a manifest resemblance. The *Scutibranchiate* and *Cyclobranchiate* orders, therefore, present this great distinguishing character, which more than any other detaches them from the others, namely, that every individual being furnished both with ovigerous and impregnating organs is sufficient to the impregnation of its own ova. Nothing, in truth, can be more simple than such an arrangement. The ovary is found, when empty, embedded in the substance of the liver, but at certain epochs it becomes so much distended with ova as to cover in great part the rest of the viscera; from this ovary arises a simple canal or oviduct, which terminates after a short course in the neighbourhood of the anus. No trace of accessory apparatus has been found, and the only part to which the office of a testis is assignable is the tube through which the ova are discharged, which probably furnishes a secretion subservient to the impregnation of the eggs. Such is the structure of the generative system in *Haliotis*, *Patella*, and others of the orders to which these respectively belong, exhibiting a simplicity of parts widely different from what is found in the division which next presents itself to our notice. The second type of the generative apparatus is common to the *Nudibranchiate*, *Inferobranchiate*, *Tectibranchiate*, and *Inoperculated pulmonary* orders; in all of which every individual is provided with both male and female organs of copulation, and, accordingly, mutual impregnation is effected by the congress of two individuals, or in a few instances by the combination of several. We shall select the common snail *(Helix pomatia)* as the most familiar illustration of the general arrangement of the parts composing this double apparatus, leaving the varieties which it presents to subsequent notice. The admirable plate of Cuvier, of which *fig.* 190 is a copy, represents the whole system with that clearness and fidelity so characteristic of all the laborious contributions to science which we owe to his indefatigable industry. The female portion consists of the ovary, the oviduct, and an enlarged portion of the oviduct which forms a receptacle for the ova, and is called by Cuvier the womb *(la matrice)*. The ovary *(q)* is a racemose mass embedded in that portion of the liver which is enclosed in the last spire of the body, i. e. that part which is placed nearest to the apex of the shell; from this proceeds a slender oviduct (*r*), folded in zigzag curves, and variously convoluted: it commences by many small branches derived from the ovary, and terminates in a mass (*s*), regarded by Cuvier as the testis, in which it becomes so attenuated that it is difficult to trace it; emerging, however, from this mass, it expands into the womb (*t*), which is a long, capacious, and sacculated canal, and capable of much distension, in which the eggs are retained until they have acquired their full development: this viscus opens into the common generative cavity at *c*, *fig.* 194.

The male organs consist of a testicle, vas deferens, and penis. The testicle *(s, fig.* 190) appears to be composed of two distinct portions, the larger of which is soft and homogeneous in texture, but the smaller has a granulated appearance; the latter (*u*) runs along the womb like a mesentery, connecting its folds as far as the termination of that viscus. The testicle varies much in size at different periods, being generally very small, but during the season of love it dilates so as to fill nearly half of the visceral cavity, at which time the womb likewise is much enlarged. From the testicle arises its vas deferens or excretory duct, which terminates in the penis near the base of that organ. The penis (*fig.* 194, *n*) is a most singular instrument, resembling a long hollow whip-lash, formed of circular fibres, and, like the tentacles, capable of complete inversion, which in fact occurs whenever it is protruded from the body; it is also furnished with a retractor muscle *(fig.* 190, *w)*, serving to draw it back again after copulation is accomplished. The penis is not perforated at its extremity, but the vas deferens terminates within it by a small aperture, which of course during the inversion of the organ opens externally at about one-third of the length of the penis from its root; the aperture by which the vas deferens thus opens upon the exterior of the penis, when that organ is protruded, is sufficiently distinct, admitting with facility an ordinary bristle (*fig.* 194, *l*). On slitting up the penis as it usually lies retracted into the visceral cavity, its inner membrane is found gathered into longitudinal folds, and this provision is needful to allow of that distension which must occur during its erection, at which time this lining membrane becomes the external integument of the protruded organ.

These parts would seem sufficient in themselves to fulfil the functions belonging to the organs of both sexes, nevertheless we find others superadded, the uses of which are not so readily assignable; these are the *bladder*, as it is called by Cuvier, the *multifid vesicles*, and the *sac of the dart*.

The sac which has been called the bladder (*fig.* 190, *z*, *fig.* 194, *o*) is invariably present; it consists of a round vesicle, variable in size, communicating by means of a canal, generally of considerable length and diameter, with the termination of the matrix: it is usually found filled with a thick and viscid brownish matter, and is generally supposed to furnish an envelope to the eggs as they escape from the convoluted oviduct, an opinion, however, as we shall afterwards see, which is not without opponents.

The *multifid vesicles* (*fig.* 190, *x*, *fig.* 194, *c*) are much less constantly met with, and are in fact almost peculiar to the snail; they are two groups of cœca, each composed of about thirty blind tubes, which after uniting into larger canals ultimately form a principal duct on each side, through which the secretion which they furnish is poured at a little distance below the orifice leading to the bladder into the passage by which the ova are expelled. The fluid furnished by these curious glandular appendages is white and milky, but as this secretion is almost peculiar to the genus *Helix*, its use is extremely problematic.

The *sac of the dart* (*fig.* 190, *y*, *fig.* 194, *b*) is another part of the generative apparatus only found in the snail, and from the extraordinary instrument which it conceals is perhaps the most singular appendage to the generative system met with in any class of animals. It is an oblong sac with strong muscular walls opening by a special aperture into the common generative cavity, like which it is capable of complete inversion. On opening it, its cavity is seen to be quadrangular, and at its bottom projects a four-sided fleshy tubercle, which secretes the curious weapon that this sac is destined to conceal. This (*fig.* 194, *b*) consists of a four-sided calcareous and apparently crystalline spike, about five lines in length, which grows by successive layers deposited at its base from the surface of the fleshy tubercle to which it is attached: it will be evident that when the sac is everted, the dart contained within it will be protruded externally. This dart, if broken off from its place of attachment, is speedily renewed.

To complete our description of the parts composing this complex organisation, it remains only to mention the common generative cavity

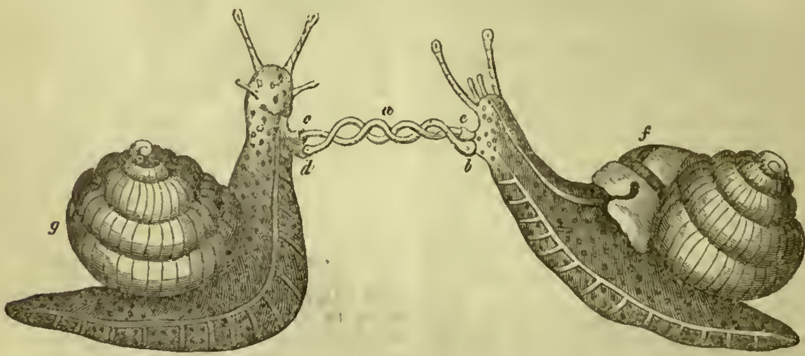
Fig. 194.

Generative organs of Helix Pomatia.

(*fig.* 194, *a*), into which the others open; this, when in its ordinary position, is a muscular bag, opening externally by a large aperture near the upper tentacle on the right side of the neck, whilst at its bottom are seen the orifices of three distinct passages, one leading to the penis, one to the female organs, and a third to the sac of the dart. This cavity, like that of the dart, is capable of inversion, which is effected partly by the action of its muscular walls, aided in all probability by a kind of temporary erection, and when thus turned inside out, the orifices leading to the penis, the womb, and the sac of the dart of course become external.

In order to understand the functions of these various parts it will be necessary to describe at length the singular mode in which copulation is effected. When two snails, amorously disposed, approach each other, they begin their blandishments by rubbing the surfaces of their bodies together, touching successively every part. This preliminary testimony of affection lasts for several hours, gradually exciting the animals to more effective demonstrations. At the end of this time the generative orifice, placed on the right side of the neck, is seen to dilate, and the common generative cavity becoming gradually inverted displays externally the three apertures which open into it. This being effected, an encounter of a truly unique character commences; the opening leading to the sac of the dart next expands, and that organ undergoing a similar inversion displays the dart affixed to its bottom. A series of manœuvres may then be witnessed of an unaccountable description; each snail, in turn, inspired with an alacrity perfectly foreign to its ordinary sluggish movements, striving with his dart to prick the body of his associate, which with equal promptitude endeavours to avoid the wound, retreating into his shell, and performing a variety of evolutions to get out of reach. At length, however, the assailant succeeds, and strikes the point of his weapon into the skin of his paramour at any vulnerable point which may be found. The dart is generally broken off by this encounter, sometimes sticking in the skin, but more frequently dropping to the ground. The reptile Cupid having thus exhausted his quiver, becomes in turn the object of a similar attack, exhibiting apparently an equal anxiety to avoid the threatening point of the weapon bared against him. At last he receives the love-inspiring wound, and the preliminaries thus completed, each prepares for the completion of their embraces. The other two apertures next dilate, and from one of them issues the long and whip-like penis, unrolling itself like the finger of a glove; this being fully developed is introduced into the vaginal orifice of the other snail, which in the same manner inserting its penis into the female aperture of the former, both mutually impregnate and are impregnated. See *fig.* 195.

Fig. 195.



It is difficult to conceive what can be the use of the dart so singularly employed; it would seem to be an instrument for stimulating the sleeping energies of the creatures to a needful pitch of excitement; yet why it should be peculiar to the snail is not obvious, for in the slug and other Mollusca certainly not less apathetic, no such structure has been detected.

In *Vaginulus (fig.* 189) a similar arrangement of the principal organs is observable, although some modifications are met with which deserve our notice. No *sac of the dart* is found in this animal, but a fasciculus of cœca, analogous to the multifid vesicles as far as their structure is concerned, is connected, not with the female apparatus, as in the snail, but with the male organs. The orifices of the two sexual systems are here separated by a considerable interval, the penis emerging at the side of the neck, near the right superior tentacle at *z*, while the orifice of the female parts is placed between the cuirass and the mantle, considerably further back. The ovary (*m*) is similar in structure to that of the snail; and its duct, in like manner, forms many convolutions in the substance of the testicle (*p*), from which it issues, much increased in size, to expand into a large membranous receptacle (*q*), corresponding in function with the tortuous matrix of the *Helices;* this part of the oviduct is filled with an albuminous fluid, and from it runs the narrower canal (*r*), which may be regarded as the vagina, and which before its termination communicates with a lateral pouch, identical with what has been called the bladder. The testicle (*p*) appears to consist of two portions, from which arises the vas deferens (*o*). On tracing this tube it is seen to divide into two branches, one opening into the bladder (*s*), an arrangement to which we shall again have occasion to revert, whilst the other runs forward to the root of the penis (*w*). The latter organ presents two portions, a long tubular cœcum (*v*), resembling the corresponding part in the snail, and a thick muscular cavity, from which the former arises as a kind of appendage; on opening the thicker portion its interior is seen to be rugose, and to enclose a small body, something like the *caput gallinaginis* in the human urethra. The *multifid vesicles* (*y*) open near the exterior orifice, through which the whole apparatus, by a process of inversion already described, is protruded so as to form the male organ of excitement.

In many of the Tectibranchiata a remarkable arrangement of the generative organs is found, as the male viscera are divided into two distinct portions, the exciting organ being at one extremity of the body, while the testis is found connected with the female apparatus in a distant part of the system. This will be seen in *Doridium Meckelii (fig.* 196); the penis (*l*), seen retracted in the figure, issues from the side of the neck, and has appended to its root a zig-zag tube, inclosed in a membranous canal, the nature of which is unknown. Quite detached from these, and placed near the anus, we have the matrix *(f)*, the testis (*g*), and the bladder (*i*), occupying their usual relative position as regards each other, and terminating in the *vulva* or sac of generation (*h*).

In Aplysia the organ of excitement is found

Fig. 196.

near the right tentacle, where it protrudes, as in the Snail, for the purpose of copulation, by the inversion of its walls; it is, however, absolutely imperforate, and receives no duct by which it can communicate with the testis so as to become instrumental in immission; but externally a deep groove is seen upon its surface when in a state of protrusion, which is continuous with a long furrow seen upon the surface of the body, continued from the base of the penis to the orifice of the female apparatus. *Fig.* 197 represents the secreting

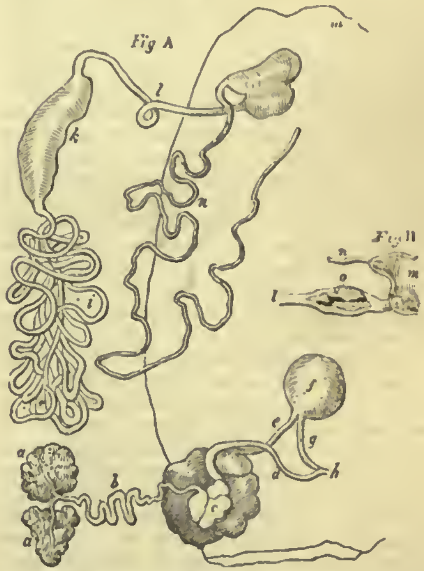
Fig. 197.

Generative organs of Aplysia.

portions of this system removed from the body, and displayed so as to expose the internal structure of the parts composing it. The ovary (*h*) is a large oval, whitish, and granular mass, from which the oviduct arises by several distinct tubes which emerge from different parts of its substance: this oviduct opens into the common tube (*e*), which may be called the vagina. The mass (*f*, *g*), called by Cuvier the testis, and supposed by him to be solid and homogeneous in its texture, is found, when opened, to be divided by spiral septa, resembling the scala cochleæ in the ears of Mammalia (*g*), and thus forms a long spiral cavity communicating with the commencement of the vagina, in which latter tube we also find apertures by which the vesicle (*p*) and the larger sacculus (*o*) communicate with the common passage.

In *Onchidium*, an aquatic species belonging to the inoperculate pulmonary order, the male and female parts are in a similar manner placed at opposite extremities of the body, but the former assume a more complicated structure than in the Tectibranchiata, which we have described. The ovary (*fig.* 198, A, *a*, *a*)

Fig. 198.



Generative organs of Onchidium.

consists of two masses replete with ova, each of which furnishes a short duct; the two thus formed unite into a convoluted tube (*b*), which is the common oviduct: arriving at the mass always regarded by Cuvier as the testis, it enlarges and forms within the substance of that organ many convolutions, on emerging from which it runs directly in the shape of a narrow canal (*d*), to the external orifice (*h*). The bladder (*f*) receives a large duct (*e*) from the mass here assumed to be the testis, and gives off another of equal size, which joins the oviduct (*d*) prior to its termination. This would seem to form a complete system in itself; yet, on examining the male organ of excitement, we find it connected with considerable appendages, the nature of which it is difficult to conjecture. The sac (*m*) is muscular, and resembles the muscular root of the penis in the genera already described, being, as in them, capable of inversion: at its base are seen two cul-de-sacs, into each of which opens a long and flexuous canal (*l*, *n*). The canal marked *n* is very slender, and when unfolded is four times the length of the body of the animal; its termination at the point most remote from the muscular sac into which it opens is apparently closed. The other tube marked *l* is much wider and of extraordinary length; its commencement (*i*) is extremely convoluted and fully eight times as long as the body; its walls are thin, but it is supplied plentifully with blood by means of a large artery interlaced with its convolutions; at *k* it becomes enveloped in a fleshy mass of considerable thickness, after which, assuming its original appearance, it proceeds to the cul-de-sac, at the bottom of which it terminates. In *fig.* B, 198, the muscular cavity (*m*) has been laid open, and the mode in which the above tubes enter it has been displayed; the smaller one (*n*) ends in a little horny papilla (*q*) seen in the engraving; the larger tube (*l*) terminates by a kind of glans penis, perforated by a large aperture and surrounded by a kind of prepuce (*p*): on opening the vessel a little before its entrance into the muscular sac, it is found to conceal a sharp horny dart (*o*), supported upon a fleshy pedicle, and readily protrusible through the aperture *p;* the analogy between this singular instrument and the dart of the Snail is obvious, for when the muscular sac (*m*) is everted, the papillæ (*p*, *q*) become external, and the horny point being pushed out of the former will probably form a stimulus of the same description.

We have hitherto abstained entirely from mixing up with our description of these principal forms which the generative system of the mutually impregnating Gasteropoda presents, the discussions which have arisen concerning the real nature of the different organs which have been described, and have designated them by the terms usually applied to the respective parts, without reference to their individual functions. It now, however, becomes necessary to lay before our readers the principal opinions which are recorded upon this subject. The chief points of debate have been the bladder, and the organ which we have described under the appellation of testicle. The bladder is, from its constant occurrence, evidently an organ of some essential use: it was regarded by Swammerdam as the secreting structure from which the colouring fluid peculiar to some species is produced, especially in the Murices and others of the marine genera; it was therefore named by him sac of the purple; but we shall afterwards find that this fluid is derived from another source. Blainville, on the other hand, considers this vesicle as analogous to the urinary bladder of Vertebrata; in reference to this hypothesis, however, we should be inclined to ask, with Cuvier, where are the kidneys? and even upon the supposition that the secretion of the bladder itself was analogous to the urinary fluid, we are not aware of any chemical proofs of its nature which are sufficient to establish the identity. Delle Chiaje again sustains that the sac of the purple is, in fact, the testis, and that its secretion, poured as it constantly is into the termination of the oviduct, is in reality the fecundating fluid; yet against this we must urge the distribution of the vas deferens met with in the *Helices*, which from its entire arrangement converts the organ of excitement in these animals into an apparatus of immission, whose nature cannot be mistaken. The opinion which we consider most consonant with all the circumstances of its position, is that it is a reservoir for the seminal fluid analogous to the spermotheca of certain insects. Cuvier expressly notices the constant relation which exists between the length of the penis and that of the canal which leads to this sacculus, and when we remark the long chains of ova which are slowly extruded in most of the Gasteropoda, we are readily disposed to admit of the necessity of such a reservoir, which, treasuring up the semen until the eggs are about to be expelled, applies it efficiently to the ova as they successively pass the orifice of its duct. This supposition derives additional weight from what we have found to be the arrangement of the seminal ducts in *Vaginulus* and *Onchidium*. In the former we observed that, besides the canal, which, as in the Snail, perforates the root of the penis and thus becomes subservient to copulation, the vas deferens actually pours a part of its contents by a separate canal into the bladder itself, which, as in all cases, communicates with the egg-passage. In *Onchidium* the connexion between the testis and this receptacle is equally striking, as will be obvious on reference to the drawing given above. In *Aplysia*, Delle Chiaje considers the testicle as described by Cuvier to be in reality the matrix or receptacle for the ova, in which they attain their full development prior to expulsion, basing his opinion upon the disposition of the spiral cavity which it contains.

We are entirely left to conjecture as to the uses of the other appendages found in particular species, and the multifid vesicles of the Snail, which are wanting even in the Slug, the tortuous canal connected with the penis of *Doridium*, and the still more singular organs belonging to the male apparatus of *Onchidium*, must still remain the subjects of observation and experiment.

The third form of the generative system in which the sexes are distinct, is met with in all the Pectinibranchiate order, and in the operculated Pulmonalia of Ferussac. In Buccinum, which we shall select as an example of the general arrangement of the sexual organs in the former, the male is at once distinguish-

Fig. 199.

Male organs of Buccinum.

able by the enormous penis attached to the right side of the neck (*fig.* 199), which is not, as in the last division, capable of retraction within the body, but remains permanently external, being, when not in use, folded back and lodged within the branchial cavity, from which however it is frequently protruded without any apparent object.

In the female there is no rudiment of such a structure, but the generative aperture is seen to be situated a little within the edge of the pulmonary cavity, being a simple hole leading to the oviduct. The internal organs of the male, represented in the annexed figure, consist simply of a testicle and its excretory canal. The testis is of considerable size, sharing with the liver the smaller convolutions of the shell; from this arises the vas deferens, which forms by its convolutions a kind of epididymis (*fig.* 199, *b*), and then increasing in diameter enters the root of the penis, through which it passes by a tortuous course (*d*) to the tubercle at the extremity of this organ, where it opens externally. The penis when opened, as represented in the engraving, is seen to contain strong transverse fasciculi of muscle, which probably cause the erection of this organ; they will at the same time lengthen it, so as to destroy in a great measure the zig-zag turns into which the vas deferens is thrown in its usual relaxed state.

In the female the position of the testicle is occupied by the ovary, while the vas deferens is represented by a thick and glandular oviduct.

In *Murex* the penis of the male is proportionally smaller; and, instead of a complete vas deferens, penetrating to its extremity, there is merely a groove along its surface, along which the semen flows. In *Voluta* the exterior groove only runs to the base of the penis, and in *Strombus* the male organ is a mere tubercle.

In the *Pulmonalia operculata* the organs of both sexes are in every respect similar to those of the Pectinibranchiate order. In *Paludina* alone (*Helix vivipara*, Lin.) the penis is retractile, issuing from a hole found in the right tentacle, and from the disparity in size between the tentacles, arising from this cause, the male is readily distinguished. The females of this genus are not unfrequently ovo-viviparous, the ova remaining in their capacious oviduct until they are hatched.

Spallanzani asserts that, if the young of Paludina are taken at the moment of their birth, and kept entirely separate from others of their species, they can reproduce without impregnation, like the Aphides and Monoculi, in which the same connexion with the male is found to fecundate not only the female herself, but her offspring for several generations. Nevertheless, whether Spallanzani's observations be correct or not, the males are fully as numerous as the females, so that it would be difficult to imagine the object of such a deviation from the ordinary proceedings of nature.

Ova.—The spawn of the Gasteropod Mollusca is found under diverse forms; it is usually in the marine species attached to the surface of stones, shells, or sea-weed, the ova being connected with each other in long ribands or delicate festoons, which are sometimes extremely beautiful and curious. The Doris and Tritonia deposit their ova in this manner, and the mass of eggs deposited by them resembles a frill of lace of extreme beauty. In Aplysia the spawn is found to resemble long gelatinous threads, in the centre of which the ova are seen, varying in tint, so as to give different colours to different parts of the thread; the whole strikingly resembles strings of vermicelli, and the Italians in fact have applied to them the name of *vermicelli marini.* In Helix and Bulimus the eggs are naked and protected by a hard shell, whilst in Buccinum, Voluta, Murex, and other marine species, the ova are enveloped in membranous sacs agglomerated together in large bunches; these sacs have been erroneously regarded as the eggs themselves; they are, however, merely coriaceous envelopes, answering the purpose of the gelatinous coating enclosing the eggs of other species, several eggs being contained in each bag, in which, when mature, the young are easily seen. It would seem that extraordinary provisions have been made by nature for the multiplication of these creatures, in spite of the numerous enemies which devour them, or the vicissitudes of temperature to which, especially in the terrestrial species, their eggs are necessarily subject. We are indebted to M. Leuchs for several interesting observations concerning the ova of slugs, which explain in a great degree the quantities of them which in some seasons infest gardens and vineyards, becoming, from the devastation which they cause, serious plagues to the agriculturist. The number of eggs varies with the healthiness of the animal, the supply of food, or the temperature of the season; yet it is probable that a single slug will lay five hundred, under ordinary circumstances: thus, supposing a thousand of these creatures to be collected in a given space, they will give birth in a few weeks to five hundred thousand young slugs, which multiplying in their turn would produce at the second laying two hundred and fifty millions of eggs. This fact is well worth the notice of the farmer, who, instead of driving away with so much assiduity crows and other birds which live upon these destructive, though apparently insignificant, animals, would do well occasionally to cherish them as fellow-labourers in his grounds. The Terrestrial Mollusca, helpless and incapable of defence, afford food to numberless indefatigable assailants, and their preservation is provided for, not only by the number of their eggs, but by a peculiar tenacity of vitality which these exhibit under circumstances which would be thought sufficient to destroy the young before they were hatched. The skin of the eggs of the slug is coriaceous and very elastic, so that when compressed they soon resume their shape: exposure to intense cold does not destroy their fertility, and they have been known to resist a temperature of 40° without apparent injury. When dried by artificial heat, they shrivel up to minute points only distinguishable by the microscope, yet in this state, if they be put into water, they readily absorb it and are restored to their former plumpness. The same thing happens to those which are dried by the action of the sun and apparently destroyed; a shower of rain is sufficient to supply them with the fluid which they had lost and to restore their fertility. This drying appears not to injure them. M. Leuchs found that after being eight times treated in this manner, they were hatched on being placed in favourable circumstances, and even eggs in which the embryo was distinctly formed, survived such treatment without damage.

Reproduction of lost parts.—Not less wonderful is the power which snails possess of reproducing lost parts, after mutilation by accident or design. The results of the experiments of Spallanzani upon this subject are very curious; he found that if the large tentacle of a snail were amputated, the extremity of the stump heals, forming a small swelling of a lighter colour than the rest of the horn; in this swelling a black point soon becomes visible, which is a new eye, and the mutilated member, increasing in length, shortly equals its original size, although it is for some time of a lighter colour than its uninjured fellow, which in other respects it perfectly resembles. The process sometimes varies a little; it frequently happens that the end of the stump, instead of becoming round, is elongated and tapers to a point, from the apex of which the new eye is seen to "squeeze out;" the end of the tentacle then assumes a globular shape, and the most accurate dissection cannot distinguish the newly formed eye from the original. If, instead of the horn, the head is cut quite off, a new one will succeed: the new head, however, does not at first contain all the parts of the old one, but they are gradually developed, piece by piece, at different intervals, until at length a head differing little, if at all, from the original pattern is completed. In some cases the object is effected by a different proceeding, the new part appearing like a round tubercle, containing the rudiments of the lips and of the smaller horns, which is united to the mouth and the new-formed tooth, the other parts, as the larger horns and the anterior part of the foot, being totally deficient. In another snail the larger tentacle on the right side first appeared, not more than one-tenth of an inch in length, but already provided with its eye, and at a short distance beneath this the lineaments of the lips separately developed themselves. In a third snail a group of three horns is seen, two of which will acquire their full developement, while the third is just above the level of the skin. These and many other varieties have been observed; but in most instances there is no perceptible difference between the new head and the one cut off, the exact line of separation being indicated by an ash-coloured mark distinguishable two years after the experiment. The same effects follow, whether the head be removed above or below the brain, and in the latter case a new brain, with all its nerves, is speedily constructed. The collar and foot are also perfectly restored after their removal.

Slugs reproduce their horns as well as snails, but their power of manufacturing a new head is much inferior.

Muscular integument.—None of the Gasteropoda have any thing analogous to an endoskeleton, a circumstance which sufficiently accounts for the varied forms which the same individual assumes under different circumstances, for the body being unsupported by any resisting framework, readily yields to the contractions of the muscular integument with which it is covered. It is from this circumstance that the zoologist finds the preservation of the natural forms of the recent animals a task of such extreme difficulty, owing to the corrugation and distortion produced by the ordinary modes of preservation; it is scarcely possible indeed, in many cases, to recognise with tolerable accuracy the natural appearance of these creatures in the shrunken specimens generally preserved in our cabinets, and the collector of these objects would do well never to omit, when circumstances allow him the opportunity, to preserve some sketch of the living forms of such exotic species as may come into his possession.

Body.—In the naked Gasteropods the whole body is found to be inclosed in a muscular integument, the basis of which is a cellular web of extraordinarily extensible character, in which the muscular fibres may be seen to cross each other in various directions, some passing longitudinally from one extremity of the animal towards the opposite end, while others, assuming different degrees of obliquity, are interwoven with the rest, so as to occasion the elongation or contraction of the body in every assignable direction. Within this muscular bag the viscera are contained, as well as the organs subservient to mastication, the apparatus of the external senses, and of the organs employed in copulation, which are, when unemployed, retracted within its cavity by special muscular fasciculi spoken of elsewhere.

Retractile muscles.—In the spirivalve genera the muscular walls which inclose the body only exist in such parts as, during the extended state of the animal, are protruded from the shell; that part of the body which is concealed within its cavity being provided with a much more delicate and membranous envelope; in such, however, a necessity exists for an additional muscular apparatus, serving to retract the body and foot within the cavity of its calcareous abode, and of course exhibiting various modifications of arrangement in conformity with the shape of the shell itself. In the turbinated shells, the retracting muscles consist of strong fasciculi of fibres arising from the columella or axis of the shell, and diverging from this point, spread in several slips, which become interlaced with the fibres composing the foot and muscular investment. In the flattened forms of Patella and Chiton, the muscular fibres arise all around the margin of the shell, excepting at its anterior part; these penetrating the mantle are intimately interwoven with the muscles forming the circumference of the foot. The animal of the Haliotis is fixed to its expanded and semi-turbinated shell by a single large and ovoid muscle, which takes its origin from near the middle of the last spire; whatever the disposition of these muscles, however, their action is obviously of two kinds; and not only are they the agents by which the creature retires within its covering, but by raising the central portion of the disc of the foot, whilst its margins are in apposition with the plane of progression, they will, by producing a vacuum beneath, convert the whole apparatus into a sucker, the adhesive power of which will be proportioned to the extent of its surface.

Foot.—The foot of the Gasteropoda is their principal agent of progression. It is generally a fleshy disc, of variable size and shape, attached to the ventral surface, and forming when expanded an organ by means of which the animal can adhere to surrounding objects. In the naked genera it is small, but in the conchiferous species, especially in such as are provided with dense and weighty shells, its dimensions and force are proportionally increased. In its internal structure it resembles the muscular investment of the body, of which in fact it is merely an expansion, consisting of muscular fibres interlacing each other in every possible direction, as may be developed by continued maceration. In the Slug, when opened from the back, the superior layer of fibres is found to run transversely, arising apparently from two tendinous lines which run longitudinally near the centre of the organ, and terminating near the margins of the disc; beneath these, longitudinal fasciculi may be detected, but so interlaced with other fibres assuming every degree of obliquity, that it is impossible to unravel the complicated structure which they form. In the Limpet (Patella) the lower fibres of the foot are transverse, but near the circumference they become distinctly interwoven with circular fasciculi; the superior stratum viewed from above consists of two series of oblique fibres, which meet at an acute angle on the middle line, whilst the substance of the organ is composed of muscular bands variously disposed: from such a structure the movements of the foot are readily understood; the transverse fibres by their contraction will elongate the ellipsis of the foot by diminishing its breadth, whilst the longitudinal, having a contrary action, will, by the combination of their effects, produce every movement needful for the progression of the creature. On minutely inspecting the foot of a terrestrial Gasteropod, as it crawls upon a transparent surface, it will be found to be divided into a certain number of transverse segments of variable size by a particular arrangement of the longitudinal muscular fibres, which seem to form, when the creature advances, undulations limited by the points of contact. These sections appear alternately to form a vacuum upon the surface where the animal is placed, that which follows advancing to take the place of that which precedes it, the transmission of movement occurring from behind forwards, a mechanism which causes the animal to advance by a slow and uniform progression.

The above structure of the foot, and consequent mode of locomotion, although the most usual, is susceptible of considerable modification. Thus in *Scyllæa*, we find it only adapted for grasping the thin stems of fuci and other submarine plants, being for that purpose compressed and grooved inferiorly into a deep sulcus. In the *Tornatella fasciata*, Lam. the structure of the foot is remarkable: beaten incessantly by the waves, in the cavities of rocks which it frequents, nearly on a level with the surface of the sea, to the violence of which it is always exposed, it has need of additional powers of retaining its hold; its foot is therefore divided into two adhering portions, placed at each extremity, and separated by a wide interval; when it crawls it fixes the posterior disc and advances the other, which it attaches firmly to the plane of progression, and this being effected, the hinder sucker is detached and drawn forwards, locomotion being accomplished by the alternate adhesion of these two prehensile discs. In *Cyclostoma* the foot is likewise furnished with two longitudinal adhering lobes, which are advanced alternately. But the foot is not merely an instrument of progression on a solid surface, in many species being convertible, at the will of the animal, into a boat, by means of which the creature can suspend itself in an inverted position at the surface of the water, where by the aid of its mantle and tentacles, it can row itself from place to place. The Bulimus stagnalis, so common in our pools of fresh water, is a good example of this mode of sailing; and in the marine species, Aplysia and Gastropteron may be enumerated as exhibiting a similar structure.

Some of the naked Gasteropods, as Aplysia and Thethys, are able to move through the water in the same manner as the leech by an undulatory movement of the whole body, a mode of progression which in Thethys is materially assisted by the membranous expansion of the mantle placed around the anterior part of the body, which forms a broad veil, and from the muscular fibres contained within it, must necessarily be an important agent in swimming.

Particular secretions.—Many of the Gasteropoda, in addition to the secretions which have been mentioned, furnish others adapted to peculiar circumstances, and produced from special organs.

In the Snail and the Slug tribes a slimy mucus is furnished in great abundance from an organ which has been denominated the "sac of the viscosity;" this is a membranous bag surrounding the pericardium, which when opened is found to be divided internally by delicate septa arising from its walls; from this proceeds a capacious duct, which follows the course of the rectum, to which it is intimately united, to open externally in the neighbourhood of the respiratory aperture. The viscid secretion of this gland spreading over the surface of the foot is most probably an assistant in progression, causing it to adhere more intimately to the surfaces over which the animal crawls.

Aplysia furnishes three distinct fluids issuing from different parts of the body. The first is a glairy mucus, which exudes in considerable quantities from the surface of the mantle, especially when the creature is irritated. The second is a whitish liquor, which is thick and acrid, and has been reputed venomous; it is emitted in very small quantities, but its smell is strong and highly nauseous: the gland which produces it is a little reniform mass placed near the vulva, close to which is the orifice of its excretory canal. Blainville looks upon this as the representative of a urinary apparatus, but it does not appear to exist in all the species, and is never emitted except when the animal is tormented.

The third secretion is much more abundant than the other two, and is generally of a beautiful lake colour, except in *Aplysia citrina*, in which it is yellow. It is contained in a spongy substance, which occupies all those portions of the little mantle or operculum to which the shell does not extend. All the areolæ of this tissue are filled with a purple matter, the colour of which is so intense, that when it is expressed it has a black violet hue, but when mixed with a large quantity of water, imparts to it the colour of port wine. This colouring fluid seems to exude through the skin of the mantle, no excretory duct having been found specially appropriated to its escape: it is apparently produced from a triangular glandular mass situated in the base of the mantle.

Several species of Murex secrete a similar fluid, which, like the ink of the cuttle-fish, serves as a defence from attack; in all cases it is expelled with force, and in such abundance as to colour the water around to a considerable distance.

There is a species of Limax, (*Limax noctilucus,*) described by M. Orbigny, which produces a phosphorescent secretion capable of emitting a light of considerable brilliancy. The luminous organ is a small disc of a greenish colour by day-light, soft in texture, and slightly contractile. The light is only visible when the creature is expanded and in motion. The disc is always covered with a greenish mucus, which, if wiped off, is speedily renewed. It is found to be connected with the generative organs, and appears to be principally useful during the season of love.

Bibliography.—*Swammerdam*, Biblia Naturæ seu Historia Insectorum, fol. 1737. *Cuvier, G.* Leçons d'Anatomie Comparée, 8vo. 1799. *Ibid.* Mémoires pour servir à l'Histoire et l'Anatomie des Mollusques, 4to. 1817. *De Blainville*, de l'Organization des Animaux, ou Principes d'Anatomie Comparée, 8vo. 1822. *Delle Chiaje*, Mémorie sulla storia e notomia degli animali senza vertebre del Regno di Napoli. *Ferussac*, Histoire des Mollusques terrestres et fluviatiles, fol. *Spallanzani*, Opuscoli di Fisica animale e vegetabile, 1776. *Reaumur*, De la formation et de l'accroissement des coquilles des animaux tant terrestres qu'aquatiques, in the Mémoires de l'Acad. des Sciences, 1709. He continued the subject in the same work for 1716, under the title of Eclaircissemens des quelques difficultés sur la formation et l'accroissement des coquilles. *Hatchett*, on the chemical Composition of Shells, Phil. Trans. 1799-1800. *Beaudant*, Mémoire sur la structure des parties solides des Mollusques, Annales du Museum, tom. xvi. p. 66. *Weiss, M.* Sur la progression des Gasteropodes Terrestres, Journ. de Physique de Rozier, An. i. p. 410. *Lamarck*, Système des Animaux sans Vertèbres, 7 vol. 8vo. 1815-1822. *Harderus*, Examen Anatomicum cochleæ terrestris domiportæ, Basileæ, 1679.

(*T. Rymer Jones.*)

GELATIN (Fr. *gelatine*; Germ. *Leim. Gallerte*). This term is applied to an important principle obtained by boiling certain animal substances in water, and filtering or straining the solution, which, if sufficiently concentrated, gelatinises, or concretes into a translucent tremulous mass on cooling, which may be again liquefied and gelatinised by heat and cold. Many varieties of gelatin occur in commerce, of which *glue* is perhaps the most important: it is obtained by boiling the refuse pieces of skin and hide, and the scrapings and clippings from the tan-yard, in a sufficient quantity of water, till a sample taken out of the boiler forms, on cooling, a stiff jelly; the solution is then strained whilst hot, and run into coolers, where it concretes, and is afterwards cut by a wire into slices, which are dried upon nets. Membranes, tendons, cartilage, horn-shavings, and other similar substances also yield a jelly, which, however, is less stiff and binding than the former, especially when obtained from young animals: *size* is a jelly of this description. *Isinglass*, which consists of several parts of the entrails of fish, and especially the sound, &c. of the sturgeon, yields a very pure and tasteless jelly, which is chiefly used for the table; the jelly of calves' feet and hartshorn-shavings is somewhat similar.

As jelly cannot be extracted by cold water, and as we have no direct evidence of its existence in the various substances from which it is obtained previous to the action of boiling water, and, moreover, as it does not occur in any of the animal fluids or secretions, it has been regarded by some chemists, and especially by Berzelius, as a product of the action of water and heat, and not as a mere educt. He compares its formation to the conversion of starch into gum and sugar, and remarks that in both cases the change is accelerated by the presence of dilute acids.

Pure gelatin is colourless, transparent, inodorous, insipid, and neither acid nor alkaline; heat softens it and exhales a peculiar odour, and it burns with smoke and flame, leaving a bulky coal, difficult of incineration and containing phosphate of lime: it yields much ammonia, and the other ordinary products of analogous animal compounds, when subjected to destructive distillation.

In cold water dry gelatin swells and becomes opaque, and when gently heated it dissolves and forms a clear colourless solution, which gelatinises when cold. According to Dr. Bostock, one part of isinglass to 100 parts of water yields a perfect jelly, but with 180 of water it does not concrete.* Those modifications of gelatin which are the least soluble in hot water yield the strongest jelly. When the same portion of jelly is repeatedly liquefied and cooled, it gradually loses the property of gelatinising, and becomes so far modified as to leave a brownish gummy residue when evaporated, which readily dissolves in cold water. L. Gmelin kept a solution of isinglass in a sealed tube for several weeks at the temperature of 212°: it was thus changed to the consistency of turpentine, was deliquescent, soluble in cold water, and partially so in alcohol.

An aqueous solution of gelatin exposed for some time to the air at the temperature of 60° to 70° becomes at first thinner and sour, and afterwards ammoniacal and fetid: the addition of acetic acid prevents the putrefaction without impairing the adhesive power of the gelatin.

Gelatin is insoluble in alcohol and ether, and in the fixed and volatile oils. When a strong aqueous solution of gelatin is dropped into alcohol, it forms a white adhesive and elastic mass, which adheres strongly to the glass, and which, like dry gelatin, softens, but does not dissolve in cold water.

When chlorine is passed through a warm and somewhat concentrated solution of gelatin, each bubble becomes covered with an elastic film, and deposits, on bursting, a white, tough viscid matter; the whole of the gelatin is thus precipitated, and free muriatic acid is formed. This chloride of gelatin is insoluble in water and alcohol, and remains acid, and smells of chlorine, even after it has been kneaded in warm water Dissolved in caustic ammonia in a tube over mercury, it evolves nitrogen and becomes mucilaginous. It is soluble in acetic acid; but the solution, though rendered turbid by dilution, gives no precipitate by ferro-cyanuret of potassium, so that the gelatin is not thus converted into albumen, No analogous compound is produced either by iodine or bromine.

The action of sulphuric acid on gelatin has been studied by Braconnot.* When one part of glue and two of sulphuric acid are mixed, they form in twenty-four hours a clear fluid, which, when diluted with eight parts of water, boiled for eight hours, (the loss by evaporation being replaced by fresh portions of water,) and then neutralised by chalk, filtered, evaporated to the consistency of syrup, and set aside for a month, yields a crystalline crust of a peculiar saccharine substance, which is insoluble in alcohol and ether, unsusceptible of vinous fermentation, and gives ammonia by destructive distillation. It combines and forms a peculiar crystallisable compound with nitric acid, which he calls the *nitro-saccharic acid*, and which combines with the salifiable bases and forms distinct salts, the properties of which closely resemble the *carbazotates*.

Dilute nitric acid dissolves gelatin without the evolution of nitrous gas, and forms a yellow solution, which, by evaporation, (or the addition of an alkali,) becomes darker, and at last evolves nitrous gas, and passes (often with ignition) into a spongy coal.† By concentrated nitric acid gelatin is converted into malic and oxalic acids, a fatty substance, and artificial tan.‡

Acetic acid dissolves gelatin and the solution does not gelatinise, but upon drying, the adhesive power of the gelatin is unimpaired: the dilute acids do not generally prevent gelatinisation.

Neither the dilute caustic alkalis nor ammonia prevent the concretion of a solution of gelatin, but they render it turbid by precipitating its phosphate of lime. Gelatin is soluble in strong caustic potash, with the exception of a residue of phosphate of lime. The solution, when neutralised by acetic acid, does not gelatinise, and yields on evaporation a compound of gelatine with acetate of potash, which is soluble in alcohol. Sulphuric acid precipitates sulphate of potash from this acetic solution, in combination with gelatin; and this compound precipitate, dissolved in water, crystallizes by spontaneous evaporation to the last drop.§

Hydrate of lime does not affect a solution of gelatin, but much lime is dissolved by it: it also takes up a considerable quantity of recently precipitated phosphate of lime.

Gelatin is not precipitated by solution of alum, but when an alkali is added the alumine falls in combination with gelatin. The aluminous solution of gelatin is used for sizing paper, and for communicating to woollen cloth a certain degree of impenetrability to water.

The acetates of lead do not precipitate pure gelatin; by corrosive sublimate its solution is

* Nicholson's Journal, xi. 244.

* Annales de Chim. et Phys. xiii.

† Hatchett, Phil. Trans. 1800, p. 360.

‡ Ibid.

§ Berzelius.

rendered at first turbid, and when excess is added a white adhesive compound falls: nitrate and per-nitrate of mercury and chloride of tin occasion nearly similar changes. But the metallic salt which is the most decided precipitant of gelatin, and which does not affect albumen, is sulphate of platinum; it throws it down even from very dilute solutions, in the form of brown flocculi, which, when collected and dried, become black and brittle, and which, according to Mr. Edmund Davy, to whom we owe this effective test, consist of about 76 per cent. of sulphate of platinum and 24 per cent. of gelatin and water.

We now come to the most important and characteristic property of gelatin, which is, that of combining with tannin, and upon which the art of tanning, or the conversion of skin into leather, essentially depends, for the true skin *(cutis)* of animals consists of a condensed and fibrous form of organised gelatin, and, when properly prepared and immersed in a solution of vegetable astringent matter or tannin, it becomes gradually penetrated by and combined with it, and when dried is rendered insoluble and durable. The tannin of the gall-nut is perhaps that which forms the most insoluble precipitate in gelatinous solutions, and is therefore the most delicate test of the presence of gelatin; but, as albumen is also thrown down by it, the absence of the latter must have been previously ascertained. (See ALBUMEN.) A strong infusion of galls occasions a precipitate in water holding less than a five-thousandth part of gelatin in solution, and, if added to a strong solution of gelatin, it throws it down in the form of a curdy precipitate, more or less dense and coloured according to the greater or less excess of the precipitant. The precipitated compound is insoluble in water, dilute acids, and alcohol, and when dried becomes hard and brittle, but again softens and acquires its former appearance when soaked in water: it may be termed tanno-gelatin. When tannin is added to a solution of gelatin, the latter being in excess, and especially if it be warm, no precipitate is immediately formed, for tanno-gelatin, when recently precipitated, is to a certain extent soluble in liquid gelatin. Tanno-gelatin does not appear to be a definite compound; at least it is difficult to obtain it as such: the precipitate by infusion of galls consists, when carefully dried, of about 40 per cent. of tan and 60 of gelatin. When obtained by other astringents, such as oak-bark, catechu, and kino, it differs in the relative proportion of its components and in its other characters, and often contains extractive matter. According to Sir H. Davy,* 100 parts of calf-skin thoroughly tanned by infusion of galls increase in weight 64 parts; by strong infusion of oak-bark 34, and by weak 17; by concentrated infusion of willow-bark 34, and by dilute 15; and by infusion of catechu 19.

Mr. Hatchett's researches have shewn that gelatin is also precipitated by the varieties of artificial tan, and that the compound thrown down resembles in its leading characters the tanno-gelatin of natural tan. The ultimate composition of gelatin (pure isinglass) has been quantitatively determined by Gay Lussac and Thenard, with the following results:—

	Atoms.	Equiv.	Theory.	Experiment.
Nitrogen	1	14	16.09	16.998
Carbon	7	42	48.28	47.881
Hydrogen	7	7	8.04	7.914
Oxygen	3	24	27.59	27.207
	1	87	100.00	100.000

As the combining proportion of gelatin has not been accurately ascertained, its equivalent number, as above given, is open to doubt, but it is probably correct, and the theoretical and experimental results closely correspond.

(W. T. Brande.)

GENERATION, ORGANS OF, (Comparative Anatomy).—Few subjects connected with physiology have been investigated more assiduously than that of the generation of animals; and in none, perhaps, has the poverty of our knowledge of the operations of nature been more conspicuously exemplified. In studying many functions of the animal economy, the laws of chemistry and mechanics have been successfully appealed to by the philosopher, and their application to the operations of the animal frame satisfactorily substantiated; but in attempting to explain the wonderful process by which organized bodies are perpetuated, all the resources of modern science have been found totally inadequate to the task, and we are still left to record facts and observations concerning the structure of the organs appropriated to the propagation of animals, without being in any degree able to connect them with the results so continually offered to our contemplation. In taking a general survey of the animal kingdom, we are at once struck with the infinite variety of forms which it presents, adapted to an endless diversity of circumstances, and might expect to meet with a corresponding dissimilarity in the organization of the generative apparatus peculiar to each: no such dissimilarity, however, exists in nature, the modes of reproduction conform to a few grand types, and the increasing complexity of parts, apparent as we ascend to higher classes, which it will be our business to trace in this article, will be seen to depend rather upon modifications in the arrangement of secondary structures than upon any deviation from the fundamental organization of the more immediate agents.

Without entering upon any discussion concerning the theories which have from time to time been advocated relative to spontaneous generation, we shall divide all animals as relates to the generative function into three great classes, grouping together such as are

1st. *Fissiparous*, in which the propagation of the species is effected by the spontaneous division of one individual into two or more, precisely resembling the original being.

* Philos. Trans.

2nd. *Gemmiparous*, in which the young sprout as it were from the substance of the parent.

3rd. *Oviparous*, producing their offspring from ova or germs developed in special organs adapted to their formation.

Of these modes of reproduction the two first are confined to the lowest or acrite division of the animal kingdom, whilst the third or oviparous type is common to all other classes.

Fissiparous generation is the simplest possible, and presupposes a corresponding simplicity of structure in the animals which propagate in this manner. It is principally confined to the Polygastric animalcules, most of which are multiplied by the spontaneous separation of an individual into two portions precisely resembling each other, and capable of performing all the functions which originally belonged to the undivided creature. Some of the larger species of Trichoda are well calculated to exhibit to the microscopic observer the steps by which this process is accomplished: the animalcule, prior to its division, is seen to become slightly elongated, and a transparent line is gradually distinguishable, indicating the course of the intended fissure; at each extremity of this line a contraction of the body is speedily observable, and the lateral indentations become deeper and deeper, till at length a perfect separation is effected. The direction in which this division occurs is not always the same even in the same species; thus, instead of traversing the shorter axis of the body it not unfrequently assumes a longitudinal or oblique direction, and from this cause it is not unusual to find the newly divided creatures differing materially in appearance from their adult or rather conjoined form; for in this process the old animalcules literally become converted into young ones.

In some of the more complex forms of Polygastrica the fissiparous mode of generation exhibits modifications which are extremely curious. In the beautiful *Vorticellæ*, whose bell-shaped bodies are supported on long and exquisitely irritable stems, the division commences at the large ciliated extremity of the animalcule, from which point it gradually extends in a longitudinal direction towards the insertion of the stem, dividing the body into two equal portions, one or both of which becoming speedily detached from the pedicle, might easily in this state be mistaken for creatures of a different genus, and have in fact been described as such by many authors. The new animalcule, when thus deprived of its pedicle, is seen to be furnished with cilia at the opposite extremity to that on which they were previously found, while from the other end, originally the mouth, a new foot-stalk becomes gradually developed, and the creature assumes the shape proper to its species. If one of the bells remain attached to the pedicle, it continues to perform the same movements as before the separation of the new animalcule; but if both become detached, the foot-stalk perishes.

In the strangely compound symmetrical bodies of *Gonium* a provision for separation appears to be made in the detached portions of which each perfect animal is apparently composed. The body of *Gonium pectorale* consists of sixteen minute transparent globes of unequal size, arranged in the same plane. This beautiful animalcule is propagated by a separation of its integrant spherules, the creature dividing into four portions precisely similar to each other, and composed individually of one of the central globules united to three of the smaller marginal ones; and no sooner is the division accomplished than the component globes of each portion increasing in number, the new animalcules assume the dimensions and appearance of that of which they originally formed parts.

In the *Gonium pulvinatum* the fissiparous mode of generation gives origin to a still more numerous progeny. The young animalcule is a minute, flat, diaphanous and quadrangular membrane, which swims through the fluid in which it is found by movements sufficiently indicative of its animal nature: as it enlarges, the surface is seen to become marked by two series of parallel lines which cross each other at right angles and divide the creature into smaller squares, which ultimately separate and become distinct representations of the original animalcule.

Some of the Nematoid worms, as the Nais, are likewise said to propagate by spontaneous division.

Gemmiparous generation.—This mode of reproduction, like the fissiparous, is confined to the lowest tribes of animal existence, and the creatures which propagate in this manner are unprovided with any apparatus specially appropriated to generation. The young appear as gemmæ or buds, which at certain periods sprout from the homogeneous parenchyma which composes the body of the parent, and these buds gradually assuming the form of the original by a kind of vegetative growth, become in a short time capable of an independent existence. The gemmiparous type of the generative function is met with through a wider range of the animal kingdom than the last, existing under modified forms in many species of Polygastric Infusoria, and of Polyps, as well as in Sponges, the Cystiform Entozoa, and probably in some Acalephæ.

It is in the Cystoid Entozoa that we find it in its simplest form. In the Cysticercus and likewise in the Cœnurus, the transparent membranous bag of which the animal consists is filled with a glairy fluid, in which occasionally young hydatids are seen floating about. These young Cysticerci in the earliest period of their formation are seen to pullulate from the parietes of the parent sac, and gradually enlarging they ultimately separate from their connexions, becoming detached and perfect animals.

Many of the Polygastrica are multiplied by a similar process, of which the *Volvox globator* may serve as an illustration. This beautiful animalcule is a minute diaphanous globe, which under the microscope is generally seen to contain a variable number of smaller globules, which are the young: these, when first discoverable, are attached to the inner surface of the parent, but speedily detaching themselves they are found rolling loosely within the body of the larger animalcule, effecting their rotatory movements by the agency of cilia of extreme minuteness, which under a good microscope are seen to cover their external surface. The contained globules having attained a sufficient maturity, the parent volvox bursts, and thus by its own destruction allows its progeny to escape from their imprisonment. The multiplication of these animalcules is effected with considerable rapidity, and it not unfrequently happens that even before the escape of the second generation the gemmules of a third may be observed within their bodies, which in like manner advancing through similar stages of development will terminate by their birth the existence of their parent.*

It would appear from the observations of Professor Grant, that in the sponges, notwithstanding their different form, the process of reproduction is entirely similar. In these curious animals the gemmules are developed in the substance of that living parenchyma which coats their porous skeletons, and when mature are expelled through the fœcal orifices to commence an independent existence. When separated from the parent sponge, these gemmules, like those of the volvox, are ciliated over a great portion of their surface, and being thus endowed with a power of locomotion, are enabled to swim to a considerable distance in search of a situation adapted to their future growth, until having at length selected a permanent support, they become attached, and developing within themselves the spicular or horny skeleton peculiar to their species, they gradually assume the porous texture and particular character of the sponge from which they were produced.

But it is in the gelatinous Polypes that we meet with the most perfect forms of gemmiferous propagation : of this the *Hydra viridis*, or fresh-water polype, affords an interesting illustration, and from the facility with which it may be procured and examined by glasses of very ordinary powers, it is well calculated to illustrate the mode of generation which we are at present considering. The body of this simple polype is transparent, and under the microscope appears to be entirely made up of translucent granules, without any trace of internal apparatus appropriated to reproduction. The gemmules by which it is propagated sprout from some part of the surface, appearing first as mere gelatinous excrescences, but gradually enlarging they assume the form of their parent, acquiring similar filamentary tentacles and a gastric cavity of the same simple structure. As long as the junction between the polype and its offspring continues, both seem to enjoy a community of being, the food caught by the original one being destined for the nourishment of both ; but at length, the newly-formed animal having attained a certain bulk, and become capable of employing its own tentacles for the prehension of food, detaches itself with an effort, and assumes an independent existence. This mode of multiplication is exceedingly rapid, a few hours sufficing for the perfect developement of the young creature ; and not unfrequently even before its separation, another gemmule may be observed emerging from the newly-formed polype, soon to exhibit the same form and exercise the same functions as the parent from which it sprouts.

The propagation of some of the lithophytous polypes resembles that of the *hydra*, the young being produced from buds or gemmules, which sprout from the living investment of their calcareous skeleton. Such are the *Fungiæ*, in which the young are at first pedunculated, and fixed to the laminæ upon the upper surface of the mass from which they spring ; in this state they might readily be mistaken for solitary Caryophyllia, but in time they separate from the parent stock, and loosing the pedicle which originally supported them, they assume the form of their species.

Oviferous generation.—In the third, and by far the most numerous division of the animal kingdom, the young are derived from ova or eggs, in which the germ of the future being is evolved, and from which the young animals escape in a more or less perfect state.

It will be seen that the ovum which gives birth to all the higher animals differs essentially from the gemma furnished by the gemmiferous classes ; in the gemmiferous type the bud or offshoot of the parent appears by a kind of vegetative evolution to assume the proportions and functions of the original from which it sprang. The ovum we would define as a nidus, containing not only the germ of the future animal, but a sufficient quantity of nutritious matter, serving as a pabulum to the embryo during its earliest state of existence, and supplying the materials for its growth until sufficiently mature to derive them from other sources. We have already shewn that in the fissiparous and gemmiferous animals there is no necessity for any special generative apparatus, but in the oviferous classes we find, for the most part, a distinct system, more or less complicated in structure, in which the reproductive ova are developed and matured. It must be confessed, however, that in the present state of our knowledge upon this subject we are not prepared to state how far the existence of a generative system is exclusively confined to the ovigerous type. We are well aware that many authors describe generative canals to exist in several of the polypiferous tribes, although the reproductive germs produced from them resemble in their ciliated organs of progression and mode of development the gemmules of less elaborately organized polypes ; yet, on the other hand, as we have abundant evidence to prove that such polypes as have the ovigerous canals most distinctly formed, as the Actiniæ for instance, produce their young perfectly organized and evidently developed from true ova, we are content, in the present state of our knowledge upon this subject, to regard the presence of generative canals as co-existent with ovigerous generation, and shall leave

* [Some physiologists, however, refer the generation of this creature to the fissiparous mode. See the succeeding article.—Ed.]

future observations to determine more accurately the mode of reproduction in the corticiferous polypes, which is a subject at present involved in much contradiction and obscurity.

Taking this view of the subject, we find, upon cursorily glancing over the ovigerous classes of animals, that important modifications of structure in the generative system render further classification necessary. In the lower forms, ovigerous organs only have been discovered, in which the ova are secreted, and when matured, escape from the body, fit in every respect for the production of a new animal. In other instances, in addition to the apparatus immediately appropriated to the developement of the ova, we find a superadded portion destined to furnish a secretion which is essential to their fertility, forming an *apparatus of impregnation*. Sometimes the impregnating organs are found in every individual, appended to the ovigerous parts, rendering each creature sufficient for the impregnation of its own ova: in other instances, although each animal possesses both ovigerous and impregnating organs, the cooperation of two individuals or more is necessary to fertility; and in other cases again, the apparatus which furnishes the ova, and that destined to the production of the impregnating fluid, are found in distinct individuals, distinguished by the appellations of male and female: we shall accordingly divide all oviparous animals into the following groups:—

1. Such as are provided with ovigerous organs only.

2. Animals having, in addition to the ovigerous apparatus, a glandular structure, the secretion of which is probably subservient to the fertility of the ova.

3. Ovigerous and impregnating organs, coexistent in each individual, but the cooperation of two or more needful for mutual impregnation.

4. The ovigerous and impregnating apparatus existing in distinct individuals.

First Division.—*Animals in which ovigerous organs only have been distinctly recognized.*

It would seem from the observations of Ehrenberg that some of the Polygastrica belong to this division, although the exact nature of the generative system in such species remains still a matter of uncertainty. In the Kolpoda Cucullus the spawn consists of a loose mass of ova, connected by delicate filaments, from which the young are gradually evolved after their extrusion from the parent animalcule, and some of the parenchymatous Entozoa appear to be similarly circumstanced.

In the Acalephæ, at least in such as have been most attentively examined, the generative system conforms to the type at present under consideration. From the researches of Gaede and Eysenhardt it appears that the ovaria are four in number, disposed in a cruciform manner upon the dorsal aspect of the body or that which is opposite to the mouth. These ovaria, which at certain seasons of the year are remarkably distended and often beautifully coloured, open into the interior of the stomach. The young Medusæ are hatched in the ovaria, and afterwards escaping into the alimentary canals excavated in the substance of the body, acquire in that situation a very perfect state of development, and are ultimately excluded through the oral aperture, or in the Rhizostomatous species through the ramified canals of the pedicle.

In the fleshy polypes (Actiniæ) the ovigerous system consists of long, convoluted filiform tubes, contained between the stomach and the parietes of the body, and separated by partitions which divide that space into compartments. These tubes are attached by a delicate mesentery, and according to Spix open in an irregular manner into the digestive cavity, into which the ova escape. The period or mode in which the eggs are hatched is unknown, but that the young escape fully formed and in every point resembling their parent through the stomachal orifice is attested both by Dicquemare and Blainville.*

The different forms of Echinodermata present a similar simple arrangement of the generative apparatus. In the Asteriadæ each ray is furnished with two clusters of short ovigerous tubes, which are closed at one extremity, but open at the other into a cavity common to each group. These organs open by a series of apertures placed around the circumference of the mouth at the base of each ray. In the spring these ovaria are distended with eggs of a reddish-brown colour, which are expelled in clusters and left upon the beach exposed to the influence of the sun, where they are ultimately hatched.†

The radiated type of structure is likewise manifest in the disposition of the generative organs of the Echinidæ: in these the ovaria are never single or simply bilobed, but are at least four in number, or, as is generally the case, five. Each ovigerous organ consists of a simple dilated sacculus, which at certain seasons is distended with ova, and at such times in some species, as in the edible Echinus, the eggs are sought after as an article of food. The ovaria open externally by a corresponding number of simple apertures, which are placed around the anal orifice when it is central, but otherwise are considerably removed from this point. Nothing analogous to a male apparatus has been detected in the Echinida. The eggs are deposited in spring in the recesses of rocks or among the fucus which covers them; and before they are hatched the young may be discovered in the interior partially covered with a calcareous shell, the rest of the integument still remaining membranous.

* Spix and Dello Chiaje assert that there are other filiform tubes mixed up with the ovarian ducts, which they regard as the testes, but neither the observations of other authors nor our own examinations confirm this view of the subject.

† Tischer and Spix describe a singular flexuous intestiniform organ which is found upon the dorsal aspect of the stomach as a male apparatus, and Blainville considers this part as in some degree connected with generation.

The Holothuridæ present in the elongated form of their bodies an evident approximation to the annulose type of structure, and a proportionate concentration of the generative system; in these we find but one ovary floating loosely in the visceral cavity, and composed of numerous very long cœca, which terminate by a single orifice placed on the median line, near the oral extremity of the animal.* The eggs when discharged are connected into masses composed of long strings of ova, but the mode of their development is but little known.

Although from the relations of the Molluscous division of the animal kingdom we might infer that a more elevated type of structure would characterize their organs of reproduction, the present state of our knowledge of the anatomy of these creatures compels us to arrange the lowest orders of that extensive class with those tribes which only possess an ovigerous system; for although an androgynous conformation is presumed by many to exist in all Bivalves, the presence of any superadded impregnating portion has not yet been pointed out, and even the course of the ova in their passage from the ovarian cavity remains a matter of speculation. In the Conchiferous order, from causes sufficiently obvious when we consider the peculiar structure of the animals which compose it, the full development of their numerous ova could not be accomplished in the ovary itself, which occupies a large portion of the body, as any material increase of bulk produced from this cause would materially interfere with the closing of the shell; at an early period, therefore, the ova are transferred from the nidus in which they were formed to the branchial fringes, between the laminæ of which they perfect their growth, and are fully exposed to the influence of the element around them. Oken traced a canal through which he supposed the ova to be conveyed directly from the ovaria to the gills;† but notwithstanding his observations Carus contends‡ that the eggs pass into the stomach through one of the openings hitherto considered as belonging exclusively to the biliary ducts, whence they are evacuated through the mouth and conveyed into the openings of the gills by the water which flows between the pallial laminæ from before backwards, and ultimately escape by two canals which open below the anal tubes.

In the Tunicata, and also in those forms of the Gasteropodous Mollusca which most nearly approximate the Conchifera in the details of their organization, the ovary is imbedded in the substance of the liver, and the ova are discharged through a simple duct, unprovided with any appendage which can be looked upon as a male apparatus. It is true, indeed, that in all these cases the walls of the oviduct may themselves furnish a fertilizing fluid, and by many physiologists they are supposed thus to supply the want of male parts; such an hypothesis, however, is, to say the least of it, entirely gratuitous; but as it is more our business to trace the development of organs than the modes in which their deficiency may be supplied, we are content to leave the question without further discussion in this place.

Second Division.—*Animals provided with ovigerous organs combined with an additional secreting structure, probably subservient to the fertilization of the ova.*

In this type of the generative system it must be obvious that the function attributed to the superadded portion is by no means indubitably substantiated, the opinions of physiologists relating to its office being rather based upon analogical reasoning than supported by direct evidence; and, in fact, some authors deny entirely that a necessity for the impregnation of the ova is more evident in this division than in the last. Nevertheless, although it is impossible distinctly to prove the identity in function between the appended portion and the testis of higher forms of organization, the evidence afforded from the position which it invariably occupies, and from the consideration of the parts connected with generation in diœeious animals to which we are insensibly conducted by this species of Hermaphrodism, is sufficiently cogent to warrant our application of the term ovarium to the nidus wherein the ova are produced, and to justify us in designating the accessory organ as a testis or apparatus for impregnation.

The Tænioid Sterelmintha furnish us with one of the simplest examples of this arrangement of the generative organs. In the long and tape-like bodies of these Entozoa each segment, with the exception of the smaller ones near the head, possesses distinct ovigerous and impregnating structures. The female part of the apparatus occupies the centre of the joint, and consists of lateral tubes ramifying from a central canal, which at times may be seen to be full of minute granular ova. From these ovigerous canals a duct issues, which communicates with the lateral pore and receives before its termination two delicate tubes, recognizable under the microscope as dark lines imbedded in the pulpy segment, and which may be presumed to furnish an impregnating secretion.

In the *Rotifera*, or wheel-animalcules, the female apparatus consists of two long and comparatively wide sacculi, in which the ova are developed; these open at the anal orifice, and receive near this point two narrow cœca, which, as in the last case, may secrete a fertilizing fluid, serving to impregnate the eggs prior to their expulsion. The ova of these minute creatures, before the escape of the young, are exceedingly beautiful subjects for the microscope, the wheels of the embryo

* Here, also, Blainville conjectures that there is a supplementary impregnating portion, but it is evident that in a treatise like the present it would be worse than useless to recapitulate the surmises of authors upon subjects only capable of solution by positive demonstration, and we shall therefore endeavour rather to adhere strictly to the narration of what is clearly established by observation, than to indicate what theory or analogy would lead us to suspect.

† Goetting, gel. Anzeigen, 1806.

‡ Introduct. to Comp. Anat.

being easily distinguished in rapid action through the pellucid coverings of the egg.

In the Cirrhopoda we have most probably an example of this mode of generation, presuming, that is, that the opinions of Cuvier upon this subject are correct. These opinions, it is true, have been disputed by various authorities, as will be evident on reference to the article CIRRHOPODA; but their correctness has been so fully supported by the dissections of John Hunter, recently given to the world,* that it seems best at least to pause before repudiating the conclusions to which these great anatomists, unacquainted with the labours of each other, were individually conducted. In the Cirripeds the ovaria are two in number, placed on each side of the stomach; the two oviducts which proceed from these unite to form a single elongated tube, the parietes of which are thick and apparently glandular. It is evident that in this case the walls of the common canal, or ovipositor as it is usually termed, may serve to secrete a seminal fluid, impregnating the eggs at the period of their extrusion; and such, in the opinion of the authors above mentioned, is a part of its office.

THIRD DIVISION.—*Ovigerous and impregnating organs co-existent, but the co-operation of two individuals necessary for mutual impregnation.*

This arrangement of the generative system occurs in some of the Parenchymatous Entozoa, in the Annelida, and also in the Pteropod and some Gasteropod Mollusca. Some of the Entozoa, as *Fasciola* and *Planaria*, furnish the simplest examples of this hermaphrodite condition. In these creatures the male organs consist of spermatic cœca, communicating with a minute extensible penis, which is placed behind the oral sucker. Near the penis a small orifice is seen, leading to the ovigerous canals, which have no communication with the impregnating apparatus; and the copulation of two individuals is thus indispensable to a reciprocal fertilization of the ova.

Those of the Annelida in which the generative system is best understood are androgynous, and mutually impregnate each other, although it is probable that in the tubicolous genera, which are immoveably fixed to the same spot, and almost deprived of locomotion, each individual may in itself be sufficient for reproduction.

In the Abranchiate and Dorsibranchiate Annelida the male apparatus is composed of several pairs of secreting bodies, arranged on each side of the mesial plane, those of the same side communicating with each other by a common vas deferens. In the Leech the vasa deferentia, which convey the secretion of the numerous testicular masses, terminate in a long protractile tubular penis, and at a short distance behind this the opening which leads to the female parts may be discovered. These latter consist of a simple uterine sacculus, or receptacle for the ova, to which two minute ovaries are appended. The congress of two individuals is effected by the reciprocal introduction of the organs of intromission into the vulvæ. In the Earthworm and Nais the intromittent apparatus is deficient, so that some authors have even doubted that the process of copulation, which is undeniably essential to fecundity, does more than stimulate each individual to self-impregnation. In the Earth-worm, as well as in Arenicola and Aphrodita, the ova, after escaping from the ovaria, are retained in the cellular meshes which surround the alimentary canal, in which they are not unfrequently hatched, the young being most probably expelled through a tubular aperture at the posterior extremity of the body.

As regards the generative system, the Pteropod Mollusca approximate the more complex type seen in the Gasteropoda. In *Clio borealis*, the ovary, which is partially enveloped by the liver, gives off a slender duct, which, after a short course, plunges into a glandular tube; this, becoming gradually narrower, terminates in a round sac placed on the left side of the head, where it opens externally: near this point is the penis, or organ of intromission, communicating with a small sacculus, by which the male secretion is probably furnished.

Fig. 200.

Testis of Helix.

The most complicated forms of this species of hermaphrodism are met with in the Gasteropod division of Mollusca, existing throughout the Nudibranchiate, Tectibranchiate, Inferobranchiate, and Heteropod orders, as well as in those pulmonary genera which are unprovided with a calcareous operculum. In all these cases the testis is single and divided into lobuli, connected together by the divisions of the vas deferens so as to exhibit a racemose arrangement, and each lobule, on minute inspection, is found to consist of little pedunculated vesicles (*fig.* 200). A slender vas deferens conducts the secretion of this testicle to the base of an intromittent organ of a most singular description; this is a muscular tube of great length, which, when not in use, is inverted and concealed within the body, but capable of protrusion at the will of the animal. The female portion of this system is composed of one ovary, provided with an ample and tortuous oviduct, which serves, indeed, as a kind of uterus or egg receptacle, wherein the

* Catalogue of the Physiological Series of Comparative Anatomy contained in the Hunterian Collection, vol. i.

ova are retained until ripe for extrusion. Near the termination of this oviduct are placed several additional appendages, some of which are apparently destined to furnish an investment for the ova, whilst one, which is constantly present, is probably a reservoir for the seminal fluid required to fertilize the eggs as they are expelled. (See GASTEROPODA.)

The external parts are so disposed that during the copulation of two individuals the male organ of each is introduced into the orifice leading to the female apparatus of the other, both thus impregnating and being impregnated at the same time.

In *Lymnæus stagnalis* we have a curious exception to this mode of copulation, for in this animal the sexual organs are so placed that mutual impregnation is impossible, and accordingly fecundation is accomplished by a combination of individuals, each of which performs the office of a male to another, while to a third it acts the part of a female, and long strings of them are often seen thus united.

FOURTH DIVISION.—*Sexes distinct, that is, the ovigerous and impregnating organs placed in separate individuals.*

This type of the reproductive apparatus extends through a wide range of animals, and is found in a great number of classes utterly dissimilar in outward form and internal structure; so that, in order to give a connected view of the comparative organization of the parts of generation, we shall be unavoidably compelled to group together animals widely separated by the laws of zoological arrangement. Feeling, however, that by so doing we shall lay before our readers a much more easily intelligible comparison of the organs belonging to our subject, we shall not scruple to bring together, in one view, analogous forms of the generative apparatus, in whatever classes they may be found. Animals in which the sexes are distinct may be divided into three classes; the first including such as are oviparous, the second embracing the ovo-viviparous orders, while the third will comprehend the strictly viviparous animals. It will be seen that the terms here employed have been used from time immemorial, but nevertheless in a widely different sense to that in which the present state of our knowledge sanctions their application. To us it appears that we ought to regard all creatures as oviparous whose offspring, at the period of their escape from the ovum, are sufficiently mature to admit of their independent existence. In the ovo-viviparous division, on the contrary, the ova are hatched and the embryo expelled at an early period of its formation; the embryo is thus born in an extremely imperfect state, the materials for its future developement being supplied by the mammary secretion of the parent; such is the case with all the marsupial orders. In the vivipara the earliest stages of growth are precisely similar to those which mark the progress of evolution in the oviparous type, and the provisions made for the nourishment of the rudimentary being in every respect analogous; the great distinction consists in the subsequent maturation of the embryo within a uterine cavity, and the formation of a placenta, which characterizes the highest form of mammiferous animals.

The oviparous classes, which form by far the most numerous division, produce their young from ova, in which the germs of the future beings are developed for the most part subsequent to the expulsion of the egg from the body of the parent. In this case the ovum necessarily contains a sufficient store of nourishment for the support of the embryo during the whole period of fœtal life, at the termination of which it is produced in a sufficiently advanced stage of its growth to render it capable of independent existence. It will readily be perceived that under this division we include many animals which, according to the old meaning of the terms, were looked upon as ovo-viviparous or viviparous in their mode of reproduction; a distinction which, as the words have been hitherto applied, appears to the writer by no means sufficiently grounded upon physiological views to admit of its continuance. It is certainly very true that some animals included in this division are found to produce their young in a living state; but the mere hatching of the egg within the oviductus of the mother, instead of subsequent to its expulsion, is not a circumstance of sufficient importance to be regarded as constituting another type of the generative process, more especially as such an occurrence is entirely fortuitous, observation having proved that the same animal at one time produces its young alive and at another in the egg state, in obedience to circumstances connected with food, temperature, or confinement. With this extension of the term, oviparous animals in which the sexes are distinct will be found in many classes belonging to the diploneurose, cyclogangliate, and vertebrate divisions of the animal kingdom, combined with modifications in the structure and arrangement of the generative apparatus, which it will be our business to trace.

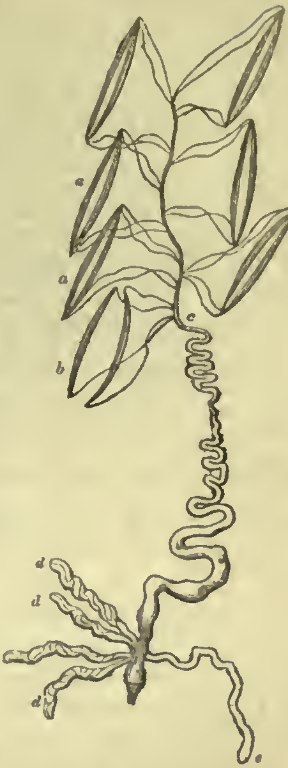
The earliest appearance of this type is found in the cavitary Entozoa (Cœlelmintha), and the sexual organs, both in the male and female of these creatures, may be regarded as exhibiting the greatest possible simplicity of structure, consisting merely of secreting tubes, which in one sex produce the seminal fluid, in the other develope the ova. The seminal organ, or testis of the male, is generally a single tube of extreme length and tenuity, winding in large folds around the alimentary canal, and occupying a large portion of the abdominal cavity; when unravelled, its length is found to be many times that of the animal; at one extremity it dwindles down to a filament of the utmost tenuity, which floats loosely in the juices of the body, whilst at the opposite end it terminates in a prolonged tubular penis, or organ of intromission, placed near the anal orifice. In the females of some species, as in *Ascaris*, the ovigerous system is composed of two tubes, each exceeding in length and tortuosity the seminal vessel of the male, and measuring in some cases upwards of six feet. These tubes, after becoming considerably increased in size so as to form a kind of receptacle for the ova which they generate, unite prior to their termination in the vulva, the aperture of which is found upon the ventral surface of the body at about one third of its length from the anterior extremity. In Strongylus the ovarian tube is single, and its orifice nearer to the mouth. In many species, as Filaria, the young are produced alive, the ova being hatched in the oviduct, a sufficient proof of internal impregnation having been accomplished.

The *Myriapoda*, in every part of their structure, form the transition from the *Annelida* to the articulated classes properly so called. They are divided by entomologists into two classes, the *Iulidæ* or *Chilognatha*, and the *Scolopendridæ* or *Chilopoda*, a division strictly in conformity with their internal structure; the former in fact represent the Annelida; like the Abranchiate division of that class, they breathe by air-sacs, communicating with spiracles seen upon the exterior of their bodies. The Scolopendræ, on the contrary, respire by tracheæ, which permeate their viscera, as in the insect classes. In the generative system of these creatures a similar relationship is evident. In *Iulus*, the generative system occupies the anterior segments of the body, the sexual apertures being found upon the rings near the cephalic extremity, whilst in Scolopendra they are placed, as in insects, near the anal orifice. As regards the internal sexual organs of Iulus, but little is known conclusively, and our own researches upon this point have not been sufficiently satisfactory to enable us to speak positively concerning them, although the result leads us to suspect that in these creatures not only are the sexual parts analogous to those of the Annelida, but that, as in many of that class, the ova are retained in cellular interstices surrounding the intestinal canal for some time prior to their expulsion.

In the Scolopendra the generative organs are more easily distinguishable, and much resemble those of insects; they are, however, exceedingly curious. In *fig.* 201 we have represented the male apparatus of the *Scolopendra morsitans*. The testes (*a, a, a*) are seven in number, and closely packed in parallel lines; each testis is composed of two parts, precisely similar to each other, which are seen separate at *b*; from each extremity of the fusiform testis arises a narrow duct, so that there are fourteen pairs of ducts arising from the fourteen secreting organs. Each of the testicular bodies is hollow internally. The ducts ultimately end in a common tube (*c*), which soon becomes enlarged and tortuous, terminating by a simple aperture near the anus. Just prior to its termination, the enlarged canal receives five accessory glands, four of which (*d, d, d, d*) are intimately united, until unravelled, as seen in the figure, while the fifth (*e*) is a simple cæcum of considerable length.

The ovarian system of the female Scolopendra is a single tube, apparently without secondary ramifications.

Fig. 201.



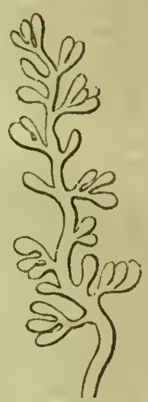
Male generative organs of the Scolopendra morsitans.

Insects.—In the numerous and diversified tribes of the insect world a great uniformity is observable in the general arrangement of the generative apparatus. The sexes are invariably separate, but while the internal organs are constantly double and symmetrically disposed on both sides of the mesial plane, the external parts which are subservient to copulation are removed to the posterior extremity of the body, and are single. Throughout the whole class the sexual system only arrives at that state of perfection which is compatible with reproduction in the perfect or imago state of the animal, although it may be detected in a rudimentary form even in the larva, being gradually more and more perfected during the developement of the pupa. The business of procreation in insects thus exclusively belonging to the perfectly formed creature, is accomplished only at the termination of their existence, and the whole tribe is remarkable from this circumstance.

The internal generative organs in male insects are described as consisting of three portions, the testes with their vasa deferentia, the vesiculæ seminales, and the canalis excretorius. The testes, or, in other words, those portions of the apparatus which are supposed to furnish the essential part of the fecundating fluid, like the rest of the glandular system, consist of cæca or utricles floating loosely in the abdominal cavity, immersed in the juices of the body, from which they derive their secretion. Nevertheless, although essentially constructed upon similar principles, the testicular cœca present a singular diversity of form in different genera, and some of the modifications are sufficiently curious, although in the present state of our knowledge it would be hopeless to attempt to explain the reason of their existence. Müller, from a comparison of the researches of various authors upon this subject, has given the following summary of the principal forms of the sperm-secreting organs, and although the catalogue of varieties might doubtless be considerably extended, those given will abundantly answer our present purpose. Beginning from the tubular vessel, which is the simplest form of the testis, he traces it through the various complications here enumerated.

1. Simple tubes not branched, but more or less convoluted and closed at one extremity.
2. Spiral tubes similarly closed, as in *Sphodrus terricola.*
3. Spiral tubes rolled up into little balls, as in *Carabus auratus, Aptinus displosor, Dytiscus,* &c.
4. Simple tubes irregularly branched, each branch vesicular near its extremity, as in *Prionus coriarius.*
5. Simple tubes, divided in a verticillate manner, each division being terminated by a capsule; *Scarabæus nasicornis,* (Swammerdam.)
6. Simple tubes, divided as the last, but each division ending in a vesicle, as in *Trichius fasciatus.*
7. Simple tubes ending in stellated capsules, the apices of which are produced into slender tubes; *Nepa cinerea,* (Swammerdam.)
8. Simple tubes giving off a series of canals, each of which is terminated by a disc-shaped capsule; *Cetonia aurata.*
9. Simple tubes, ending in flower-shaped capsules, i. e. each capsule consisting of a central vesicle, with other smaller ones placed around it, as in *Asida gigas, Œdemera calcarata, Diaperis violacea, Tenebrio obscurus, Œdemera cærulea,* &c.
10. Simple tubes, each terminated by a transverse capsule, resembling the anther of a flower, as in *Apis, Bombyx, Scaris, Calvinia,* &c.
11. Simple tubes, dividing into minute radiating utricles; *Bostrichus capucinus.*
12. Simple tubes, each terminated by a capsule, which is covered externally with innumerable little vesicles or utricles, as in *Musca asilus, Elater murinus, Blaps gigas, Telephorus fuscus.*
13. Simple tubes, ending in an elongated sacculus, to the sides of which are appended small vesicles arranged in longitudinal rows, as in *Scmblis bicaudata.*
14. Simple tubes terminating in verticillate utricles, as in *Clerus alveolarius.*
15. Simple tubes, from which arise utricles arranged like the teeth of a comb, as in *Hydrophilus piceus.*
16. Simple tubes, terminated by a simple sacculus; *Gyrinus natator.*
17. Simple tubes, terminated by a bunch of vesicles.
18. Simple tubes, dividing into minute canals, forming a kind of cauda equina; *Trichodes apiarius.*
19. Branched tubes, each branch being terminated by a vesicle, as in *Staphilinus maxillosus.* (*Fig.* 202.)
20. Tubes very much branched, some of the ramusculi ending in bunches of leaf-like utricles, others dilating into pedunculated vesicles; *Sylpha obscura.* (*Fig.* 203.)
21. Simple loculated utricles, as in *Ephemera.*

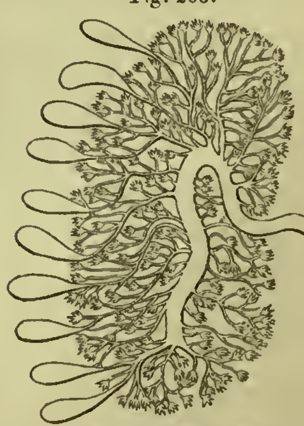
Fig. 202.



Testicle of Staphylinus maxillosus.

It is manifest from this survey that, although the secerning organs differ so much in form, the canals composing them invariably terminate in blind extremities; nor is it less obvious that the nature of the testis does not depend upon any peculiar arrangement of the seminal tubes, but upon the increase of surface obtained by the various arrangement of the vessels. Secretion, therefore, here, as in every other case, is effected by the internal surface of tubes, utricles, sacculi, &c. the same end being accomplished in some cases by means of very long simple canals, which in others is effected by smaller branches, tubes, or agglomerated vesicles.

Fig. 203.



Testicle of Silpha obscura.

Appended to the excretory ducts of the testicular organs, near their termination, is found a group of cœcal tubes, evidently destined to provide an accessory secretion; these have been named from analogy *vesiculæ seminales.* They vary much in their form, being sometimes elongated, tortuous, convoluted, or ventricose, or at others short and straight. The seminal vesicles are generally two in number, even in those Lepidoptera in which the testis is single. In some insects, as *Tenebrio molitor* and *Hydrophilus piceus,* there are four; in others, as *Dytiscus marginalis,* six; and in *Locusta* and *Blatta,* they are very numerous. In some insects these tubes are found to be of surprising length; thus in *Oryctes nasicornis* they are twenty times as long as the body, and in *Cetonia aurata* even sixty times the length of the animal. The vasa deferentia and vesiculæ seminales ultimately terminate in one common tube, the canalis excretorius, which communicates with the root of the penis; this canal is composed of muscular walls largely supplied with tracheal vessels, serving as a receptacle for the genital secretions, and no doubt is the agent by which, during coition, their expulsion is effected. The penis of insects is a hollow tube, capable of being protruded from the anal extremity of the body: its texture is generally membranous, but sometimes horny, and its shape exhibits considerable variety; it is usually cylindrical or nearly so, becoming more slender towards its termination. In *Chermis pyrus,* however, the end is enlarged; in the common *wasp* it is spoon-shaped; in *Crabro* bilobed, and in some *Vespæ* curved and bifid at its extremity. In *Musca vivipara* its apex is covered with spines; in *Tyrophaga putris* and some other Muscidæ it is spiral. The penis of Coleoptera is furnished with a bivalve sheath, destined to open the vulva of the female prior to its insertion. In some Diptera (Muscidæ) a remarkable inversion of the usual arrangement of the organs of copulation is observable; in these the females are provided with a retractile penis, whilst in the males the generative apparatus terminates by a simple aperture. During coition in this case, it is the penis of the female which is introduced into the genital opening of the male, and thus becomes the recipient of the fecundating fluid. The Dragon-flies (Libellula) are remarkable from the position which the male organ is found to occupy, being placed under the anterior part of the elongated abdomen, but in the female the sexual aperture occupies the usual situation near the anus. This arrangement accounts for the singular position which these insects assume during copulation.

In addition to the organs above enumerated as composing the male system in insects, we may notice appendages which are found in some tribes which materially assist in effecting the intercourse of the sexes: these are named *prehensores,* and serve to seize and secure the female during coitus. These holders assume a great variety of shapes, and likewise are differently disposed according to circumstances. They generally surround the aperture through which the penis is extruded, but in Libellula the mode in which the sexes embrace each other renders additional security indispensable; in this tribe, therefore, besides the anal *prehensores,* an additional pair of forceps is placed under the second abdominal segment. The prehensores are generally two in number; but in many Lepidoptera, Conopis and Libellula, three are placed around the anus. In Culex there are two pairs. In *Locusta morbillosæ* there are five, and in Formica six holders. In some tribes, as Megachilis, Agrionidas, and Locusta, they are retracted within the abdomen when not employed.

In insects the ovigerous or female generative apparatus consists likewise essentially of tubes or cœca, the arrangement of which is tolerably uniform. They may be divided into the ovaria, the oviducts, the spermotheca, or receptacle for the seminal fluid of the male, the accessory glands, and the ovipositor, which latter is, in many insects, an instrument adapted to introduce the eggs at the period of their extrusion into situations suited to their developement.

The ovaria are double throughout the whole class, each being composed of a variable number of membranous tubes arising from the oviduct. Rifferschweils considers the ovaries to be formed upon two primary types, being either *flagelliform,* that is, composed of conical tubes of equal length, which are inserted at the same place at the extremity of the oviduct, as in the *Lepidoptera,* the *Bee,* &c.; or racemose, consisting of short conical tubes, so proceeding from the primary branches as to render the ovary racemose or pinnated, such as they are in many *Neuroptera, Coleoptera,* and *Diptera.*

The number of tubes composing each ovary varies in different genera and species; sometimes there are but two, at others four, five, six, eight, or twelve, and in the more prolific insects this number is much increased; thus, in *Acrida viridissima* there are thirty, and in the hive-bee not fewer than a hundred and fifty cœca in each ovarian packet. The number of eggs will of course depend upon the number and divisions of these ovarian tubes, and thus while some insects only lay two, four, or six eggs, others will produce sixty or seventy, and some gregarious insects a much greater number: thus the hive-bee will probably give birth to many thousand young, and in the Termite ant (*Termes bellicosus*) the fecundity of the female is absolutely incalculable. This extraordinary fertility renders indispensable certain restrictions which we find imposed upon this numerous class, tending materially to limit their excessive multiplication. Thus, throughout the whole race one generation only is produced from the same insect, the business of reproduction being usually the termination of its existence; and in the most prolific tribes, namely, those which live in society, as the *Bee* and the *Termite,* one female only in each community is found to be fertile, the sexual organs of all the rest remaining in a rudimentary or undeveloped state, although capable of developement, should the destruction of the queen render such a provision for the preservation of the race indispensably necessary. (See Insecta.)

The *oviductus* or excretory canal common to the ovarian tubes of the corresponding side of the body, sometimes opens into the cloaca, the eggs escaping by the anal passage; but in other cases, having joined that of the opposite side, it terminates externally by a distinct aperture; near its extremity, however, it receives the auxiliary tubes or cœca, namely, the spermotheca and the accessory glands.

The *spermotheca* is a membranous sacculus of varying size and shape, regarded by Herold and Malpighi as a receptacle in which the seminal fluid of the male is deposited and retained,—an opinion which has been sanctioned by subsequent anatomists; it is found only in such insects as deposit their eggs in slow succession, and is presumed to be a provision for the gradual fertilization of the ova during their transit through the oviduct. It is only upon this supposition that it is possible to account for the impregnation of some insects which are employed for a long period in the business of oviposition, as is the case, for instance, with the hive-bee, in which a single coitus fertilizes all the eggs that are laid for a space of two years, amounting sometimes to twenty or thirty thousand in number; and yet, in this case, it is difficult to conceive how so small a reservoir, scarcely larger indeed than the head of a pin, can retain a sufficiency of this fluid for such a purpose, a difficulty which is scarcely lessened by admitting the hypothesis of Dr. Haighton, who refers the act of impregnation rather to some penetrating effluvium or *aura seminalis*, which the seminal liquor may emit during a long period, than to actual contact between the semen and the ova.

The auxiliary glands *(glandulæ succenturiatæ)*, which are appended to the oviduct of insects, perform an office which is by no means satisfactorily determined; the most usual supposition is that they furnish some secretion connected with the investment of the ova, either for the completion of the shell, or, as is more probably the case, for the purpose of uniting them together by a tenacious mucus into the long strings or masses in which they are not unfrequently extruded. The structure of these secerning cœca differs in different insects, but will be found to conform in most cases to one or other of the following types:—

1. Most frequently they are merely elongated tubes closed at one extremity while the other opens into the oviduct.

2. In some cases the primary cœca give off secondary branches.

3. In others, as in *Hippobosca*, they are ramified tubes terminated by blind canals.

4. In *Elater Murinus* they present a very remarkable structure, being composed of a number of triangular capsules united by canals arising from each angle until the terminal vessels are reduced to simple cœca.

The *ovipositor* is the last part of the female generative apparatus of insects which we have to notice. This singular appendage to the oviduct presents many varieties in its structure, being adapted to the introduction of the ova into certain localities either fitted for their maturation, or, as is more frequently the case, suited to the necessities of the larva after its escape from the egg; but a detailed account of the forms which this organ assumes in different tribes would necessarily be incompatible with the limits of this article, and the reader is therefore referred for further information to the article INSECTA.

Some insects are ovo-viviparous in a modified sense, and their offspring are produced in the larva or even in the pupa state, the eggs being hatched in the body of the parent, and the young matured to a certain extent before they are expelled. In such cases the oviducts unite to form a capacious matrix, in which at certain seasons the larvæ are contained either agglomerated in masses, or arranged parallel with each other in flat bands. In his state each larva is invested in a delicate membranous bag. It is remarkable that all these larvæ are carnivorous, their office being to remove putrifying flesh; hence the necessity of their being produced in such a state as immediately to commence the woik to which they are destined.

Some *Aphides*, or plant-lice, are ovo-viviparous in the early part of the year, but oviparous as winter approaches,—a provision evidently intended to secure the preservation of the embryo during the inclement season, the eggs remaining unhatched until the return of spring.

The Aphides likewise in their mode of generation furnish the physiologist with one of the most extraordinary anomalies met with in the animal kingdom. From an accurate series of observations, first instituted by Bonnet, and subsequently confirmed by the indefatigable Lyonnet, it is now received as an established fact that the females of these insects have the faculty of giving birth to young ones without having had any intercourse with the other sex. From the experiments of these naturalists it appears to have been incontestably proved that if a female Aphis at the moment of its birth be rigorously kept from communication with others of its species, it will, if supplied with proper food, give birth to a brood of young ones, and not only so, but if one of the offspring so produced be similarly treated, it likewise will prove fruitful, and so on to the fifth generation, according to Bonnet, or even still further, as Lyonnet afterwards ascertained. Bonnet supposed, in explanation of this circumstance, that the Aphides are truly androgynous, each being possessed both of ovigerous and impregnating organs; yet this supposition is incompatible with the fact, that the male insect is almost as common as the female, and that the sexes copulate in the usual manner during the termination of the summer season. The only solution of this phenomenon appears to be that one intercourse with the male suffices for the impregnation of all the females which in one season spring from the same union. But the *Aphides* are not the only examples of this curious fact, as some of the Branchiopod Crustaceans, as *Daphnia pennata*, Müll. *(Monoculus pulex, L.)* are equally capable of producing fertile females through several successive generations; nevertheless both Bonnet and Jurine observed that the female Aphides and Branchiopods that were fertile without the usual intercourse of the sexes were less fruitful than their mother, and those of the last generation less so than the first.

Arachnida.—In the Arachnida the generative system, both in the male and female, is even more simple than that of insects. The testes of the male are two in number, each being an elongated membranous bag, closed at one extremity, whilst the opposite is continuous with a slender and tortuous vas deferens, the terminations of which are indicated externally by two very small orifices distinguishable on the under surface of the abdomen near its junction with the thorax. The apertures through which the seminal fluid is discharged are totally unprovided with any apparatus of intromission or excitement; in lieu of which many genera are provided with a singular substitute, or at least with an organ supposed by some authors to be an exciting organ. This is found at the extremity of the maxillary palpus, but for a detailed account of its structure and presumed functions the reader is referred to the article Arachnida.

The female organs of the Araneidæ are equally devoid of complication. The ovaries are simple membranous bags, which occupy when distended a considerable portion of the abdomen, and are found to contain ova aggregated together in considerable numbers. From each of these ovigerous sacs a short canal leads to an aperture situated near the base of the abdomen, through which, when mature, the ova are discharged. The most remarkable circumstance observable in this form of the generative system is the complete separation which exists between the sexual organs of the two sides of the body, which, both in the male and female, not only do not communicate internally, but open upon the exterior by distinct apertures; the insulation is, in fact, so perfect that in some cases the eggs generated in the two ovaria are laid at distinct and distant periods. According to Audebert some spiders are rendered fertile for several years by one intercourse with the male.

In the Scorpions the male generative apparatus consists of a testis composed of numerous tubes united together, so as to form a series of loops, the secretion of which is discharged externally by a double penis resembling that of some reptiles, which is protruded through a valvular aperture seen upon the ventral surface of the thorax.

The female organs of the Scorpion, like those of the male, are composed of loops of tubes, uniting together at different points, and when distended with ova resembling a necklace of beads: they open by two canals, (vol. i. *fig.* 84, *c*, p. 205), at the same point which the sexual aperture of the male has been seen to occupy, each having a small cæcum or succenturiate gland appended near its termination. The eggs of Scorpions are hatched in the oviducts, and the progress of the developement of the embryo may be easily distinguished through the transparent coats of the ovum, resembling most accurately that observed by Herold in the evolution of the young spiders, figures of which are given elsewhere.*

Crustacea.—As in the Arachnida, the generative system of Crustaceans is for the most part double, the parts belonging to the two sides of the body being generally completely distinct from each other, not only internally but at their termination. In the higher orders the testes of the male and the ovaries of the other sex are found to be situated in the dorsal region of the thorax; in both cases these organs appear at first sight to be of a dense glandular structure, but, on examination, are found to be essentially composed of tubular convolutions. In both the male and the female, the excretory canals are simple tubes, which, after some convolutions, terminate in the male by prominent apertures, found upon the coxal portion of the fifth or posterior pair of true legs, and in the female by similar openings at the base of the third pair.

As in Insects, the female organs have in many genera a sacculated appendage, or copulatory pouch as it is termed, which is, in fact, analogous in function to the spermotheca of insects, serving as a reservoir in which the male semen is detained for the purpose of impregnating the eggs as they successively escape from the body. After their exclusion from the oviduct the eggs of Crustaceans are generally carried about by the female. In the *Decapoda* they are appended by a glutinous material to the false feet situated under the tail. In the *Isopoda* and others they are retained in receptacles formed by scales placed under the abdomen, whilst in the Entomostracous forms, as well as in many Epizoa approximating the Crustacea in structure, a remarkable provision is made for perfecting the eggs external to the bodies of these minute creatures, the females being provided with one or two membranous sacs appended to the posterior part of the abdomen, into which the oviducts open, and in which the ova are retained until they arrive at maturity.

Mollusca.—Several of the more perfectly organised Mollusca come likewise under this division of our subject. Such are the *Pectinibranchiate Gasteropoda*, in which the structure of the generative apparatus is sufficiently simple. In the male a large testis, composed of racemose follicles, shares with the liver the convolutions of the shell: from this the seminal secretion passes by a long and tortuous vas deferens to the extremity of the penis, which is in these creatures an extensile and very muscular organ, situated on the right side of the neck, and not unfrequently of enormous size when compared with the bulk of the animal.

The ovarium in the female *Pectinibranchiate* Gasteropods corresponds in position with the male testis; the oviduct arising from it is capacious, glandular, and convoluted, serving in some genera, as in *Turbo*, as a receptacle

* Vide Article Arachnida.

in which the eggs are frequently hatched. Near its termination the oviduct communicates with a glandular apparatus supposed to furnish the viscid envelope by means of which the eggs are generally agglutinated together.

In the *Cephalopoda* likewise, as in the Mollusca generally, the generative system is single. In this class the testis is an azygos viscus, composed of elongated branched cœca, inclosed in a membranous capsule, into which apparently the seminal fluid escapes. The vas deferens is narrow, and convoluted at first, but afterwards it enlarges and becomes muscular in its structure, serving doubtless as an instrument for the expulsion of the semen. This seminal canal receives the duct of a large glandular mass, and dilating into a pouch, ultimately terminates at the root of a rudimentary penis, apparently adapted to intromission, although it has not yet been ascertained whether actual copulation takes place, or whether the ova are fecundated after their extrusion, as is the case with fishes.

In the female *Cephalopoda* the ovarium, like the testis of the male, is azygos, and placed in the same situation. Its structure is remarkable, being a strong capsule, to the interior of which adheres a cluster of vesicular bodies denominated ovisacs, from which, at certain seasons, the ova escape. From the ovarian capsule arises the oviduct; this is in some instances a single tube, but in others divides into two canals; in either case, before its termination behind the base of the syphon, it passes through a thick laminated glandular structure, which secretes the dense coriaceous investment enclosing the ova, and the material which unites them into the racemose clusters in which they are usually found.

Vertebrata Ovipara.—In the vertebrate division of the animal kingdom the generative system presents great varieties, although from the lower to the higher orders we may distinctly trace a series of gradations which, in a physiological point of view, are of the highest interest.

In Fishes the ovaria are formed upon two distinct types. In the osseous fishes they are for the most part two large membranous sacs, which, when distended, occupy a considerable share of the abdominal cavity; these open by a short canal in the vicinity of the anus. In these capacious sacs the ova are developed: they are found united together by a delicate membrane, and attached in numerous festoons to the walls of the ovary until sufficiently mature for expulsion, when, breaking loose from their connexions, they escape into the ovarian cavity and are discharged through its excretory duct. In this case the Fallopian tubes found in other vertebrata do not exist, the oviduct being prolonged from the ovary itself in the same manner as the duct of a secreting gland, and the whole apparatus, in fact, strongly resembles what we have found in the Conchifera and other Mollusks, the great distinction consisting in the necessity which here exists for the impregnation of the ova by the agency of the male. The fecundation of the eggs is effected externally, after their expulsion, and, in fact, it is the spawn rather than the female, which forms the object of the pursuit of the male, as in most instances both sexes appear as careless concerning each other as they are of the offspring which they produce. The ova, which are incalculably numerous, are deposited in shallow water, where they may receive the influence of the solar beams, and in this situation are eagerly sought after by the males destined to make them fertile; these, urged apparently by the necessity of ridding themselves of an inconvenient load, discharge the secretion of their voluminous testes into the water, which, becoming diffused in the vicinity of the ova, is sufficient for their impregnation. In the males of this class of fishes the testes are of enormous size, equalling in bulk the ovaria of the other sex, and occupying a corresponding situation in the abdomen. Each testis is made up of a congeries of seminal canals, which, when inflated through the excretory duct, distend the whole organ. The seminal tubes are in most instances arranged parallel to each other, and are closed at one extremity while the other terminates in the common canal or vas deferens, which in every respect resembles the oviduct of the female.

This is the most usual structure of the male apparatus of fishes, but in some, as in the Shad (*Clupea Alosa*), the seminiferous tubes form innumerable ramifications and anastomoses in the substance of the testicle, easily discernible by the naked eye; and from the plexus thus produced cœcal tubes are prolonged to the surface of the organ, where they terminate by rounded extremities, giving the whole viscus, externally, a granulated appearance. (*Fig.* 204.)

A few of the osseous fishes form remarkable exceptions to the usual mode of impregnation, the ova of the female being in such fecundated prior to their expulsion by actual copulation with the male; and in some rare instances, as in the *Blennius* viviparus, the young are even produced alive, the ova being retained within the oviduct until they are hatched. In such cases the termination of the vas deferens swells into an external projection resembling a rudimentary penis, and, indeed, actually performing the office of an organ of intromission.

In the more highly organized cartilaginous fishes, and even in some osseous genera, the structure of the generative system is entirely different, commencing that type which characterizes the reproductive organs of all the other vertebrate classes. In these the ovaria are not hollow sacs which have their cavity prolonged to the exterior of the body, but the ova are developed between layers of membrane suspended in the abdomen, which are unprovided with any canal immediately communicating with them. Such are the ovaria of the Eel and the Lamprey, which are formed of numerous festoons of delicate and vascular membrane suspended in front of the spine. The ova produced between these membranous layers when mature break loose into the cavity of the abdomen, and are discharged through a simple orifice in the neighbourhood of the anus. In

Fig. 204.

Structure of the Testes in Clupea Alosa.

this arrangement we have, therefore, the simplest form of the isolated ovaria of Reptiles, Birds, and Mammalia, *in all of which the ova escape from the surface of the ovary, not from its interior;* and in the orifice through which the eggs are ultimately expelled from the abdomen we see the first rudiment of a Fallopian tube. In the Lamprey this orifice is prolonged into a short canal, and in Rays and Sharks assumes the form of an oviduct with which we shall afterwards see the Fallopian tubes of Mammals are identical; for whatever the complication which it afterwards assumes, the oviduct or Fallopian tube (for the two are the same in function) only receives the ova after their escape into the cavity of the abdomen to facilitate their ultimate expulsion. In Rays and Sharks the oviduct is double, commencing, however, by a fimbriated aperture common to both, which receives the eggs from the ovaria; each oviduct is at first narrow and membranous, having its lining membrane longitudinally plicated, but before its termination the walls suddenly increase in thickness, developing in their interior a large gland destined to furnish the horny covering which invests the eggs of these creatures. Beyond the gland the oviduct expands into a capacious bag, which communicates with the cloaca.

In this class of fishes the testis, like the ovary, is not hollow. In the Eel and Lamprey the secretion of the testis escapes from the external surface of the organ into the abdominal cavity, whence, like the eggs in the females of the same tribes, it is expelled through a simple orifice provided for its egress. In these creatures the testis and ovarium are so entirely similar that they have been confounded by authors, the secreting granules in the one sex and the ova in the other being both disposed in regular laminæ, and only differing inasmuch as the testicular granules are smaller than the mature ova.

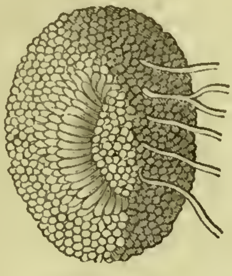
The structure of the testis in Rays and Sharks is peculiar, these animals being apparently provided with both the kinds of testis above described. Each testicle consists of two portions quite detached from each other; the one is formed of an aggregation of globular masses as large as peas, from which no excretory duct has been found to issue; the other is made up of convoluted canals, which, gradually uniting together, terminate in a capacious tube. The tuberculated mass has been described as the testis, while the convoluted tubes of the other portion were regarded as an epididymus, whence the vas deferens took its origin. There is, however, no communication between the granular part and that whence the vas deferens issues; it is, therefore, probable that the former is analogous to the solid testis of the Eel and Lamprey, pouring its secretion into the abdominal cavity, whence it is emitted through the apertures well known to communicate in these creatures between the peritoneal bag and the exterior, while the latter is identical with the usual form of the testis in osseous fishes.

The Batrachian Reptiles in their mode of generation, as well in so many other points of their economy, form the transition from the branchiferous to the pulmonary forms of the Vertebrata, and hence the study of their sexual organs is exceedingly interesting. The ovaria of these animals in their entire organization resemble those of the Lamprey. Their size, however, is much inferior, and the whole organ exhibits a more concentrated arrangement. The vascular membrane which forms each ovary is arranged in large folds on the sides of the spine, and the ova are deposited in great numbers between the lamellæ of which it consists. The oviducts are long and tortuous, each commencing by a fimbriated aperture which is found to be situated at the side of the pericardium, and so bound down in that position by its peritoneal attachments that when the interval which separates this point from the ovaria is considered, it is difficult to conceive how the ova, when dislodged from the nidus in which they were formed, can be brought into the oviduct; the only supposition, in fact, which will account for it is, that the eggs break loose into the abdominal cavity and thus make their way to the extremities of the oviducts. Before terminating in the cloaca the oviducts expand into capacious receptacles, in which the ova are collected prior to their expulsion, and glued together by a glairy secretion into masses which distend the whole of the abdomen.

The ovaria of the Salamanders resemble those of the frog, as do the oviducts, but the membranous sacs which retain the ova are less considerable than in the Anourous Batrachia: the same observations apply to the perennibranchiate orders.

The structure of the testis in frogs is almost the same as that of the same organ in the cuttle-fish. If the investing tunic be removed, the whole substance of the organ appears composed of globules; but if these are gently separated, they are found to be merely the blind terminations of as many seminal tubes which run from the centre to the circumference of the testicle. The seminiferous ducts arising from

Fig. 205.

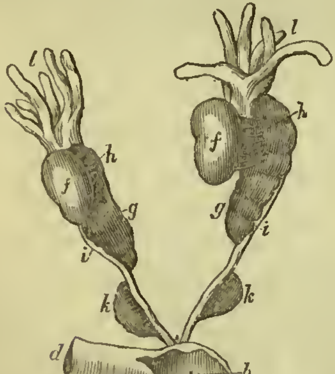


Testis of Frog.

these perforate the investing tunic of the kidney, upon which the testis is placed, and, according to Swammerdam, terminate in the ureters, which thus perform likewise the office of the vas deferens.

We have carefully repeated Swammerdam's dissection of these parts, which are represented at *fig*. 206.

Fig. 206.



Generative organs of Male Frog.

a, Cloaca; *b*, opening of genito-urinary canal; *c*, opening of bladder into cloaca; *d*, rectum; *e*, bladder; *f*, testes, that of the right side in situ; *g*, kidneys; *h*, seminiferous tubes; *i*, tube serving both as ureter and vas deferens; *k*, vesiculæ seminales; *l*, fatty appendages to the kidney.

In other Amphibia the organization of the testis is essentially the same, but the seminal cœca, owing to their greater length, are tortuous and convoluted.

The ova are impregnated in exitu by the aspersion of the seminal secretion of the male, who, firmly fixed upon the back of his mate, assists by his embraces the expulsion of the gelatinous masses in which the eggs are imbedded. No organ of intromission, therefore, is required, and the generative ducts, both in the male and female, open by simple apertures into the cloaca. Nevertheless, in a few instances internal impregnation is effected; such is the case with *Triton*, Laurent. in which, although no copulation takes place, the male fluid diffused through the surrounding water finds its way into the genitals of the female in sufficient quantities to secure fecundation. Moreover, in the Salamander *(Lacerta Salamandra)* an intromission is accomplished, the male possessing a rudimentary organ for that purpose; in this latter case the eggs are even hatched in the oviduct and the young produced in the tadpole state.

In the other reptiles the structure and arrangement of the generative organs is very similar; the same organization, in fact, exists through the whole class with slight modifications adapted to the different forms or habits of different orders.

Fig. 207.

The testes are invariably double, placed symmetrically on the two sides of the body, and attached by membranous connexions to the vertebral column. On unravelling their internal structure they are found to consist entirely of blind tubes enclosed in a membranous capsule; these seminiferous canals are much longer than in the amphibious tribes, and, consequently, present a tortuous arrangement, readily seen through the transparent covering of the testes. *(Fig.* 207.) From these tubes a variable number of efferent canals proceed, which, after remaining for a short distance enclosed in a prolongation of the tunics of the testicle, unite into a vas deferens, which is prolonged on each side to the cloaca, and there terminates at the root of the rudimentary penis.

In the higher Reptilia impregnation is always effected internally, and the males are consequently provided with an organ of excitement, differing much in form, but invariably imperforate, being merely grooved upon its surface by a channel, along which the semen flows into the cloaca of the female, but without any provision for its forcible expulsion.

This kind of penis consists entirely of the corpora cavernosa, arising by two crura, which unite intimately along the upper aspect of the organ, but leave inferiorly a deep fissure which is continued to the extremity. In the *Chelonia* this organ of excitement is very large, and terminates in a single point, but in many *Saurian* and *Ophidian* species its extremity is bifid, each division being covered with sharp and recurved spines, an arrangement which, in creatures so deficient in organs of prehension, is evidently adapted to ensure efficient copulation.

In the females of these reptiles the structure of the ovaria is interesting, gradually leading us from the folds of vascular membrane, between which the numerous eggs of the Batrachia are generated, to the form which they present in Birds. Each ovary assumes a racemose appearance, and consists of a number of ova in various states of perfection, which are loosely attached to the sides of the vertebral column by folds of peritoneum. Their structure, however, is essentially that which has been already described, and the ova, when matured between the vascular laminæ of the ovarian investments, escape, as in frogs, from the surface of these viscera by a laceration of the investing membrane, and would break loose into the abdominal cavity did not the more perfect developement of the oviducts, which here have their patulous extremities so disposed that they can grasp the ovaria during excitement, prevent such an occurrence, by receiving the germs immediately from the ruptured ovary. The oviducts are two in number, membranous at first, but glandular as they approach their termination in the cloaca. In these the eggs receive an albuminous investment which they absorb in the first portion of the canal, and prior to their expulsion are furnished with a coriaceous or calcareous covering produced from the thicker portion of the oviferous tube.

The females of the *Chelonia* have a clitoris, or rudiment of the male penis, which is in a similar manner provided with muscles for its retraction into the cloaca after extrusion. In other Reptiles the clitoris is deficient.

Birds form a remarkable exception to the usual arrangement of the internal sexual organs in oviparous vertebrata, the ovarium and oviduct being single throughout the class, an organization which is evidently in relation with that lightness and activity essential to their habits. This deviation from the usual type, however, is only apparent, arising from the non-development of the ovary and its duct on one side of the body, although both exist in a rudimentary state.

The ovarium, as in Reptiles, is racemose, consisting of ova in different stages of growth, each enclosed in a vascular membrane, which forms a pedicle attaching it to the general cluster, and is ruptured by the escape of the germ enclosed within it. The oviduct is short in comparison with that of many reptiles, and the structure of its lining membrane indicates the offices performed by different portions of the canal, being smooth and vascular in its upper portion, where the yolk receives its albuminous covering, but becoming villous and plicated where it secretes the shell.

Male birds, like reptiles, are furnished with two testes, which, from their comparatively insignificant size, do not materially interfere with the bulk of the viscera; yet even these only assume their full proportions at stated times, namely, at that period of the year when their office is required.

The testes are constantly situated in the abdominal cavity immediately behind the lungs and under the anterior extremity of the kidney: as in all cases, they consist of sperm-secreting tubes, but of such extreme tenuity that their diameter was estimated by Müller as not greater than the 0·00528 of a Parisian inch. These canals are enclosed in a proper capsule, which sends septa into the interior of the organ; they unite to form a slightly flexuous vas deferens, which accompanies the ureter of the corresponding side. The vasa deferentia terminate by separate orifices in the cloacal cavity near the root of the rudimentary penis when such exists, but even in its most perfect forms the male organ is merely an instrument serving for the conveyance of the seminal liquor along a groove seen upon its surface, there being as yet no corpus spongiosum or inclosed urethra as in the Mammiferous classes, adapted to an efficient injection of the semen into the female parts, nor any auxiliary secretions subservient to the same purpose. In the females of those genera in which the penis is most developed, a clitoris is found to occupy a similar position.

The Mammalia differ remarkably from the other vertebrate classes in the elaborate developement of the sexual organs in both sexes. The increased complication of these parts is attributable in the male to the necessity for a much more efficient intromission of the spermatic secretions during coitus, and in the female to the superadded function of gestation which characterizes the class.

On comparing the male organs of Mammifera with those of the oviparous vertebrata, several circumstances demand our notice, the most striking of which is the separation of the canals provided for excretion into two distinct systems, each terminating externally by an appropriate orifice, thus detaching entirely the digestive emunctory from the genito-urinary apparatus, which hitherto we have found to discharge themselves by one common orifice communicating with a cloacal cavity. With one interesting exception furnished by the Monotremata, such a separation exists throughout all the Mammiferous orders. Internally a still further isolation is evident in the separation of the urinary and generative organs by the provision of a urinary bladder, in which the secretion of the kidneys is stored up until its expulsion becomes necessary; the same excretory canal, however, is still common to both these systems. In the ovipara the penis was merely furrowed with a sulcus, along which the semen trickled during the union of the sexes without being impelled by any expulsive apparatus; but in the class of which we are now speaking the urethral canal becomes surrounded by vascular erectile tissue, forming a complete tube through which the seminal liquor is powerfully ejaculated during copulation by a muscular arrangement provided for that purpose; and in the last place the emission of the fecundating fluid is further provided for by the addition of secondary secretions, which from augmenting its quantity facilitates its ejection.

We shall proceed to speak of these circumstances seriatim, examining first, the structure and position of the testis and its duct; secondly, auxiliary glands which add their secretions to the seminal liquor; thirdly, the structure of the penis, and arrangement of the organs of intromission.

We have found in all the classes of vertebrata of which we have hitherto treated, that the testes consisted essentially of blind tubes. In Frogs these sperm-secreting canals were exceedingly short; in other Amphibia they become elongated and flexuous. In Reptiles their length and convolution was still further increased, until at length in Birds and Mammalia their length is so great, and their delicacy so excessive, that they are with difficulty unravelled. In all animals the terminations of the seminal tubes are found to be closed, neither is any increase or diminution perceptible in the diameter of one of these vessels throughout its whole course. Another circumstance which, with one or two exceptions, is common to all Mammals, is that they never ramify or divide.*

Mammalia differ much amongst each other as regards the length, number, convolutions, and general arrangement of these secerning vessels of the testis. In the Ass they are very delicate; of greater diameter in the *Cynocephalus* and larger Carnivora, as well as in the Hog and Rhinoceros. They are very large in the *Glires*, and in *Sciurus* their diameter reaches ·0·01453 inch (Paris), whilst in the Hedgehog they are only 0·00970 inch.

The tenuity of the walls of these seminal vessels is extreme, and scarcely applicable by the micrometer; they are united together by a most delicate tissue of capillary bloodvessels, serving to imbue them with that blood from which the semen is separated, which when secreted accumulates in the cavities of these tubes in readiness for expulsion.

The testes are very variously situated in the adult state of different mammals. Sometimes they are contained within the abdominal cavity, attached on each side of the spinal column by folds of the peritoneum, as in the ovipara; at other times they descend into the skin of the groin through the inguinal canal, and not unfrequently are contained in a scrotal pouch formed by the integument behind the pubic arch; and in the Marsupial division, which, when describing the female sexual organs, we shall find to constitute a distinct type of the generative system, they are suspended in front of the pelvis.

The excretory duct of each testis or vas deferens is formed by the junction of the seminal canals of the testis; it is at first much convoluted, forming a mass appended to the testicle, denominated the epididymus; and whatever may be the position of the testicle, it runs to discharge itself into the canal of the urethra near the commencement of that tube.

The *prostate gland* is a secreting body of peculiar structure, which, in man, embraces the neck of the bladder, and opens by ten or twelve ducts into the urethra near its commencement. It is very constant in its existence, being found in all orders of Mammalia, excepting, perhaps, the greater number of the Rodentia, the Mole, and the Hedgehog, in which it is apparently replaced by secerning organs of a widely different structure; otherwise, the internal organization of this gland is nearly the same in all animals that possess it, consisting essentially of cells, each of which is subdivided into others of extreme minuteness. From these cells the excretory ducts take their rise, and the whole organ may be readily inflated by forcing air into the canals which issue from it: the whole is enclosed in a dense fibrous capsule. In some animals, as the Elephant and Solipeds, the prostate is double or even quadruple, and in this case the centre of each portion has within it a large cavity which communicates with the smaller cells, and gives origin to the excretory tube.

Cowper's glands.—These glands in the human subject are two very small bodies situated behind the bulb of the urethra, which furnish minute canals, opening obliquely into the urino-generative canal near its posterior portion; but minute as they are in man, they are found in other creatures to be much more voluminous, not unfrequently equalling the prostate in size, and in some cases, especially in the Marsupial division, they are increased in number; thus in the Opossums and Kangaroo-rat there are four, while in the Wombat (*Phascolomys*), the Kangaroo, and others, even six are found: nevertheless in most of the Carnivora, except the Felidæ and Hyenas, and in the greater number of Ruminants, Solipeds, Amphibia, and Cetacea, they are deficient.

The internal structure of *Cowper's glands* varies. In man and many others they are composed of simple follicles; in other cases, as in *Sciurus*, the Marmot and the Hog, they consist of conical sacculi, which exhibit internally a cellular appearance. In the Beaver (*Castor Fiber*) their texture is spongy, being formed of large cells, divided by septa into smaller ones of extreme minuteness; those of the Mole are similarly constructed. In *Viverra Zibetha*, the feline tribes and the Hyena, they are made up of separate lobules; and in the Ichneumon these glands are composed of vesicles united by a common duct. In the Hedgehog (*Erinaceus Europæus*) they are found in a very singular position, being partly situated beneath the rami of the pubis and ischium, and partly beneath the skin on the inner side of the thigh, being so remote from the other glands that their existence was overlooked by Cuvier. Each gland consists of pyramidal lobules, which, by their apices, give rise to the excretory canals.

In some of the Marsupiata their minute structure resembles what is found in the Hedgehog; and each of them is surrounded by a

* In *Sciurus* they have been observed to divide dichotomously.

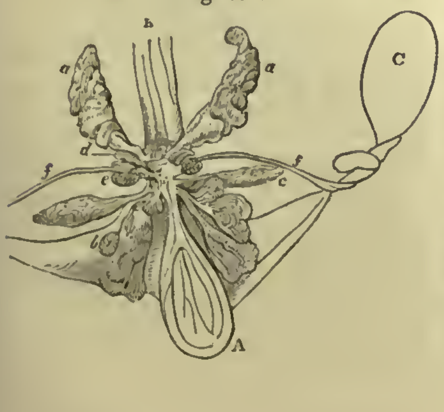
powerful muscular sheath, calculated to ensure the expulsion of the fluid which they elaborate.

The most remarkable arrangement of Cowper's glands is seen in the Ichneumon (*Herpestes Ichneumon*, Illiger): in this animal they are very large and occupy their usual position, being invested with a strong muscular coat; but their excretory ducts, instead of terminating as usual in the bulbous portion of the urethra, are prolonged beneath the penis nearly to the extremity of that organ, where they open into a cul-de-sac common to them and the canal of the urethra.

Accessory vesicles. — These are auxiliary glands, which pour their secretions into the canal of the urethra. They appear, when present, to take the place of the prostate, being only found where that organ is deficient, and accordingly, although of a totally different structure from that body, they have been called prostates by various authors. They are usually packets of membranous cœca, more or less ramified, and in the season of sexual excitement are filled with a fluid resembling that contained in the vesiculæ seminales. These organs exist in all Rodents except Squirrels, Marmots, and Hares, and also in the Hedgehog and the Mole, but have not been found in any other mammalia. They are invariably composed of intestinules or branched cœca, arranged in packets, the number of which varies much. Thus in the Mole there are five such bundles, forming a mass of ramified tubes larger than the bladder; in the Hedgehog there are four, and in *Cricetus vulgaris* and *Dasyprocta Aguti* two fasciculi.

But besides the secreting structures above enumerated as forming the ordinary appendages to the male generative system of Mammifers, additinnal ones are occasionally found, placed out of the positions in which the succenturiate glands usually exist. Thus in Solipeds a long cœcum containing a glairy fluid is placed between the insertions of the vasa deferentia, which communicates with the urethra by an appropriate orifice; and in *Cricetus* and many of the *Muridæ* the ends of the deferent canals before their termination are provided with bunches of small glandular follicles, which in the former resemble small bunches of grapes.

Fig. 208.



The annexed figure, (*fig.* 208,) representing the male generative viscera of the Rat (*Mus Rattus*) exhibits an example of the greatest complication of these parts, and will serve to illustrate the situation of the organs above described. A represents the bladder turned forwards, B the rectum, and C the testis of the left side. The succenturiate glands here found are *a*, *a*, the *vesiculæ seminales*; *b*, the anterior fasciculus of the *accessory vesicles* or anterior prostate of some authors, which on the opposite side is unravelled to display the cœca which compose it; *c*, the middle prostatic cœca; *d*, the anterior prostatic cœca. These all communicate with the urethra, and in addition to these we have on each side the racemose bunch of follicles (*e*) which is appended to the termination of the vas deferens (*f*).

Structure of the penis.—The great difference between the penis of Mammifers and that which has been described as existing in the oviparous vertebrata, consists in the inclosure of the canal of the urethra, which is no longer a simple groove formed by the junction of the *corpora cavernosa*, but becomes surrounded with a cylinder of erectile tissue usually denominated the *corpus spongiosum urethræ.* The *corpus cavernosum*, which generally forms the great bulk of the organ, arises by two crura, which are firmly attached to the rami of the ischium in the males of all placental Mammalia; and even in the *Cetacea*, where there is no pelvis, two bones placed on each side of the corpus cavernosum give a support to the penis, which is attached to them by fibrous ligaments; nevertheless, in the Marsupiata the crura of the corpus cavernosum are quite free, or only loosely attached to the ischiadic bones by the muscular sheaths in which they are enveloped. The crura of the corpora cavernosa unite to form the body of the penis, their union being generally marked by a strong septum, which more or less completely divides the organ into two lateral halves. In some animals, as in the Dog, this septum is very distinct; but in other cases, especially in many of the Plantigrade Carnivora and in most of the Pachydermatous and Cetaceous tribes such a partition is entirely wanting; in such cases the fibrous lamellæ, which arise from the dense capsule surrounding this portion of the penis, and traverse the vascular tissue which is contained in its interior, unite at a central part in a kind of cord formed by their union. In some animals the organ is supported by a bone developed in its interior: this arrangement exists in the *Quadrumana*, *Cheiroptera*, the *Plantigrade* and *Digitigrade Carnivora* (except the Hyæna), and in the *Rodentia*, also in Seals and Cetaceans. In a few instances it is so large as to form a large portion of the penis, as in Whales; in others, as in many Carnivora and Rodentia, it is extremely small, but whatever its form or size it is invariably found intimately connected with the corpus cavernosum.

The *urethra*, as in man, consists of a muscular and of a vascular portion, the former receiving the ducts of the succenturiate and seminal glands, the latter embedded in the erectile tissue of the corpus spongiosum. The muscular portion does not always join the vascular part in a straight line; but, on the contrary, in some animals, as in Ruminants generally and in the Boar, the former opens by an orifice perforated in the upper wall of the latter, at a little distance from its commencement, so that a cul-de-sac is left excavated in the bulb of the urethra or commencement of the spongy portion, in which the fluids poured into the muscular part are mixed with the secretion of Cowper's glands, which enters the sides of the excavation.

In Squirrels and Marmots a similar cul-de-sac exists, which only receives the secretion of Cowper's glands, and is continued forwards as a narrow tube surrounded by vascular tissue, beneath the urethra, as far as the middle of the penis, where the two canals unite.

The course of the urethra in the great Kangaroo *(Macropus major)* is peculiar; instead of passing, as is usually the case, beneath the corpus cavernosum, it is inclosed in a canal passing through the centre of the penis, from which it only emerges at the extremity of the glans; owing to this arrangement, the spongy investment of the canal is in this animal confounded with the vascular tissue of the *corpus cavernosum.*

In others of the Marsupiata the *corpus spongiosum*, like the cavernous body, arises by two crura, which are quite unattached, each being invested with a strong muscular sheath, and even in some placental Mammals, as the Water-rat and the Camel, rudiments of this division are distinguishable.

The *glans penis*, or extremity of the intromittent organ, presents many modifications in form and in the nature of its surface. It is frequently smooth and highly sensible, as in man, being only covered by a delicate skin; yet in other instances, as in the feline Carnivora, it is armed with stiff recurved bristles; sometimes the armature represents horny scales or strong spines, and in not a few genera we find horny serrated plates projecting from its surface; and, as though these formidable saws were insufficient, they are occasionally combined with horny prongs protruded from the extremity of the penis during its erection. These last appendages are found in various families of the Rodentia, as in Guinea-pigs and Agoutis. The limits of this article will not permit us to expatiate further on this part of our subject; we must therefore refer the reader for a description of the various forms of the penis and of the muscles belonging to that organ to the articles which treat of the Mammiferous orders individually.

The female Mammalia exhibit in their generative system a beautiful gradation of structure. They naturally divide themselves in conformity with their mode of gestation into two classes, viz. the *Ovo-vivipara* or Marsupiata, and the *Vivipara*, properly so called, comprising the placental orders.

The former division approximates in every particular to the oviparous type of structure: the ovaria are racemose, as in birds; the oviducts, which now assume the name of uteri, are still double, opening by distinct orifices into the vagina, which also is not unfrequently divided. But the great feature which distinguishes the ovo-viviparous mammals is the peculiar apparatus in which gestation is completed, the embryo being expelled from the uterus at a very early period, without ever contracting any vascular connexion with that organ, to be lodged in a marsupium or pouch connected with the abdomen of the mother, in which the nipples are contained. In this situation it becomes attached by its mouth to one of the teats, and thus derives from the mammary secretion the nourishment essential to its growth.—See Marsupiata.

In the Placental division gestation is completed within the uterine cavity by the development of a vascular mass of different construction in different classes, called the Placenta. The ovaria here gradually lose their racemose appearance, and are converted into small and solid masses, in which the ova or Graafian vesicles are evolved. The uterus, at first completely divided, as in some of the Rodentia, in which the two cornua open separately into a single vaginal canal, by degrees unites, and by a progressive coalescence attains that concentration most perfectly exhibited in the human female.

To enter more largely into details connected with the generative organs of the Mammiferous classes would needlessly swell the bulk of this article, in which our object has been to lay before the reader a connected view of the modifications met with in the reproductive system throughout the animal kingdom, and thus to connect with each other the numerous facts relating to this subject which are elsewhere more minutely recorded in this work.

For the anatomy of tho Organs of Generation in Man, see Penis, Prostate, Testis, Vesiculæ seminales.

(T. Rymer Jones.)

GENERATION (in Physiology) *generatio;* Fr. *génération;* Germ. *Zeugung;* Ital. *generazione;)* is the process by which the young of living bodies are produced, and their species continued. In common language the term is frequently confined to the mere act of union of the sexes of animals; but in general and animal physiology it is generally employed in the more extended signification given to it in the following article, viz. to denote the assemblage of all the functions of animals concerned in the formation of their young, and as synonymous, therefore, with the function of Reproduction.

In directing our attention to the mode in which the function of reproduction is effected in various classes of animals, so many striking differences present themselves, that we find it difficult if not impossible to point out any general circumstances in respect to which they all agree. Some animals, for example, are propagated by the division of their whole bodies into pieces, each of which by a peculiar change becomes an independent individual entering upon a new life. Others arise like the parts of a tree by buds which remain for a time attached to the parent stem, and being afterwards separated from it assume an independent existence. A third class of animals have the power of forming and throwing off from their bodies a small portion of organized matter, which, though at the time of its separation from the parent, not resembling it either in form or organization, is yet possessed of the power of living for itself, and, after passing through a variety of successive changes of growth and evolution, of at last acquiring the exact semblance of the parent by which it was produced. In a fourth and last class, comprehending much the greatest number of animals, the function of reproduction involves a greater complication of vital processes than in the three other classes above alluded to. The union of two individuals of different sex becomes necessary, and the young owe their origin to the evolution of a more complex organized structure termed the egg, which is formed in and separated from the body of the female parent, and is the product of the union of the male and female of all animals in which the distinction of sex exists. The ovum or egg is most familiarly known to us in the eggs of domestic birds, to which the product of sexual union in all animals belonging to this fourth class bears a strict analogy in every essential particular.

It may be stated as a general fact, that the reproductive function involves a greater number of vital processes in the higher and more complicated than in the lower and simpler kinds of animals. Yet there are exceptions to this rule, and we do not always trace a correspondence between the degree of complication of the generative process of any animal and the place which that animal holds in the scale of being; for there are some tribes of animals which are propagated in more than one of the ways above mentioned, and there are some, to which, from the simplicity of their other functions and organization, a low place in the zoological scale has been assigned, and which nevertheless resemble the higher animals in respect to their mode of reproduction.

A very superficial view, however, of the varieties of the form obvious in the reproductive process of different animals demonstrates the importance of the reproductive functions in the economy of life, as it points out the intimate relation which these functions bear to the habits, mode of life, and organization of each animal, and shews the infinite care and foresight with which nature, in every variety of circumstance, has provided for the regular and undisturbed performance of those acts by which the species of organized beings are continued from age to age, in an undeviating succession of generations. These facts also fully justify our regarding, along with Cuvier, the reproductive function as constituting one of the fundamental divisions in a classification of the processes of the animal economy.

While, therefore, the principal object of the present article is to describe the process of generation in Man and the higher Vertebrated animals, it will be necessary and proper for us to allude also to the reproductive function as it is performed in all the various members of the animal series; for in this, as in other departments of Physiology, the more complicated forms of the process derive much illustration from the study of the more simple, and we may hope thus more fully to point out the general importance of the functions now under consideration.

We purpose to follow an arrangement adapted chiefly to the consideration of Human Generation. In all the animals in which distinction of sex subsists, the male and female organs subservient to reproduction must co-operate for the completion of the generative process; and in the greater number of the more perfect animals, as also in Man, the two kinds of sexual organs being placed on separate individuals of the same species, the concurrence of both these individuals, or of both male and female parents, is necessary for the formation of the fruitful products from which the offspring proceeds. The circumstances, then, which give rise to the union of the sexes, and the phenomena which accompany that union, form some of the topics of the present article. The product of fruitful sexual union in all animals is one or more eggs, from each of which, under the influence of certain favourable circumstances, different in different tribes, the young animal is produced by an intricate process of vital growth. The greater part of the substance composing the egg is furnished by the female parent: but this egg of the female would be wholly barren, or would not undergo any of those changes by which the young animal is formed, unless it received in some way or other the influence of the product of the generative organs of the male; and the egg formed by the female may be regarded as imperfect until the change now alluded to has been effected in it. It is then said to be fecundated or rendered fruitful by the semen of the male. The mode of formation of the egg and seminal matter, the mode of their separation from the place of their formation, the structure and properties of each of these products, the manner in which they are brought together, the influence which they exert upon one another, and the consequent result in the production of the young, constitute the principal remaining topics which fall to be discussed by us at present. In this article our attention must chiefly be confined to such operations or functions of the male and female parents as are preliminary to or necessary for the formation of a ripe and fruitful ovum,—that is, an egg capable of giving birth to a new animal the same as either of its parents, when placed in those circumstances which are favourable to its evolution. It is not intended to speak in this place of the changes of the ovum itself in which the formation of the young animal consists: the consideration of these is reserved for the article Ovum.

Before treating in detail of Human Generation, we introduce some remarks on the nature of the reproductive function in general, and a sketch of the principal varieties of the forms it assumes in different classes of animals.

I. THE FUNCTION OF REPRODUCTION GENERALLY CONSIDERED.

1. *Introductory remarks.*—The process by which the young of animals are formed has, from the earliest periods of science, always been an object of peculiar interest and attention to inquirers into the functions of animated beings. Scientific men as well as the more ignorant have looked with a mixed feeling of wonder and admiration upon the intricate changes which precede and accompany the first appearance and gradual formation of all the different textures and organs belonging to animal bodies. The gradual construction or building up of the whole frame-work of the animal body, and its various important organs,—the formation of the nerves and brain that feel and think, the muscles that move, the blood with its containing organs that propel it and apply it to the purposes of nutrition,—the appearance step by step of all the remarkable structures out of which the different organs are formed,—the development of the appropriate vital powers of each of them,—the comparatively simple structure of the substance of the egg, and the impossibility of detecting in it by the most exact scrutiny, before the commencement of the formative process, any appearance of the parts afterwards arising there—have naturally led physiologists to inquire minutely into the properties of that egg, and the process by which so remarkable a production is generated. The ascertained fact that the egg possesses vital powers belonging to itself, and that its life is in a great measure independent of that of its parents,—that the vital powers of the egg are capable of being called into operation and influenced in many animals by determinate external physical agents, such as heat, air, light, and electricity,—the obscure nature of the influence exerted by the male upon the female product in the perfecting of the egg,—the preservation of the specific distinctions of animals from one generation to another in undeviating succession,—the transmission of occasional varieties or peculiarities of form and of hereditary resemblances from parent to offspring,—and, in fine, the important relation which the generative process bears to other functions of the animal economy, are among the more prominent circumstances which, while they throw a certain air of mystery over the functions of reproduction, have at the same time given them an interest in the eyes of the physiologist, which increases as his acquaintance with their details becomes more extended.

It is a common remark that generation is at once the most obscure and the most wonderful of the processes occurring in organized bodies. Hence, perhaps, it has happened that, while there are few subjects of physiological inquiry upon which so many authors have written, there is none upon which so many have freely indulged their fancies in framing unwarranted hypotheses and absurd speculations. This is an error which belongs to the early stage of investigation in most branches of natural knowledge, and which in the instance before us may be traced very directly to the comparative want of correct information which for a long time prevailed regarding the phenomena of the generative processes. For, if we except the remarkable investigations of Aristotle, Fabricius, Harvey, Malpighi, Wolff, and Haller, it may be said that it is only towards the conclusion of the last or the commencement of the present century that our subject has been studied with that accuracy of observation and freedom from hypothesis which are calculated to insure steady progress in the attainment of physical knowledge. When extended observation shall have rendered more familiar to the physiologist the different steps of the intricate processes by which an egg is formed and the young animal is developed from it, although he may not cease to admire the changes in which these processes consist, the feeling of wonder will be in a great measure lost to him; and he will not be inclined to look upon the gradual formation and growth of the child as more extraordinary than the constant and regular nutrition of the fully formed body. Are the inscrutable workings of the brain and nerves, the constant energy of the beating heart, the unwearied and powerful exertions of the voluntary muscles, the secretion of different fluids from the glands, and the regular supply of suitable organic materials to all parts of the body, so as to maintain the healthy structure of each and fit them for the performance of their respective offices, less remarkable and astonishing, or, in other words, less far removed from our accurate knowledge and comprehension, than the first origin and early growth of the same organs at a time when both their structure and functions are greatly more simple? Certainly not. These remarkable changes are all objects of wonder to the vulgar in proportion as they are unknown. The man of science regards the ultimate cause of all vital processes as equally inexplicable, and, aware of the bounds set to his knowledge of life, limits his inquiries concerning its various processes to the investigation of their phenomena.

At the same time it may be allowed that the fact that the mere contact of the male seminal fluid seems to awaken and call forth from the otherwise inanimate egg all those vital powers which are afterwards concerned in sustaining the life of the new being, is one of the most striking and simple examples of vital agency, and one less suited than most others to be observed or experimentally investigated. The theoretical physiologist, in contemplating this fact, is apt to conceive that here he has arrived at one of the primitive causes or foundations of animal life, and that he has here obtained the key to many of its hidden wonders: he passes the limits which ought to bound his inquiries, and in most instances invents fanciful and curious speculations rather than makes sound generalizations of ascertained facts.

2. *Theories of generation.*—The vast number of the theories of generation renders it impossible to mention even the more important in this place. Drelincourt, an author of the last century, brought together so many as two hundred and sixty-two "groundless hypotheses" concerning generation from the writings of his predecessors, "and nothing is more certain," quaintly remarks Blumenbach, "than that Drelincourt's own theory formed the two hundred and sixty-third."*

Of these theories two principal classes may be distinguished, according as they more directly relate, 1st, to the action of the parent organs, or 2d, to the changes in the egg belonging to the formation of the new animal. Of the first of these classes of theories Haller made three divisions, according as the offspring is supposed to proceed, 1st, exclusively from the organs of the male parent, 2d, entirely from those of the female, or 3d, from the union of the male and female products. The second class of these theories, that, viz. which relates more particularly to the formation of the new animal, may be arranged under two heads, according as the new animal is supposed, 1st, to be newly formed from amorphous materials at the time when it makes its appearance in the egg, or 2d, to have its parts rendered visible, by their being expanded, unfolded, or evolved from a previously existing though invisible condition in the germ.

The greater number of the older theories of generation may then be brought under one or other of the above-mentioned divisions, viz. the theory of the Ovists, of the Spermatists, that of Combination, Evolution or Epigenesis.

According to the first-mentioned of these hypotheses, or that of the Ovists, the female parent is held to afford all the materials necessary for the formation of the offspring, the male doing no more than awakening the formative powers possessed by, and lying dormant in, the female product. This was the theory of Pythagoras, adopted in a modified form by Aristotle; and we shall afterwards see that it resembles most closely the prevailing opinion of more modern times. The terms, however, in which some of the older authors expressed this theory are very vague, as, for example, in the notion that the embryo or new product "is formed from the menstrual blood of the female, assisted by a sort of moisture descending from the brain during sexual union."

According to the second theory, or that of the Spermatists, among the early supporters of which Galen may be reckoned, it was supposed that the male semen alone furnished all the vital parts of the new animal, the female organs merely affording the offspring a fit place and suitable materials for its nourishment.

* See Blumenbach über den Bildungstrieb, 12mo. Gotting. 1791. Anglice by A. Crichton: An Essay on Generation, 12mo. Lond. 1792.

Immediately upon the discovery of the seminal animalcules, these minute moving particles were regarded by some as the rudiments of the new animal. They were said to be miniature representations of men, and were styled homunculi, one author going so far as to delineate in the seminal animalcule the body, limbs, features, and all the parts of the grown human body. The microscopic animalcules were held by others to be of different sexes, to copulate, and thus to engender male and female offspring; and the celebrated Leeuwenhoek, who was among the first to observe these animalcules, described minutely the manner in which they gained the interior of the egg, and held that after their entrance they were retained there by a valvular apparatus.

The theory of Syngenesis or Combination seems to have been applied principally to the explanation of reproduction of quadrupeds and man, the existence and nature of the ova of which were involved in doubt. This hypothesis consists in the supposition that male and female parents both furnish simultaneously some semen or product; that these products, after sexual union, combine with one another in the uterus, and thus give rise to the egg or structure from which the fœtus is formed. In connexion with this theory we may also mention that of Metamorphosis, according to which a formative substance is held to exist, but is allowed to change its form in order to be converted into the new being; as also the notion of Buffon that organic molecules universally pervade plants and animals, that these are all endowed with productive powers, that a certain number are employed in the construction of the textures of organized bodies, and that in the process of generation the superabundant quantity of them proceeds to the sexual organs and there constitutes the rudiments of the offspring.

The theories of generation proposed before the commencement of the seventeenth century are either unsatisfactory or erroneous from the entire want of accurate knowledge prevailing before that time regarding the relation of the egg to reproduction. The conversion of one animal into another, constituting equivocal or spontaneous generations, was very generally believed in; and the process of the formation of the egg was equally ill understood in the lower and higher classes of animals. It was in the course of the seventeenth century that the labours, first of Harvey, and afterwards of Swammerdam, Redi, Malpighi, De Graaf, and Vallisneri, gave rise to greater precision of knowledge and opinions regarding this subject, and finally established the Harveyan dictum, "omne vivum ex ovo," which may be regarded as the starting-point or basis of modern researches.

The theories of generation seem after the period of Harvey to have changed somewhat their object, and to have been directed more exclusively to the explanation of the formative process, or the manner in which the parts of the fœtus are first formed in the egg and afterwards attain their ultimate structure and configuration.

It was then that the foundation was laid for the discussion between Epigenesis and Evolution, the two theories of generation which have more recently occupied the attention of men of science, and which, as has already been remarked, relate principally to the nature of the formative process. Harvey and Malpighi may be regarded as the first who endeavoured, from the observation of facts, to establish the general law of Epigenesis as opposed to the older views of Preformation entertained by the Ovists or Spermatists; but it was not till near the middle of the last century that these opinions were opposed to one another in a decidedly controversial manner.

At that time Caspar Frederick Wolff* supported the system of Epigenesis by a reference to observations on the minute changes of the egg of the fowl during the early stages of formation of the chick, while Haller and Bonnet advocated the opposite opinion of Evolution.

Wolff and those who followed his system held that no appearance of the new animal is to be found in the perfect impregnated egg before the commencement of incubation, but that when the formative process is established by the influence of heat, air, and other circumstances necessary to induce it, the parts of the fœtus are gradually put together or built up by the apposition of their constituent molecules. Haller† referred both to his own observations on the chick and to a variety of collateral arguments in support of the system of Evolution, holding that when the fœtus makes its appearance in the egg, it does so merely in consequence of the enlargement or evolution of its parts which pre-exist, though in an invisible condition, in the egg. Bonnet‡ carried this theory further than any one else, but trusting mainly to the observations of Haller on the formation of the fœtus, he supported his overdrawn views on highly hypothetical reasoning. Bonnet, in what is termed the theory of Emboitement, held not only that the whole of the parts of the fœtus pre-exist in the egg before the time of their appearance, but also that the germs of all the animals which have been or are to be born pre-exist from the beginning in the ovaries of the female; that the genital organs of the first parents of any species, therefore, contain the *germs* of all their posterity; that these germs lie dormant in their abode until one or more are aroused by the exciting influence of the male; and that consequently there is not in nature the new formation of any animal.

We shall have occasion to shew in the article Ovum that the most recent researches concerning the mode of formation of the fœtus in birds, quadrupeds, and other animals, and more particularly the microscopic observations of Meckel, Pander, Baer, and Rathké,* have shewn the theory of Epigenesis or superformation of parts to be much more consistent with what is known from observation than the theory of Evolution. In modern writings, however, the term Development is, without reference to theory, employed to denote the mode of growth of the fœtus more frequently than any other.

We would further remark in relation to our present subject that various names have at different times been given by authors generalizing the phenomena of development to the powers supposed to operate in the formation of the young; as, for example, the *Anima vegetativa*, *Nisus formativus*, *Vis plastica*, *Vis essentialis*, expansive, resisting, and vegetative forces. These terms can be considered as little else than general expressions of the fact that the fœtus is formed and grows in the egg, and are not more satisfactory explanations of the cause of its formation than the hypothesis of organic affinity is of the process of assimilation in the adult animal. As the knowledge of minute anatomy and physiology has increased, and the accurate observation of the process of developement has been more extended, the number of such hypotheses has gradually diminished.

Thus the somewhat vague discussion as to the relative probability of Epigenesis and Evolution has led to the laborious and accurate investigation of the various steps of the formative process or developement of the fœtus, and the conjectures as to the forces or causes which give rise to the growth of the new animal have fallen into comparative neglect; the erroneous notions respecting the source of the germs of male or female offsprings from one or other ovary or testicle have been replaced by a more satisfactory examination of the mode of developement of the sexual organs in the early stages of their advancement; and the inquiry as to the share taken by one or other parent in the process of generation has been pursued in more modern times by the attentive investigation of the functions of the male and female organs of reproduction, upon the same principles that guide the physiologist in his attempts to explain any other class of functions of the economy.

Recent writings on our subject are not, however, altogether free from vague hypotheses of the same nature as the older theories of generation above mentioned. The mechanical explanation of fecundation by the entrance of the seminal animalcule into the egg has been revived by one author; a second considers all the changes of development as under the influence of electro-magnetic currents; and a third explains the same changes by attributing them to a spontaneous motive power and organic affinitive properties of the molecules of the ovum.

It has been well remarked by Professor

* Theoria Generationis, published as an Inaugural Dissertation at Berlin in 1759, and republished in 8vo. in 1774.

† Elementa Physiologiæ, &c. tom. vii. Mém. sur la formation du Cœur dans le Poulet. Lausanne, 1758. Opera Minora, tom. ii.

‡ Palingénésie Philosophique, Genève, 1769; also in his Considerations sur les Corps Organisés.

* After these observers may be mentioned Serres, Prevost and Dumas, Dutrochet, Rolando, Purkinje and Valentin, Coste, and others, as contributing materially to the knowledge of this subject.

Burdach that the generative function, comprising the production of a fruitful egg and the formation of the young animal from it, are natural phenomena not more secret in their essence than others occurring in organized bodies, and which, therefore, ought to be investigated by obtaining a knowledge of the conditions in which they take place, and of the operations and changes in which they consist.

The illustrious Harvey in his 51st Exercitation expresses himself thus decidedly a supporter of the theory of Epigenesis,—" it is plain that the chicken is built up by Epigenesis or the additament of parts budding one out of another;" but he does not admit that separate powers, such as the "alterative or immutative, formative, attractive, retentive, digestive, and expulsive faculties, or those of apposition, agglutination, and assimilative nutrition described by Fabricius," can be distinguished in the production of the chicken. He thus limits our knowledge of the subject in the 54th Exercitation: " But as in the greater world we say *Jovis omnia plena*, all things are full of the Deity, so also in the little edifice of a chicken, and all its actions and operations, *digitus Dei*, the finger of God or the God of nature doth reveale himself." " A more sublime and diviner artificer (than Man is) seems to make and preserve man; and a nobler agent than a cock doth produce a chicken out of the egge. For we acknowledge our omnipotent God and most high Creator to be every where present in the structure of all creatures living, and to point himself out by his workes; whose instruments the cock and hen are in the generation of the chicken. For it is most apparent, that in the generation of the chicken out of the egge, all things are set up and formed, with a most singular providence, divine wisdom, and an admirable and incomprehensible artifice." " Nor can these attributes appertain to any but to the Omnipotent Maker of all things, under what name soever we cloud him; whether it be the *mens divina*, the divine mind with Aristotle, or *anima mundi*, the soul of the universe with Plato; or with others *natura naturans*, Nature of nature herself; or else Saturnus or Jupiter with the heathen, or rather as befits us, the Creatour and Father of all things in heaven and earth; upon whom all animals and their births depend: and at whose beck or mandat, all things are created and begotten."*

3. *Spontaneous generation of animals.*—In this introductory view of the function of generation, it may be proper shortly to inquire whether a regular affiliation from parent to offspring be an indispensable condition for the continuation of the species of every kind of animal,—a question somewhat speculative in its nature, but of considerable interest in relation to some of the general doctrines of physiology, as well as closely connected with our present subject. It has already been stated in general terms that origin by generation and the power of reproduction are characteristics belonging to all organized bodies whether of the vegetable or animal kingdoms. The existence of life implies the sequence of decay and death, or in other words, those varied operations and changes which together constitute the living state continue to occur in each organized body for a limited period only: they sooner or later undergo a gradual alteration, are less regularly performed, and ultimately entirely cease in death. But although every individual belonging to the organized kingdom of nature is necessarily subject to death, the species of each plant and animal never becomes extinct, but is continued upon earth in an undeviating succession of generations. The origin of a mineral, on the other hand, is wholly independent of any pre-existing body of its own kind; and, in the mineral kingdom, all those bodies are held to belong to the same species which agree in external form, physical properties, and chemical constitution. The mineral owes its first origin, as its subsequent increase, to the simple union of its component particles; but the successive generations of every species of organized bodies constitute an uninterrupted chain extending from the time of their first creation, and in which the formation of every new link that is added depends on its temporary attachment to that which preceded it. So fixed, indeed, is the law of continued reproduction of organized bodies, that many naturalists have, in the absence of more definite distinctive characters, adopted the circumstance of reproduction as the only certain means of determining what individuals ought to be regarded as belonging to one species.

While most naturalists readily admit the correctness of the above-mentioned general law, some are inclined to hold that it is not universally applicable, and that there are exceptions to it both in the vegetable and animal kingdoms of organized nature. It is among the simplest kinds of plants and animals that these exceptions are conceived to exist, and more particularly among cryptogamic plants of the nature of mould, small microscopic animalcules formed in infusions of decaying organic matters, and the Entozoa which live in the bodies of other animals. These living productions are supposed by some to arise independently of others of the same kind, nearly in the manner of minerals, by the aggregation of their component molecules, with this difference, that these molecules are of an organic kind. This sort of production without parents has been termed Spontaneous Generation. It has also received at different times various other appellations, such as equivocal, doubtful, primitive, original, and heterogeneous generation.

At one time it was a common belief among scientific men as well as the vulgar that many animals might be produced by spontaneous generation, as for example, the numerous insects or their larvæ infesting putrid substances, various kinds of worms (Annelida), and Molluscous animals, as well as even

* Anatomical Exercitations concerning the Generation of Living Creatures. London, 1653, p. 310 et seq.

some fishes and reptiles; but the increased knowledge of the structure and habits of these animals, and in particular the observations of Redi* and others, demonstrated the error of this opinion, and shewed it to have arisen merely from the circumstance of their real mode of generation not having been observed. After this many felt inclined to reject entirely the occurrence of spontaneous generation in any class of organized beings, and at the present day the question cannot be regarded as by any means entirely set at rest. From the nature of the observations and experiments required in an investigation of this nature, there is almost an impossibility of arriving at a perfectly satisfactory conclusion; but so far as the facts at present entitle us to form an opinion, it may be stated that spontaneous generation, if it occurs, takes place in the simplest kinds of organized beings only; that in most of them it is only occasional; and that therefore this form of generation is to be looked upon as a rare exception to the usual and almost universal mode of reproduction by the separation of a living portion from a parent body.

Minute animalcules, the greater number of which are so small as to be visible only with the microscope, are formed in the infusions of almost all kinds of organic matter, such as starch, sugar, gum, seeds, and different animal substances, when these infusions enter into putrefaction. The kinds of these animalcules are very numerous, and the circumstances which seem to determine the formation of one or other sort are infinitely varied. Thus the nature of the substance suspended in the infusion; and, in the same infusions, the degree of heat, the extent of the decomposition, the quantity and nature of the air admitted, the rapidity with which it is renewed, and the strength of the infusion or the relative proportion of water and organic matter in it, all appear to exert a certain influence in determining the formation of one or other of the kinds of animalcule.

Two suppositions may be entertained regarding the first origin of Infusoria; the one, that of their spontaneous generation; the other, that of their developement or evolution from some pre-existing egg or germ. Those who disbelieve in the first and adopt the second hypothesis hold that the ova of the animalcules exist in the substances of the infusions, or are floating every where in the atmospheric air; that these ova become developed in that species of infusion only which is suited to serve as their proper nidus or matrix; and that all the varieties of animalculæ in different infusions depend upon the infusions being suited, from their composition or the external agencies to which they are subjected, to cause the development of different sorts of ova. The supporters of the hypothesis of Spontaneous Generation hold, on the other hand, that certain changes of composition of the organic molecules in the infusions, in whatever way induced, are the sole cause of the formation of one or other kind of animalcule.

Spallanzani,* one of the most strenuous opponents of the hypothesis of spontaneous generation, shewed by very accurate experiments that no animalcules are formed when the access of air to the infusion is completely prevented, as for example, when it is covered with a little oil, or the vessel containing it is closely sealed; and he thence concluded that the germs of the animalcules must exist in the atmosphere; but the supporters of the hypothesis consider themselves as entitled to hold that no production of animalcules takes place in these circumstances, merely because the exclusion of the air has the effect of preventing that species of decomposition which they regard as necessary for the formation of the Infusoria.

It is stated by some experimenters that animalcules are produced when the infusions are exposed to hydrogen and nitrogen gases, or to atmospheric air artificially prepared; in which it is held that there can be no living ova of animalcules. Again, it appears from numerous experiments, that when the infusions have been exposed to a boiling temperature, which is generally believed to have the effect of destroying the life of all organized productions, the quantity of animalcules formed is not diminished. Some air, it has already been stated, must always be present; but so far as we are aware, the experiments on this point have not been performed in such a manner as to ascertain, whether or not, when an infusion is allowed to come in contact with a considerable portion of confined air, and the whole apparatus is exposed to a temperature above that of boiling water, the production of Infusoria may still take place; and we are consequently obliged, in the absence of more direct experiment, to have recourse to analogical reasoning.

The following considerations appear to us to throw the balance of evidence in favour of the spontaneous production of Infusoria, mould, and the like.

Firstly, those organic matters which are most soluble in water, and at the same time most prone to decomposition, give rise to the greatest quantity of animalcules or cryptogamic plants.

Secondly, the nature of the animalcule or vegetable production bears a constant relation to the state of the infusion, so that, in similar circumstances, the same are always produced without this being influenced by the atmosphere. There seems also to be a certain progressive advance in the productive powers of the infusion, for at the first the animalcules are only of the smallest kinds or Monades, and afterwards they become gradually larger and more complicated in their structure; after a time the production ceases, although the materials are by no means exhausted. When the quantity of water is very small and the organic matter abundant, the production is usually of a vegetable nature; when there is much water, animalcules are more frequently produced.

Thirdly, on the supposition that infusory animalcules are developed from ova, it is neces-

* De Generatione Insectorum. Amst. 1686.

* Tracts on the Nature of Animals and Vegetables. Edin. 1799, (transl.)

sary to conclude, from the experiments already referred to, that these ova are in some instances derived from the atmosphere, but yet the number of Infusoria is by no means in direct proportion with the quantity of air. We are also reduced to the necessity of holding that every portion of the atmospheric air is equally impregnated with infusorial germs or ova, and that these bodies may remain for years dissolved, as it were, or invisibly suspended in the atmosphere, and in a perfectly dry state—a supposition contrary to analogy, and not fully warranted by the fact that Vibriones may be resuscitated by means of moisture after they have been kept in a dry state for long periods.

Fourthly, it may be remarked that the existence of ova, as belonging to many of the Infusoria, is entirely hypothetical, since most of these animals are known, when once formed, to propagate by other means, as by the division of their whole bodies or by budding.

The production of infusorial animalcules from solutions of granite, silex, &c. recently described by Mr. Crosse, we have no hesitation in pronouncing to be either a mistake, or the result of changes occurring in admixed particles of organic matter.

The Entozoa, or that class of animals which live only in the bodies of others, afford proofs of spontaneous generation still more convincing than those already mentioned. These remarkable animal productions are capable of existing no where but in the bodies of those animals which they naturally inhabit: they live either loose or attached, within cavities or imbedded in the substance of the textures; sometimes in places, such as the alimentary canal or respiratory passages, to which the external air has access, and at other times in close cavities of the body, into which there is no opening from without, such as the chambers of the eye, the serous sacs, cysts, and other cavities, in the parenchyma of organs, the bloodvessels, &c. Entozoa do not live for any length of time after being discharged from the natural places of their abode; and they survive a very short time only after the death of the animals in which they live.

If Entozoa are not admitted to be the product of spontaneous generation, in order to account for their origin, it becomes necessary to suppose either that these creatures themselves or their ova pass directly from one animal to another, or that they are introduced through the medium of air or water. Upon the first supposition, carnivorous animals ought to be affected with entozoa, at least in greatest quantity, if not in some instances exclusively; and the entozoa infesting any particular animal ought to be of the same kind as those which exist in the animal serving it for food. But such is by no means the case. Herbivorous as well as carnivorous animals have entozoa, and in no less quantity, and each animal is the abode of its own peculiar kind. The same entozoa infest the same animals in all localities and climates; thus all the human entozoa, with the exception of the Dracunculus or Guinea-worm, which is an external parasite rather than a true entozoon, are the same in all races of men. Neither do we recognise any similarity between the entozoa infesting animals of a particular district and allied tribes of animals living in the neighbouring waters.

In adopting the second supposition that the eggs or germs of Entozoa may gain the bodies of animals by circuitous routes, we are met by many difficulties in addition to those already stated in reference to a similar explanation of the origin of Infusoria. Many Entozoa reside only in particular organs of the body, and in the very interior of these organs, as the human Cysticercus cellulosus in the choroid plexus of the brain, in the substance of the brain itself, in the chambers of the eye, &c. so that it is necessary to suppose the ova of Entozoa to have been introduced into the circulation, carried through the smallest bloodvessels, and deposited in the places in which they are developed. Animals living in the same situations and feeding on the same substances have different kinds of Entozoa. The ova of some of the Entozoa, as for example, those of the common round worm, (Ascaris lumbricoides,) are so large that they could not pass through the largest even of the capillary bloodvessels: the ova are so heavy that they could not be transmitted through the atmosphere; and the supposition of the passage of the ova from parent to offspring is opposed by the mechanical difficulty of the transmission, as well as by the facts that parent and child are not always affected with the same kinds of worms, and that though the complaint of worms may be said to run in families, yet many escape, and one or more generations in the hereditary succession are frequently exempt from it. Entozoa have been observed in the fœtus of animals, and supposing them to be introduced from without, it would be necessary to hold that the entozoa themselves or their ova have passed directly from the mother to the child in the uterus, or to have traversed a route through which the globules of the blood are not transmitted.

Some of the Entozoa, we may further remark, when once formed, are viviparous or bear their young alive; and with regard to these kinds it would be necessary to suppose that they may arise by invisible ova or germs as well as propagate in the viviparous mode.

These facts appear to us to speak strongly in favour of the occasional occurrence of spontaneous generation,—"a doctrine which, had it not been applied in many instances where it was manifestly untrue, would have met with less ridicule and a more just appreciation than it has usually obtained." The epithet "spontaneous," which we have retained as the most common, is equally inappropriate as applied to this or to any other of the processes of nature; and the analogy of by far the greater number of plants and animals militates against the probability of the hypothesis; but it must at the same time be held in mind that the organized bodies in which spontaneous production has been said to occur differ widely in their general structure and functions from those which are reproduced by means of ova; and we are scarcely entitled to reject the hypothesis of their spontaneous generation, merely on the ground that, in this respect, they do not agree with the rest of the animal kingdom. Harvey even, who established the proposition *omne vivum ex ovo*, seems yet to have acknowledged the necessity of admitting some difference between the more ordinary form of generation by means of an egg and that which he called of the spontaneous kind.*

In conclusion, we may remark, that while we feel inclined to admit the existence of spontaneous generation among some species of cryptogamic plants, infusorial animalcules, and entozoa, it must be held in recollection that many of these productions, after their first origin, propagate their species as parents,—that the so-called spontaneous kind of generation is to be looked upon as no more than an exception to the general law of reproduction,—and that therefore extreme caution is necessary in admitting any organized body to be the product of spontaneous generation upon the mere negative evidence of the absence of its seeds or ova.

II. Sketch of the principal forms of the reproductive function in different animals.

Before proceeding to detail the different steps of Human Generation, which forms the more immediate subject of consideration in this article, we shall endeavour to present a short preliminary sketch of the various forms which the reproductive function assumes in different classes of animals.

Reproduction may be divided into non-sexual and sexual, according as the whole process is accomplished by one class of organs in a single individual, or by the concurrence of two different kinds of organs placed either upon one or upon two separate individuals of the same species; the first form occurring among the simplest kinds of animals only, the second belonging to all the vertebrated and the higher classes of invertebrated animals.

1. *Non-sexual reproduction.*—Of the non-sexual mode of reproduction three principal kinds may be distinguished, viz. first, by division; second, by attached buds; and third, by separated gemmæ.

Fissiparous generation.—The most common form of the fissiparous generation, as the first of these varieties has been called, is met with in some of the simpler Infusoria; but it also occurs occasionally in animals higher in the scale. It consists essentially in the division of the parent animal body into a certain number of subordinate masses, each of which, being endowed with independent life, becomes a new individual similar to that of which it originally formed a part. In some of the Infusoria in which the process of subdivision has been minutely observed, fissures are seen to form in the sides of the animal which is about to be reproduced; these fissures gradually enlarge, and meeting with one another, completely separate the parts. In one kind of fissiparous generation the parent body is split into irregularly shaped masses, in some two in number, in different others, four, six, eight, or twelve, and in one, the Gonium pectorale, into as many as sixteen. Each of the subordinate masses, when first separated from its fellow, has an irregular shape, from which it gradually passes into the form and size of its parent.

In a second form of the fissiparous generation, the infusorial animal is divided into two equal and symmetrical halves; in some instances in a longitudinal direction, as in Bacillaria and some Vorticellæ; in others in a transverse direction, as in Paramœcium, Cyclidium, and Trichoda.

The propagation of the Volvox globator, a remarkable infusorial animalcule, may perhaps be considered as belonging to the first of the above-mentioned varieties of fissiparous generation.* This animal consists of an external vesicle of a lenticular shape, moving rapidly through the water by means of cilia in a whirling manner. Within this outer vesicle there are smaller ones of the same kind, in the interior of each of which still smaller ones may be distinguished by the aid of a high magnifying lens. The outer vesicle may be regarded as the parent, and the inclosed vesicles as its young, for in propagation the outer vesicle bursts and is torn into shreds, while the inclosed ones are set free, each of them to execute its independent motions in the water, and in its turn to burst, and thus propagate its like in discharging those which it contains.

A fissiparous kind of generation is not, however, confined to the Infusoria, but occurs also in some of the Cestoidea and Annelida. The most remarkable example is met with in the Nais and Nereis. In the first of these genera, a small portion separated from the tail becomes the new animal. Before the actual separation of this caudal portion, it is marked off from the rest by a notch, and there are gradually formed on its sides the joints, hairs, and other indications of the organs of the complete animal in miniature. The notch enlarges, and the part at last drops off capable of independent existence. In the Nais, that part of the offspring by which it is attached to the parent becomes the head, and in this way, according to the singular notion of Gruithuisen, who observed this sort of reproduction with attention,† the tail of a Nais may be considered as gifted with perpetual life, since this part is extended into each of the new descendants.‡

We may regard as somewhat analogous to this kind of propagation the multiplication of individuals by division, which happens occasionally only or from accident in several of the lower animals which are usually reproduced

* See his Exercitations, as before quoted, pp. 327 and 343.

* Another view taken of the reproduction of the Volvox globator is, that the young are formed in the manner of internal buds.

† Nov. Act. Nat. Curios. tom. xi.

‡ The segments of the infusorial animalcule that is propagating in the fissiparous mode are united by the parts which afterwards become the tails of the new individuals.

in another manner. The most remarkable examples of this are met with in Polypi, Entozoa, and Annelida. When the Hydra viridis is cut through either longitudinally or transversely, each segment continues to live and grow, and is gradually furnished with those parts of the body of which it was deprived by the division. Thus, when the polype is divided across the body, the part with the head and tentacula is gradually furnished with a body, while tentacula grow on the elongated extremity of the other part. When, again, the animal has been divided in a longitudinal direction, and four tentacula are left on each part, the opposite edges of each segment turn round and unite so as to complete the tube of the stomach, and four additional tentacula are formed upon each.

Segments of the Tape-worm, Filaria, and also of some other Entozoa, are capable of living after separation and being converted into independent animals. In the Leech and Earth-worm, as well as some other Annelida, the division of the body into two or more segments is not invariably followed by death, but some or all of the portions continue alive, and, acquiring the deficient organs, become converted into more or less perfect animals.

Gemmiparous generation.—The second form of non-sexual propagation that deserves our attention is that in which the new individual grows upon the parent as a bud or sprout, at first exhibiting little appearance of the form or structure of the perfect animal; gradually assuming its form while still attached to the parent stem; and being afterwards separated to enjoy independent existence.

The best known examples of this kind of generation occur in the polypine and coralline animals, and the process has been observed with great attention by Trembley in the Hydra viridis.* In this animal the young polype makes its first appearance as a small conical eminence on the body of the parent: this gradually enlarges and becomes cylindrical; a cavity is formed in its interior, which at first is separate, but afterwards comes to communicate with the stomach of the parent, so that aliments taken by the parent penetrate into the stomach of the offspring. As the new polype enlarges, the internal cavity opens at the free extremity, where a mouth, provided with tentacula, is formed. The young animal then catches and swallows food for itself: this food at first finds its way into the stomach of the parent, but after some time all communication between the two stomachs is prevented by the closure of the root of the stem of the small polype; and afterwards the offspring is detached from the parent, becomes a separate individual, and in its turn propagates new ones from its sides. The time at which the separation takes place seems to depend in some measure on the quantity of food within the reach of the parent; this occurring at an early period when the supply is small, and when there may be supposed to be a necessity for the young to move about from place to place in search of sustenance. Sometimes indeed the separation is much retarded, and the young ones also propagate while remaining on the parent stem; so that the polype assumes a branched form, the parent stem bearing families of several generations.

The Sertularia, Vorticella, Zoantha Ellisii, and Cornularia Cornucopiæ, also propagate by shoots somewhat in the same manner as the Hydra.*

Reproduction by separated buds or sporules.—The last form of the non-sexual reproduction is that in which the young are formed from small detached masses after they are separated from the body of the parent. These bodies, generally of a rounded form, may be regarded as buds formed in the parent body, as those of polypes are, but detached from it before the evolution of the new animal begins. They bear the same relation to the offspring as the egg of higher animals to their fœtus or embryo, and might be regarded as ova but for an important difference of structure to which we shall afterwards advert. They are called sporæ, germina granulosa, and gemmæ, or germs: they are homogeneous in their structure, and the whole of the substance of which they are composed is converted in the process of their development into the new animal.

In some animals these sporules are formed in all parts of the body indiscriminately, and are therefore found dispersed through it; in others there is present a peculiar organ in which they are formed, constituting the simplest form of a reproductive organ. The Actinia, Medusæ, and some of the lower tribes of Mollusca belong to the first of these sets. In the Aphrodita the sporules lie in the interstices between the different organs of the animal. In those animals in which a particular organ is provided for the formation of the sporules, the name of ovary is given to that organ,—an application of the term not strictly correct, as it belongs more properly to the organ in which complete ova are produced. The production of sporules from a particular generative organ is much the most frequent mode of their formation, and it obtains in the greater number of the lower tribes of Mollusca.

It is a fact worthy of notice that the sporules of some Zoophytes, as those of the Sponge observed by Dr. Grant, are endowed with a faculty of moving, sometimes darting with rapidity in various directions through the fluids in which they are produced. These motions seem to depend on Cilia: the sporules are also provided with a hook, by which they become attached to other objects when they settle,

* Mém. pour servir à l'Hist. des Polypes d'eau douce. Leyden, 1744.

* According to Burdach the propagation of the Volvox globator, already mentioned, and of the Vibrio, Cercaria, and Cysticercus, is effected by the formation of buds, and differs from that of the polype merely in the buds being formed and discharged inwardly. We might, perhaps, consider the regeneration of lost parts which takes place in some animals higher in the scale than those propagating by buds as a manifestation in them of a similar power.

preparatory to their growth and conversion into the fixed and immoveable Zoophyte.

We may here recal to the recollection of the reader that the different forms of non-sexual reproduction which we have now attempted to sketch are not confined respectively to particular classes of animals, for several of these animals are reproduced in more than one manner.

The alleged instances of non-sexual propagation occurring in animals higher in the scale than those already mentioned are very doubtful, and ought to be regarded either as founded in imperfect knowledge of their reproductive organs, or as rare exceptions to the general law of their propagation by the sexual mode.*

2. *Sexual reproduction.*—The existence in animals of generative organs of two kinds, and the necessity of the co-operation of both these organs in reproduction constitute the distinction of sex, or of male and female. In sexual reproduction both kinds of organs produce a substance essentially concerned in the process. The product of the female organ, or ovarium, as it is called, is the ovum or egg, a consistent organised body of a regular and determinate shape, in which the new animal is first formed and resides during its early growth. A whitish fluid is almost always the product of the male organ or testicle,—termed semen, or the seminal fluid, from a belief formerly prevailing that it constituted, like the seed, the greater part of the new being.

Nature of the ovum.—The egg is naturally produced by the female without the concurrence of the male, that is, the whole substance is apparently formed by the female organ, but the egg so formed is incapable of giving birth to a new animal unless it receive a certain portion of, or influence from, the seminal substance of the male. This addition of seminal fluid to the egg makes no immediate perceptible alteration in its structure or appearance, but awakens in it the power of reproduction, fructifies or fecundates it by causing a physical or vital change, the essential nature of which is not fully understood.

In the egg immediately after its fecundation, none of the parts of the new animal are visible. A certain time must elapse during which the egg is exposed to certain favourable influences of heat, air, &c. before the commencement of those changes of development and growth in which the formative process of the new animal consists. The great mass of the substance composing the egg consists of a fluid, holding in suspension granules of animal, albuminous, and oily matter. The form of the egg is given by the external coverings, and there is in every egg a determinate part or region, corresponding in all animals, at which the small rudimentary parts of the embryo first make their appearance. To this part of the egg, which might be called its germ, the power of independent life and reproduction appears more immediately to belong; the granular fluid serves but to afford nourishment to the young being for a certain period. A gemma or sporule, on the other hand, is generally held to differ from the ovum in being homogeneous in its structure, having no investing membranes, and being entirely converted into the substance of the new animal produced from it. In the present state of our knowledge, however, the distinction between an ovum and a sporule must be admitted to be somewhat arbitrary.

The position of the male and female generative organs upon the same or upon different individuals, and the place or manner of the development of the young animal from an egg, are the two most prominent circumstances in regard to which the forms of sexual reproduction differ from one another in various animals. The principal processes in which sexual reproduction essentially consists, are, 1st, the formation of an egg by the female organs; 2nd, the secretion of the seminal fluid by the male organ; and 3rd, the union of the sexes, and means by which the seminal fluid is applied to the egg so as to confer fecundity upon it.

Hermaphrodite generation.—In some of the lower tribes of animals belonging chiefly to the Annelida, Acephala, and Gasteropoda, the male and female sexual organs are placed on one individual, an arrangement of the sexual organs termed Hermaphrodite, and all the individuals belonging to one species are consequently similarly formed In Insects, Crustacea, some of the Mollusca, and all the Vertebrata, the different sexual organs are placed on two distinct individuals, which are thus constituted respectively male and female. In the greater number of those animals in which the last-mentioned arrangement exists, besides the sexual peculiarities, there are in each certain general differ-

* In many of those instances in which female animals have been supposed to give rise to productive ova, the males have at first escaped notice from the smallness of their number or other causes; and with regard to others of the lower animals, it may very reasonably be doubted whether the products called ova have not been rather of the nature of gemmæ or sporules, such as those formed in the Actinia and other animals naturally propagating in the non-sexual manner. As in this predicament may be mentioned, according to Burdach, Oxyuris, Filaria, Ligula, Tricuspidaria, and others of the Entozoa; Serpula, Sabella, and other Tubicola; Cirrhopoda, and Mussels, and Scutibranchiata and Cyclobranchiata. The Syngnathus was erroneously regarded by Pallas, and the Perca Marina by Cavolini, as propagating without sex. It is, however, probable that some animals provided with both sexual organs, and which usually propagate in the sexual mode, are occasionally reproduced without the immediate concurrence of the male. Thus the female Aphis, after being once impregnated by the male, bears, for a certain portion of the year, female young only, which are capable of being reproduced for nine generations without any of these female animals receiving any new influence from the male. In the last of these generations occurring in autumn, males also are produced which impregnate the females destined to carry on the same succession of generations during the next season. According to some this extension of the fecundating influence of the male through more than one generation is not confined to the animals just mentioned; but without doubt the instances in which this has been supposed to be the case have been greatly over-reckoned.

ences in the structure of the other parts of the body.

In Hermaphrodite animals there are two modes in which fecundation takes place. In some of the Acephala, and in the Holothuriæ, the union of the sexual organs necessary for fecundation takes place in a single individual; while in others, as Helix and Lymneus among the Gasteropoda, copulation, or the union of two individuals, is required, and there is mutual impregnation, the female organ of each animal being fecundated by the male of the other,—a mode of impregnation which also exists in the common Earth-worm, Leech, and some other animals. Occasionally we find that three or more individuals engage in this sort of mutual fecundation, being arranged in a chain or circle.* (See HERMAPHRODITE.)

Diœcious reproduction, or with distinct individuals of different sexes. Oviparous and viviparous generation.—In those animals again in which the position of the sexual organs on separate individuals renders copulation necessary, the mode of production of the new animal from the egg seems to be the most prominent circumstance according to which the reproductive process is modified. Thus, while in a certain number of them the young are born alive, in others they are hatched from eggs laid by the female parent. This constitutes the difference between Viviparous and Oviparous animals; to the first of which classes Mammalia belong, to the second Birds, and most Reptiles and Fishes. A short comparison of the more important steps of the generative process in the Mammiferous animal and the Bird will most readily explain the difference between viviparous and oviparous generation.†

In both these classes of animals ova are formed from the ovary, and in both the ova are fecundated within the body of the female parent. The process by which the egg is separated from the place of its formation, and the changes it undergoes in being perfected after this separation, are the same in both: but after the fecundation and completion of the egg, it is differently placed in the two classes of animals; for in birds the egg passes through the oviduct and leaves the body of the female parent, to be hatched into life under the influence of favourable external agents; while in the mammiferous quadruped, the egg remains within the uterus of the female generative organs, becomes attached to it, and has there formed from it the young animal, which does not quit the body of the parent until it is capable of independent life. The egg of the bird leaves the body of the mother provided with a considerable quantity of organic matter, by which alone, under the influence of heat and air, the embryo is nourished during incubation. The egg of the mammiferous animal is extremely small compared to the size of the young animal at birth, and the fœtus consequently draws a continual supply of the materials of its nourishment from the uterus of the mother, with which it is more or less intimately connected. The residence of the child or young animal in the body of the mother during its formation and growth is termed pregnancy, or utero-gestation.*

Ovo-viviparous generation.—There are other animals, however, besides Mammalia, which bear their young alive, as is the case in many cartilaginous and a few osseous fishes, in several Batrachia, Sauria, and Ophidia, and also in some Gasteropodous Mollusca, Insects, Annelida, and Entozoa. But there is an important difference to be pointed out between the viviparous form of generation occurring in these animals and that which belongs to the Mammalia. For the female generative organs of the above-mentioned animals, as well as the eggs they produce, resemble much more closely in their structure those of oviparous than those of strictly viviparous animals. As, in the animals now under consideration, the

* In the Cyclostoma viviparum the sexes are distinct.

† Harvey in the Sixty-third Exercitation thus enforces the analogy between the oviparous and viviparous modes of reproduction. "I have already given you the reason why I have drawn out documents concerning all other egges from the egges of Hens; namely, because they are cheap and every man's purchase."—"But there is more difficulty in the search into the generation of viviparous animals; for we are almost quite debarred of dissecting the humane uterus: and to make any inquiry concerning this matter in Horses, Oxen, Goats, and other Cattel, cannot be without a great deal of pains and expense. But those who are desirous to make tryal whether we deliver the truth or not, may essay the business in Doggs, Conies, Cats, and the like."—"But we in the entrance of these our observations have concluded that all animals are in some sort produced out of an egg: For the fœtus of viviparous creatures is produced after the same manner and order out of a pre-existent conception, as the chicken is formed and constituted out of an egge. There being one and the same species of generation in them all, and the exordium or first principle of them all is either called an egge, or at lest something answerable and proportionable to it. For an Egge is an exposed conception from which a Chicken is produced; but a conception is an egge retained within, untill the fœtus have attained its just bulk and magnitude: in other matters it squares with an egge," &c. "Besides, as a Chicken is hatched out of an Egg, by the fostering heat of the sitting Hen, or some other ascititious hospitable patronage, so also the fœtus is produced out of the conception in the egge, by the soft and most natural warmth of the parent.—"And then, concerning that which relates to procreation, the fœtus is produced out of the conception in the selfe same manner and order as the chicken out of the Egg; with this only difference, that in an egge, whatever relates to the constitution and nutrition of the Chicken, is at once contained in it; but the conception (after the fœtus is now formed out of it) doth attract more nourishment out of his parent's womb; whereupon the nourishment increases with the fœtus."—"The first Conception, or Rudiment, therefore, of all Animals is in the uterus," (this applies to Quadrupeds,) "which, according to Aristotle, is like an egg covered over with a membrane when the shell is pilled off." And Harvey finally concludes with Aristotle: "All animals, whether they be swimming, walking, or flying animals; and whether they be born in the form of an Animal or of an Egge; are all generated after the same manner."

* The nature of the egg of viviparous animals, which has only recently been fully understood, will be described in a subsequent part of this paper, and more in detail in the article OVUM.

egg is proportionally large, the fœtus grows principally by the assimilation of materials procured from it, and there is not that intimate connection of structure nor interchange of substance between the mother and fœtus which occurs in Mammalia. The term ovo-viviparous is applied to the variety of reproduction now under consideration; as expressing that in it, although the fœtus is produced fully formed and alive, the ovum is merely hatched within the parent body. We find, accordingly, that this form of generation is liable to vary, and occasionally to run into the truly oviparous kind. Thus, some animals which bear live young at one season lay eggs at another season of the year, as occurs in some Insects; and in others, as Lacerta agilis, the ova remain within the mother's body for a part only of the time employed in the development of the young; the process of hatching beginning and going on for a longer or shorter time within the female parent, and being completed as in the bird without.

In all truly viviparous, in most ovo-viviparous, and also in many oviparous animals, the ova are fecundated within the parent's body; and we find provided for the purpose of introducing the seminal fluid into the female genital organs, a more or less complicated apparatus in both male and female, by which the union of the sexes is brought about. In the greater number of strictly oviparous animals, and particularly those that are aquatic, as osseous fishes and Batrachian Reptiles, fecundation is operated externally to the parent body; that is, there is no union of the sexual organs of the male and female, but the ova laid by the female are covered with a certain quantity of seminal fluid shed by the male.*

Utero-gestation in the Mammalia is terminated by parturition or the birth of the young; while in the bird or oviparous animal birth consists in the exclusion of the young from the egg. At this period in Mammalia, the organic connection between mother and offspring is dissolved, and in both viviparous and oviparous animals the birth is accompanied by important structural changes, which fit the offspring for independent life and aerial or aquatic respiration. The young of Mammalia after birth, though they cease to be organically connected with the mother, continue to derive a certain quantity of support from her, feeding on the milk secreted by the mammæ. But in all other classes of animals, the young are at birth capable of feeding on external aliment.

Varieties in respect to utero-gestation and the developement of the young.—There is considerable variety among different animals in the degree of perfection at which the young have arrived at the period of birth. Thus, Insects, Batrachian Reptiles, and some other animals leave the egg at a very early period; differing widely from their parents in structure and functions, they live for a time in a masked or larva condition, and undergo afterwards various changes or so-called metamorphoses before attaining the mature condition. Fishes leave the egg while their structure is yet very incomplete; and even in the higher animals we observe varieties in this respect: thus, some birds, more especially those building on trees, are unfledged, blind, and helpless when the shell is broken; and some quadrupeds, among which may be mentioned the Rodentia, Feline, and Canine species, are at birth blind and weak, and with little power of supporting their natural high temperature.* The most remarkable instance of variety of the kind now alluded to, however, occurs in the Kangaroo and other Marsupial animals, the generation of which deserves more particular mention in this place as it exhibits a considerable deviation from the more ordinary reproductive process in Mammalia, and is attended with some important modifications in the structure of the generative organs.

In the Mammalia generally, it has already been stated that there is an intimate organic connection between the fœtus and mother, by means of which the former is supplied with the materials of its growth. The intimacy of this union (as we shall explain more fully elsewhere) varies much in different tribes of animals. It is greatest in the placenta of the human female, and from this there may be traced a series of animals in which it becomes more and more loose. According to recent researches in Comparative Anatomy, there is also observable in the descending series of these animals a nearer and nearer approach in the general structure of the body, and in the conformation of the generative organs to the oviparous type. This approach to the oviparous structure is most strongly marked in the Marsupiata, as the Opossum, Kangaroo, &c. and in the Monotremata, as the Ornithorynchus and Echidna.†

Marsupiate generation.—The fœtus of the marsupiate animal leaves the uterine system of the mother or is born at an early period of its formation, while it is yet of a very small size, and its organs are comparatively imperfectly formed. On being born it is introduced by the mother into the pouch or marsupium formed by a reduplication of the integuments of the lower part of the belly, and a short time after it gets there, the fœtus is found attached by its mouth to one of the nipples of the mammæ, which are concealed within the marsupium. The young of the marsupiate animal

* In the land Salamander, which is ovo-viviparous and breeds in the water, although there is no sexual union of the male and female, there is yet internal fecundation, the seminal fluid being carried into the oviduct of the female along with the water in which it is effused.

* Under the head of OVUM we shall shew that all animals undergo changes which constitute metamorphoses of one kind or other during their formation or development.

† See the interesting papers by Mr. Owen on the Generation of the Kangaroo and Ornithorynchus in the Philosophical Transactions, part ii. for 1834, p. 333, and in the Transactions of the Zoological Society, vol. i. p. 221.

there receives its food by the mouth and is nourished by digestion at an early period of its advancement; and, although its external form and organization very much resemble that of the fœtus of other mammiferous animals at a similar stage of their advancement when they are still confined to the uterus of the mother, their internal organization undergoes at the time of their exclusion the same remarkable changes which occur at birth, and which are connected with aerial respiration and the independence of the vital functions.*

Monotrematous generation.—The generation of the Ornithorynchus and other monotrematous animals deserves also to be noticed here as differing in some respects from that of other Mammalia; but, unfortunately, this subject, which has been involved in obscurity ever since the first discovery of these remarkable animals, notwithstanding that several important facts have been recently ascertained, cannot be considered as completely understood. The Ornithorynchus and Echidna were long regarded as holding an intermediate place in respect to their organization between Mammalia and Birds. The existence of mammary glands was denied by the first dissectors of these animals; and from this circumstance principally, together with the analogy in general structure already alluded to, the Ornithorynchus was believed by many to be oviparous. The recent investigations of Owen have proved the existence of mammary glands as well as the suckling of the young, while they at the same time shew that the generative organs and the ova within the ovaries partake in a great degree of the oviparous structure.† In this approach to the oviparous type, however, it has been satisfactorily shewn that the Ornithorynchus resembles the class of Reptiles rather than that of Birds. The ova of this animal have not, however, been found in any of its haunts; and, although no one has yet had an opportunity of dissecting the gravid uterus, naturalists are now inclined to hold the opinion that it bears its young alive. Should this be fully proved to be the case, the Ornithorynchus may with justice be considered as an example among mammiferous animals of the ovo-viviparous form of generation, most analogous to that occurring in the Slow-worm or Adder; the ovum being, at the time of its descent into the oviduct, of proportionally large size, and there being no proper placenta or intimate organic union between the mother and fœtus.

Comparison of animal and vegetable reproduction.—In concluding this rapid sketch, it may not be out of place to introduce here a few remarks upon the analogies existing between animal and vegetable reproduction.

The seed of plants is generally regarded as corresponding to the egg of animals. The seed and egg correspond in being both the residence of the germ or living part from which the new organized body springs, and also in both containing a certain quantity of matter destined for the temporary nourishment of the growing embryo; but the germ is in a different state in the seed and egg; for while in the egg none of the parts of the new being are visible at the time of its separation from the parent, the rudiments of the embryo are frequently to be found, small but simulating in some degree the plant, in the germ of the seed when it is perfected, and before the commencement of germination. The circumstances favourable to evolution give rise to the development of the embryo in both, but in the animal the influence of the male conferring fecundity on the egg makes no perceptible alteration in the germ, while in the plant no part of the seed, neither cotyledon nor germ, is formed unless fecundation by the pollen of the male takes place; and the seed is not separated from the ovary or place of its production until the rudimentary parts of the embryo are already sketched out.

We have examples of non-sexual reproduction of plants among the Cryptogamia, in which the new plant springs from sporules or granules endowed with the independent vital properties of the seed.

The greater number of monocotyledonous and dicotyledonous plants may be regarded as hermaphrodite, as both the seeds and pollen are formed on the same individual, while in others the position of the sexual organs on distinct individuals corresponds with the more common arrangement in the animal kingdom.*

In different tribes of plants we also observe examples of occasional propagation in a manner different from the more common one by seeds or sporules. Thus the buds and branches, which are the means of their ordinary growth and increase, may, when removed, be capable of independent existence and give rise to distinct plants, or even when still on the parent stock may take root and grow anew. Some buds separate naturally and are evolved in the manner of seeds when placed in favourable circumstances; and in a third class of instances separated buds are preserved in the collections of nutrient matter constituting the tuberous and bulbous roots by which many plants are propagated.

To complete the enumeration of the points of analogy between animal and vegetable reproduction, it may be stated that there is the same reason for believing in the spontaneous generation of some of the Cryptogamic plants as in that of Infusorial animals.

* For the details respecting the structure and functions of the generative organs of the Marsupiata, the mode of passage of the embryo from the uterus to the pouch, see the article upon the Comparative Anatomy of these animals, MARSUPIATA. It is curious to note that until the discovery of the uterus of these animals by Tyson, the vaguest conjectures prevailed respecting their mode of reproduction, it being even supposed by some that the fœtus grew from the first attached to the nipple, and consequently originated as a bud.

† The name of Monotremata applied to these animals, it may be remarked, means *with one vent*, they having a cloaca.

* As in strictly Hermaphrodite, Monœcious, and Diœcious plants.

The following table is intended to exhibit a synoptical view of the various forms of the reproductive process occurring in different classes of animals.

Reproduction.	Non-sexual	Fissiparous	Parent splits, each part a new animal. 1. Transverse. 2. Longitudinal. 3. Irregular. Parent splits and discharges the young.
		Gemmiparous ..	Budding upon the parent stock. Separated buds. Gemmæ or sporules. 1. On all parts of the body. 2. On one part or organ only.
	Sexual	Hermaphrodite.	Both sexual organs on one individual. 1. Self-impregnation. 2. Mutual impregnation.
		Diœcious......	Oviparous, laying eggs which are hatched. 1. External fecundation. 2. Internal fecundation. Ovo-viviparous. Eggs hatched within the maternal body. Mammiferous, suckling the young. 1. Monotrematous. 2. Marsupial. 3. Placental or strictly viviparous.

III. Reproductive function in man and the higher animals.

1. *Sketch of this function in man.*—In now proceeding to a more detailed account of the function of generation, our description must be confined to the process of reproduction in the human species and in those animals which are most nearly allied to man.

The following may be mentioned as the principal steps of the reproductive process in the female of the human species.

The human offspring is derived from an egg like that of all the more perfect animals. The egg is gradually formed in the Graafian vesicle of the ovary at the period of maturity. In productive sexual union the vagina and uterus receive a certain quantity of the male seminal fluid, and a series of changes are induced in the female generative system which have the effect of dislodging one or more ova from their residence in the ovary, and of bringing these ova into contact with the seminal fluid, in order that they may be fecundated or rendered fruitful. The mechanism of the discharge of the ova is the following. The Graafian vesicle swells, and bursts at its most prominent part. The ovum escaping from its interior is received by the fimbriated cavity at the commencement of the Fallopian tube, along which tube it gradually passes until it reaches the interior of the uterus, where it arrives probably in ten or twelve days after sexual union. There is every reason to believe that before the ovum reaches the uterus it has already been exposed in some part of the genital organs to the influence of the male semen, and that it is consequently fecundated. We shall have occasion afterwards to inquire more minutely into the place and manner of this fecundation. The female is now said to have *conceived* or to be impregnated, and the ovum to be *fecundated*. We shall endeavour, for the sake of clearness, to bring the history of the steps of this process under the three distinct heads of, first, the changes of *conception* as regards the female, secondly, the process of *fecundation* as relating to the male, and thirdly, the effects of the union of the male and female product.

Before the ovum reaches the uterus a change has already commenced in the interior of that organ, which in its farther progress has for its object to bring about an organic union between the uterus and the fœtus with its coverings. The minute embryo soon becomes visible in the ovum, has envelopes formed over it which become connected with the lining membrane of the uterus, and as it advances in growth continually receives a supply of nourishment from the bloodvessels of the uterus. It is nourished in this way during the whole of its intra-uterine life, at the termination of which the child is brought into the world or born, being expelled from the uterus by those painful efforts and contractions of the uterus constituting parturition or labour. The child is now capable of being nourished by digestion of food in the stomach, independently of any organic connexion with the mother, and breathes air by its lungs. Although all organic connexion, however, between the mother and child is now dissolved, yet the infant is for a time dependent on the mother for nourishment, receiving by sucking from the mammæ the milk, which it assimilates by its own independent powers. In the present article our object is to describe only the processes of conception and fecundation, referring to the article Ovum for an account of the growth of the fœtus, and to the articles Uterus, Ovary, &c. for the more minute anatomical and functional relations of these organs in the unimpregnated and impregnated states.

Organs of reproduction.—The organs of reproduction in both sexes are frequently divided by anatomists into external and internal, according as they are situated more or less near the surface of the body; but a more suitable arrangement of these organs in a functional point of view is that which is founded on the part which each of them is destined to perform in the generative act. The male organs consist of the penis and urethra, testicles, seminal vesicles, seminal ducts, prostatic body, and Cowper's glands: the female organs, of the vulva, clitoris and nymphæ, vagina, uterus, Fallopian tubes, and ovaries. The testicles in the male and the ovaries in the female are the productive organs, secreting or forming by an organic process the product of each respective sex; the vasa deferentia and vesiculæ seminales conduct and retain for a time the seminal fluid; the Fallopian tubes conduct downwards the ovum from the ovary to the uterus; the uterus receives and retains the ovum during pregnancy or the formation of the child. These constitute the internal organs; the remaining parts are the external organs, and are chiefly connected with sexual union or the expulsion of the products from the body. The glans penis, the clitoris, and the neighbouring parts are the seat of that feeling which accompanies the venereal act: the penis, with its urethra, serves to conduct the seminal fluid into the vagina and uterus of the female: the vagina, besides receiving the seminal fluid, is the issue for the child when it is expelled from the uterus in parturition.

Puberty.—It is only during a stated period of life that animals are capable of reproduction. In infancy, youth, and old age the functions of the sexual organs are in abeyance. The name of puberty is given to that period of life at which either sex first becomes capable of reproduction, at which time various important structural and functional changes occur both in the sexual organs and in the whole economy.

These changes are upon the whole more marked in the female than in the male, a circumstance which may be attributed to the longer and more intimate connexion of the female with the product; the maternal parent affording a supply of nourishment to the child during the whole of its intra-uterine life, while the male does no more than furnish momentarily a small quantity of the seminal fluid necessary for fecundation.

Structural differences of the sexes.—In infancy and youth the two sexes do not differ materially in the general shape of the body, nor in physical powers; but as the age of puberty approaches, and the sexual organs undergo those changes which fit them for the performance of their appropriate functions, the male and female bodies become altered in form, and acquire a more marked difference, while the mental and physical powers also partake of this discrepancy.

We shall do no more than mention here the most striking of these peculiarities, as a more detailed account of them belongs to another place.

Besides these differences which belong immediately to the sexual conformation, the comparatively broader shoulders and wider chest of the male, and the larger pelvis and abdomen of the female, are universally known as constituting the chief peculiarities in the general contour of the body. The smaller size of the whole body in the female, amounting in general to a tenth of the whole height, the greater slenderness of the female frame, the less prominence of the muscles, the more tapering and rounded shape of the limbs, the greater quantity of fat under the skin and elsewhere, the smaller, smoother, and finer bones, and the more delicate texture of some other parts of the body, are all peculiarities of female conformation contrasting with the opposite qualities in the male body. As belonging to the male may be mentioned the low and rough voice from the larger size of the larynx and longer vocal cords,* the occurrence of hair on the chin, upper lip, and cheeks, as well as over the body and limbs, in which situations it is rarely met with in the female, the greater physical power and activity, capability of enduring fatigue and daring, &c.

As these changes in either sex are gradually developed, hair grows on the skin covering the symphysis pubis, in the neighbourhood of the genital organs,† and later under the axillæ.

The local changes attendant upon puberty in the male are the enlargement of the penis, its more frequent erection, and accompaniment of this by the sexual feeling; the enlargement of the testicles, vesiculæ seminales, prostatic gland, and other accessory parts; the more depending condition of the testicles in the scrotum; the secretion of a certain quantity of the seminal and prostatic fluids; and, after the attainment of the full sexual powers, the occasional spontaneous emission of some of the seminal fluid, occurring in general at night during sleep, and being accompanied by some sexual feeling in dreams.

In the female at this period, both external and internal organs undergo a considerable and rapid enlargement; the mons veneris and external labia become more full; the clitoris and nymphæ in many, but not in all, become susceptible of a certain degree of swelling or erection; the breasts enlarge, the vesicles in the ovaries become dilated, and some of them more prominent, and there is established a periodical discharge of a certain quantity of a sanguineous fluid from the internal genital organs.

Menstruation.—This periodical loss of blood demands the attention of the physiologist as one of the most remarkable of the sexual peculiarities of the human female, and as bearing an intimate relation not only to the generative process, but to most of the other functions of the economy.

The periodical recurrence of the discharge of blood every lunar month or twenty-eight days

* Comparative measurements have been made of the length of the vocal cords in boys immediately before and after puberty, and those of the young men have been found to be nearly double the length of those of the boy.

† Hence the name of this bone and of the period of life of which we are now speaking—pubes and puberty.

has given to it the name of menses or menstruation: the Greek word catamenia is also employed to denote it by medical men, and the English expressions of "the illness" or "the courses" are those in most common use among the vulgar.

The menstrual flow of blood lasts usually for about five days, beginning and leaving off gradually, and being in greatest quantity towards the middle of the period. The interval is thus generally about twenty-three days. The discharge in general takes place slowly, or drop by drop.

The menstrual flow of blood is preceded in most women by some symptoms of fever, a quicker and fuller pulse than usual, languor, headach, pains in the back, and frequently in the hypogastria or region of the ovaries, and by many other symptoms of general derangement of the functions, particularly in weak or unhealthy women. In young women upon the occasion of the first appearance of the menses all these symptoms are frequently more strongly marked.

Menstruation may be regarded as the most certain sign of the arrival of puberty, and of the fitness of the human female for marriage, as there are very few instances on record in which conception has taken place before the occurrence of the menstrual discharge. It continues for the whole of that period of life during which women are capable of bearing children; and after this, when it ceases, a considerable change in the female constitution ensues: the "change of life" or "critical period" is said to have arrived, from the liability there then is to the conversion of the plethoric state, previously relieved by menstruation, into some morbid affection either of the sexual or other organs of the body.

During menstruation, the uterus, vagina, ovaries, and other parts of the genital organs are usually more vascular and turgid with blood than in the interval; the mammæ, which exhibit at all times a remarkable sympathy with the condition of the uterus, frequently participate in this increased activity at the menstrual period, as they then swell and become hard.

Menstruation consists essentially in the exudation of a fluid resembling blood from the female genital organs, and principally from the uterus. Haller states that the blood has actually been observed to proceed from the uterus in women labouring under prolapsus of that organ, and John Hunter as well as others have found the cavity of the uterus filled with the fluid in women who have died during menstruation.

Menstruation usually ceases during pregnancy, and in the majority of women during lactation also. In those instances in which the monthly flow has continued to take place during pregnancy, there is reason to believe, according to Haller, that it may have proceeded from the upper part of the vagina, as the first changes attendant upon utero-gestation usually close firmly the neck of the uterus.

The quantity of fluid which exudes during one menstrual period amounts in general to five or six ounces; but this is subject to great variation from the mode of life of the individual, state of her health, diet, and other circumstances. The quantity is usually greatest, cæteris paribus, in healthy women living well, but the increase of the quantity above a certain point or its diminution below another are equally to be regarded as unnatural or diseased states of the action. In tropical countries the quantity is greater than in more temperate regions, amounting occasionally to twelve or even twenty ounces. In Lapland and some other northern countries the quantity is, on the other hand, much below the mean, being occasionally as low as three ounces; and yet in both these situations the women are to be regarded as within the bounds of health.

The quantity of fluid lost in menstruation is increased by all those circumstances which cause a determination of blood to the pelvis or its contained viscera; hence the effect of posture, irritating diuretics, drastic purgatives, and those medicines termed emmenagogues.

The nature of the fluid discharged in menstruation has not yet, we believe, been investigated with sufficient accuracy. It bears a close resemblance to blood, having generally the colour of the venous kind. It is generally fluid, but sometimes coagulates from exposure to air: it is generally believed to contain less fibrine than blood, and to be less prone to putrefaction.

Respecting the causes of the menstrual discharge and its uses in the economy, many very absurd hypotheses have been advanced in medical writings. It was a common belief among the ancients that the menstrual fluid exerted a baneful influence on every living object, plant, or animal, and many of the institutions and laws of antiquity shew that this natural process was looked upon with abhorrence. The correspondence in the length of time of the moon's changes with the recurrence of the menstrual period induced many to believe in an influence exerted by the moon on the female generative system; but the error of such a notion is sufficiently proved by the circumstances, first, that more women are not found to menstruate at one period of the moon's changes than at another. and, second, that the women of any place mentruate at all different times. Besides this, many women do not menstruate regularly every lunar month. In some this change takes place every three weeks, in others every fortnight, and there are many in whom there is a variation of one or two days on either side of the common period of twenty-eight days.

When we consider the circumstances previously mentioned respecting the intimate connexion subsisting between the menstrual flow and the processes of reproduction, we shall be led rather to the opinion that menstruation is to be regarded as a means of relieving the female system periodically from an overplus of blood which exists during the whole of the time in which it is capable of propagation. It occurs at this period of life only, it generally ceases during pregnancy, and it may therefore correctly be regarded as the indication of the presence in the system of that quantity of nutrient matter, which, during pregnancy, is destined to serve for the nourishment of the child. We say that this flow does no more than *indicate* the surplus quantity of blood in the female genital organs; for, as Burdach remarks, the loss of six ounces of blood for ten successive lunar periods amounts to only three pounds twelve ounces, whereas the fœtus and its appendages during that period attain the weight of from ten to fifteen pounds, to which we might add the enormously increased weight of the uterus in order to estimate the whole addition which is made to the uterine system during pregnancy. Again, during lactation or nursing the tendency to a superabundance of blood or plethora in the uterus is generally relieved by the flow of milk from the mammæ, which, as has already been remarked, sympathize very constantly with the uterus and other parts of the generative system.

Such a tendency to plethora as that we have just alluded to, it is scarcely necessary to remark, can have no connexion with lunar or planetary influences, and we are, perhaps, more justified in classing it along with those other changes of the economy which indicate a remarkable tendency in the human constitution to periodical recurrence of its actions.

The crises of fevers on days terminating periods which are most frequently of the duration of seven, fourteen, twenty-one, or twenty-eight days, are of this kind; and it is deserving of notice that menstruation recurs more frequently in periods, the number of days of which are multiplies of seven, than in any others.*

It has been attempted to be shewn that the male is subject to a periodical plethora in some respects similar to that which gives rise to menstruation in the female, but without any just reason, unless we choose to consider as such the gradual accumulation of seminal fluid, which frequently takes place in healthy men of sanguine temperament, and which gives rise to its periodical emission.

With regard to menstruation we shall only farther remark that, according to Haller, Burdach, and some others, women are more liable to become pregnant immediately or within a few days after the cessation of menstruation than at other parts of the interval; the probable reason of which will appear from details given in a subsequent part of this article.

Periodical heat in animals.—None of the lower animals in the natural state appear to be subject to anything like a menstrual change or periodical discharge of blood. In lascivious Apes and in some of the domestic animals fed highly, an exudation of bloody mucus from the vagina and external genital organs of the females sometimes occurs, but this is manifestly quite different from menstruation. There is, however, in most of the lower animals a very obvious periodicity in the functions of the reproductive organs; for while the human female is, during a certain period of life, nearly equally fit for propagation at all times, this is the case with very few animals, and, indeed, chiefly among those living in the unnatural state of domesticity.

At certain seasons of the year there occurs in most of the lower animals a determination of blood to the genital organs of the female, accompanied by sexual desire, which leads them to the propagation of their species. This state of excitement, generally named " the heat,"* lasts for a longer or shorter period; in the ewe for twenty-four hours only, in the cow and mare for a few days, in the bitch nine or ten days, and in the hen-pheasant for as long as two months. In most animals, after it has run its accustomed course, it disappears naturally, but it is more certainly and sooner dispelled by fruitful sexual union.

The heat belongs more properly to the female than to the male, as there are many species whose females receive the male only at particular seasons, while the male is at all times fit for propagation. In others, constituting the majority of instances, the male organs are subject to the same periodical increase of activity as the female. The male in these animals is usually in heat at an earlier period than the female.†

In some animals there is a more frequent periodical return of the heat than in others; thus the ewe which remains unimpregnated comes in heat every fourteen days; the cow and some apes, the mare, ass, and buffalo every four weeks; the sow every fifteen or eighteen days; but in these animals the high feeding attendant on domesticity may very probably occasion a more frequent and less natural return of the period of heat than would occur in the wild state.

It would appear that the season of the year at which animals most commonly breed is subject to very many and extensive variations, according to the temperature, latitude, and other circumstances connected with the country which they inhabit.

During the continuance of the heat a peculiar odour is exhaled from the genital organs, and there exudes chiefly from the external organs some bloody mucus, which, in some lascivious apes, resembles blood so much as to have given rise to the belief already alluded to that these animals menstruate.

Age at which puberty occurs.—The appear-

* According to the researches of Mr. Roberton of Manchester, detailed in an interesting paper, published in the Edinburgh Med. and Surg. Journal, vol. xxxviii. p. 237, out of 100 women, in sixty-eight the menstrual discharge returned every fourth week; in twenty-eight every third week; in one every second week; in ten at irregular intervals. These varieties usually exist as family and constitutional peculiarities.

* Termed the Rut in the deer, wild boar, &c.

† In some male animals the signs of heat are very apparent. The fine colour of the plumage of most male birds in the breeding season, the deep colour of the comb, &c. in gallinaceous fowls, the thickness and bushy hair of the deer's neck, the greatly enlarged size of the testicles in the cock-sparrow, may be mentioned as familiar examples.

ance of puberty is gradual in both sexes, but, upon the whole, more slow in the male than in the female. The age at which it takes place varies in the same and in different countries according to the mode of life, physical and moral education, and other circumstances. It takes place at an earlier age in woman than in man: in the former most frequently in this country at from the age of thirteen to sixteen years, in the latter from fifteen to eighteen years; but instances are not unfrequent of girls menstruating and of boys passing into manhood one or two or even more years sooner or later than the above-mentioned periods, as from ten or eleven to twenty or twenty-two years.*

These variations are to be considered as dependent on constitution in the greater number of instances; but in respect to their occasional causes, it may be stated that all those circumstances which produce a determination of blood to the sexual organs or pelvic viscera, which relax the body generally, or turn the attention of the young to the sexual function, tend to bring on sooner than natural the local changes of puberty. Warm rooms, a sedentary mode of life, particular kinds of reading, and some bad habits are all hurtful in this respect.

According to the observations of many travellers, puberty arrives sooner in warm than in temperate climates; and some have hence too hastily concluded that the warmth of the tropical country has been the cause of the more precocious appearance of menstruation in women and puberty in men, an opinion the error of which is shewn by the fact that instances of very early puberty are not unfrequently met with in high northern latitudes.† The occurrences of marriages, therefore, or sexual union at the early age of six or seven years in the South Sea Islands and elsewhere is to be looked upon rather as a proof of the barbarous and debased state of civilization of these people, than taken as an evidence of their being fitted by nature for the functions of propagation at the period of life now mentioned.

There do sometimes occur, however, in all nations unfortunate examples of precocity in the development of the sexual organs and activity of their functions. Thus in male or female children of four and even of only three years old all the changes of the sexual organs, and some of those of the body generally, which belong to puberty of a more advanced and natural age, take place. The attention of such children is soon called by their local feelings to the condition of the sexual organs, and vicious habits are induced, which, from the misery they carry along with them, it becomes the duty of the medical man to counteract by all the resources of his art.

Period of life during which the generative function is exercised.—The length of time during which the male and female of the human species retain the power of propagation is subject to the same variations which attend the arrival of the age of puberty. The most healthy women are in general capable of bearing children between the ages of fifteen and forty-five, or for a period of thirty years. Men retain the powers of their sex for a longer time, as from the age of seventeen to sixty or seventy, that is, for forty-five or fifty years. There are, however, on record instances of both sexes, but more especially the male sex, having retained their respective powers for a longer period than that just stated;—of women menstruating a second time (after the cessation of this function at the usual period) at the age of sixty or seventy,* and in one or two instances bearing a child at that advanced age;—of propagation in the male sex to the age of seventy, eighty, and ninety, and in the celebrated case of old Parr even to that of one hundred and thirty years.†

Among the lower animals the variations in this respect are so numerous as to preclude the possibility of our mentioning even the more im-

* According to Mr. Roberton's observations previously quoted, the following are the ages at which 450 women began to menstruate:

In their	11th year	10	women.
,,	12th ,,	19	,,
,,	13th ,,	53	,,
,,	14th ,,	85	,,
,,	15th ,,	97	,,
,,	16th ,,	76	,,
,,	17th ,,	57	,,
,,	18th ,,	26	,,
,,	19th ,,	23	,,
,,	20th ,,	4	,,

This table shews that the age of puberty of females in this country extends over a considerable number of years, and is more equally distributed than is commonly alleged.

† The opinion that menstruation happens at an earlier age in warmer climates is very generally entertained, as may be seen by a reference to the works of Haller, Boerhaave, Denman, Burns, Dewees, and others. Mr. Roberton has successfully shewn its inaccuracy by an appeal to the facts stated by modern travellers, as Hearne, Franklin, Richardson, and Back with regard to the Northern Canadian Indians; by Lyon and Parry with respect to the Esquimaux; by Clarke in reference to the Laplanders; and by Tooke in relation to the Northern Russians; all of which shew that puberty is attained in the arctic regions at least as early as in more temperate climates. On the other hand, from the evidence of Crawford and Raffles relative to the inhabitants of the Indian Archipelago, of Messrs. Ellis and Browne (missionaries) in regard to those of Polynesia; of Dr. Winterbottom on the native Africans round Sierra Leone; of the laws of the Koran in regard to the Arabs; and of the observations by Russel on the Egyptians, Mr. Roberton endeavours to prove that though early marriages are common in warm and equinoctial countries, yet the period of puberty and of the capability of procreating is nearly the same as in temperate and northern latitudes. Mr. Roberton is therefore induced to form the conclusion that the variations from the standard or more common period of puberty in different nations are not greater than the individual differences to be observed in our own country, and that the opinion above referred to ought to be looked upon as a vulgar error.

* These instances are very rare indeed. Mr. Roberton states that of 3000 women delivered in the Manchester Lying-in Hospital, only one was above fifty years of age.

† See Haller's Elementa for an enumeration of such examples.

portant in this place. The male of some insects, it is well known, die as soon as they have fecundated the female; many plants and animals propagate only once, while others give rise to many successive families; but we are not acquainted with any general law to which such differences can be referred.

Effects of castration.—Nothing illustrates in a more striking manner the intimate relation which the sexual function bears to the general organization and functions of the body than the effect of castration, or the removal of the formative and essential parts of the sexual organs in either sex. When both the ovaries or testicles have been removed or destroyed, the power of propagation is of course entirely lost. When this operation is performed at an early age, there is also caused a remarkable alteration of the constitution and general habit of body of the animal. The functional and structural peculiarities of the body become less marked, and there is a great tendency in general to the universal deposition of fat in different textures.

In the castrated male, the form and texture of the body approaches that of the female, and the mental faculties seem to partake in a certain degree of a similar modification. The voice remains high and clear; and hence the barbarous custom prevailing to the present day in Italy and elsewhere of making eunuchs for the sake of their high voices in singing.

In the spayed female, on the other hand, there is a certain approach to the characters of the male. In women in whom it has been necessary to extract the ovaries on account of disease, the bones and muscles have been observed to have a more masculine contour, the voice is harsh like a man's, the breasts are flat, and there is frequently a formidable beard, and hair on different parts of the body.

The same or similar circumstances have been remarked in those unfortunate malformed individuals who present an approach to hermaphrodite formation, or in whom there is imperfect development of either the male or female genital organs. So also it has been observed that the females of some animals, as the sow, pheasant, and pea-hen, and even the human species, when the period of life for propagation is passed, assume some of the male characteristics, such as the plumage in the birds mentioned, bristles in the sow, &c.

It is well known that the annual change of the horns in deer is intimately connected with the generative function. Mr. J. Hunter first shewed by experiment that when the deer are castrated while the horns are complete, they remain permanently and are not changed as in the natural condition; and that, if the operation be performed when the horns have fallen, they will not again be renewed.

The operation of castration, particularly when it is not performed till late in life, while it produces complete sterility in the female and impotence in the male, does not entirely destroy sexual desire, for eunuchs and the castrated males of many animals are known to be lascivious. Some writers would even have us believe that it is possible for the power of propagation to remain in the male after castration. These cases appear extremely doubtful, and, even admitting the truth of the statement that a castrated male has propagated, this by no means invalidates the statement that the removal of the testicles has destroyed all productive power, because it is possible that some seminal fluid may have been retained in the seminal vesicles and vasa deferentia. The operation does not prevent the erection of the penis or venereal orgasm from taking place; consequently the act of sexual union, and even some emission of fluid from the vesiculæ seminales and prostatic body, may occur in the castrated animal; and in some kinds of animals, it may further be remarked, that the union of such males with the females, though altogether unproductive, is attended with several of the more important changes which belong to fruitful sexual union, such as the excitement of the internal organs of the female, the discharge of vesicles from the ovary, and the formation of corpora lutea.

The removal of one testicle or ovary only does not appear to be attended with any change in the sexual or other functions; and it appears to be equally inconsistent with fact, that those originally provided with only one of these essential organs, are endowed with less procreative power than others, as that those who are said to have had more than the usual number are remarkably salacious or fertile.

3. *Sexual feeling.*—In all animals in which the distinction of sex exists, the first act of the generative process or the union of the sexes is insured by instinctive feelings experienced by both of them in a greater or less degree. These feelings generally depend upon the condition of the body, and in particular of the genital organs, which at the time of propagation are in a greater than ordinary state of excitement. From the increase of peculiar secretions, at the breeding season, the odour of the genital organs of animals becomes stronger than at other times, and seems to have a very direct effect in exciting the sexual appetite. These feelings are in the greater number of animals strongest in the male, and he consequently generally seeks the retiring female; but in other instances the reverse is the case.

In the human species also, similar feelings exist, but under the control of the intellectual and moral powers of the mind. Hence the immense variety we observe in the effects of the exercise of the sexual passions on different people, and hence the various modifications which they undergo from the state of civilization among different nations; on the one hand being productive of scenes and habits of disgusting obscenity among those barbarous people whose propensities are unrestrained by mental cultivation; and on the other, attended by social ties and higher intellectual ideas among those in whom, from education and the cultivation of the mind, the bodily appetites or passions, subject to the reason, assume a milder, less selfish, and more elevated character. Hence it comes that the various customs of different nations, legislative enactments of ancient and modern statesmen, and even some religious injunctions and ceremonies relating to marriage and concubinage, are to be regarded rather as a picture of the state of civilization among the different people to which they have belonged, and as the result of local situation and circumstances, than a consequence of their physical organization or natural endowments, as some would have us to believe. But the consideration of these modifications in the customs and habits of different nations belongs more appropriately to the province of the political economist than of the physiologist.

4. *Relation of reproduction to the brain.*—In how far the sexual feelings just spoken of, and the reproductive function as a whole, are connected with the brain or any of its parts, we leave to be discussed by others. We shall only remark in this place respecting this connection, that the mental feeling and local affection relating to sex are very intimately associated together; on the one hand, the local irritation of the genital organs exciting mental desire, and on the other, the erection and other signs of affection of the sexual organs being immediately caused by all those ideas and passions of the mind which bear a relation to sex. In the same manner as the action of the heart, the flow of the blood in some of the bloodvessels, the processes of digestion, respiration, and secretion are modified by mental emotions, the sexual function may be regarded as subject to their influence, and consequently subject to modification from the condition of the mind or brain.

In the phrenological system, as is well known, it is held that the cerebellum is that particular part of the encephalon which presides over the sexual function,—in other words, that sexual feeling belongs to the cerebellum as its sensorium commune, to which impressions of a sexual kind proceed, and from which emanates sexual desire, as well as the influence under which the reproductive organs execute their appropriate functions. The proofs alleged in favour of the phrenological hypothesis are principally of the following kind: 1st, that the back of the head and neck, and particularly the cerebellum, is largest in those of the human species who shew much sexual love, and among animals in those in which sexual feeling and productive power are greatest; 2d, that local affections of the genital organs, and variations in the degree of sexual desire, frequently coincide with congenital deviations from the natural form and structure of the cerebellum, and morbid organic changes of that organ, such as inflammation, suppuration, effusion, tumours, and softening, or violent injuries, such as wounds producing the destruction or removal of portions of the same part of the brain.* We leave to others the examination of the truth of this view, observing merely that we are not inclined to adopt the hypothesis as already established upon sufficiently accurate or extensive data; and we would remark that the comparative anatomy of the brain (in which, rather than in experiments on animals, we should feel disposed to place much reliance, from the acknowledged difficulty of making correct deductions as to function from the effects of morbid alteration or artificial injury of the encephalon) affords very few arguments in favour of the view now alluded to, and furnishes several facts which militate strongly against it.

5. *Distinction of species. Mules.*—The instinctive feelings which lead to the union of male and female animals of the same species may be looked upon as one of the means provided by nature for the distinct preservation of each specific race. So general indeed is the law that animals of one species propagate with one another only, that, as we already remarked, this circumstance alone has been adopted by some as the true specific character. We shall see reason, however, to doubt its sufficiency.

While the natural repugnance which the males and females of different species or genera have to propagate together may be regarded as one of the most powerful means by which the distinction of species is insured, we must not lose sight of other circumstances which contribute to the same effect. Among these may be mentioned, in the first place, the unfruitfulness which generally attends the union of different species when it has occurred; then the difference in the size of animals, the discordant properties of the semen of the one and ova of the other, the difference of season at which nearly allied animals come into heat, as well as many other circumstances which put a bar to the extension of races by promiscuous propagation of species or genera.

In the state of domesticity, however, this,

* The proofs of the connection of the cerebellum with the sexual function may be more fully stated as follows:

1st. The coincidence of barrenness or impotence with hydrocephalus, ramollissement, suppuration, or wounds of the head, and in particular of the back part and cerebellum.

2d. The coincidence of excited states of the reproductive organs, as priapism, nymphomania, and satyriasis, with inflammation of the same parts.

3d. Instances occurring in birds (mentioned by Serres) of cerebellar apoplexy from the persistence of unsatisfied sexual desire.

4th. Coincidence of cerebellar apoplexy, inflammation, &c. and diminution of the sensorial power, with over-exertion of the sexual powers, excess in venereal pleasures, &c.

5th. Large size of the cerebellum or upper and back part of the neck in those individuals among the human species or among animals in which the sexual desire and reproductive power are greatest.

6th. The reverse being the case in those in whom the function is inactive; as the small size of the back of the neck, &c. in castrated animals.

In endeavouring to ascertain the value of this kind of evidence adduced in favour of the phrenological view, we must consider well the nature of the alleged facts themselves, and weigh them candidly against facts of an opposite tendency adduced on the other side, such as those cases of small size or absence of the cerebellum, in which the sexual propensities have been highly developed, and the converse cases; and we must, at the same time, not lose sight of those other experiments and observations which would tend to shew either that the cerebellum is intimately connected with other functions than the reproductive, or that the sexual powers are influenced by the condition of other parts of the brain besides the cerebellum.

like other laws of the reproductive function, is subject to some modification, and we find accordingly several allied species of the domestic animals breeding freely together; and there are not wanting, even in the wild state, examples of the mixture of distinct species.

The animal produced by the union of the male and female of distinct species receives the name of Hybrid or Mule, which generally partakes of the qualities of both its parents in a greater or less degree. Here again we find another effectual impediment put by nature to the mixture of different species, in this circumstance, that the mule, whether male or female, is usually unfit for propagation. The offspring of male and female of distinct species is much more frequently fruitful than that of distinct genera.* The instances of the former are not few, as in the wild and tame cat, the wild boar and domestic hog, the pheasant and domestic fowl, the wild and tame duck. But the instances of the latter or mixture of distinct genera are very rare, and most of them require confirmation. We must at the same time always hold in mind that the distinction of species by naturalists is at all times artificial or made by man, how much soever he may conceive his classification to be founded in nature, and those animals which are regarded by one naturalist as different species of the same genus are made by others to constitute distinct genera.

It is well known that in gardens and elsewhere, although the pollen of very various plants is almost constantly flying about through the air, it is only among the most nearly allied races or varieties that mixture occurs, and the instances of the mixture of different species of plants are very rare indeed. Many of the mixed varieties so produced cannot be propagated by seeds; so that there is in the vegetable as well as in the animal kingdom a constant tendency to return to the original distinct species.

The milt and spawn of different fishes are at the same time floating in the same water, but even thus brought into close union with one another, no mixture happens. The ingenious experiments of the celebrated Spallanzani, who attempted to impregnate artificially the ova of one animal with the seminal fluid of another, and the unsuccessful attempts of many to cause different animals to breed together, afford still farther proofs, were they wanting, of the number and completeness of the impediments which nature has opposed to the promiscuous breeding of distinct species.

The horse and ass are caused, it is known, to unite by man, and do not naturally do so; and in the wild state it is probable that the exceptions to the general rule before-mentioned occur only when the male is deprived of his natural female. It seems scarcely necessary to state that the stories of fruitful union of either male or female of the human species with apes or other animals, considered as authentic by some authors, are entirely fabulous.

In a subsequent part of this article we shall have occasion to revert to the subject of the mixture of races in our remarks upon the transmission of the qualities of the parent to the offspring.

6. *Functions of the external organs of reproduction.*—In addition to sexual feelings, the state of turgescence or erection of the external organs by which copulation is effected, is a more or less constant antecedent and concomitant of the first act of the generative process. This condition belongs more properly to the external sexual organs of the male, and especially the penis; but it also frequently exists in some parts of the female organs.

The erection of the penis producing the rigidity of that organ necessary to ensure ejaculation or forcible emission of the seminal fluid, consists essentially in the increased quantity of fluid in its bloodvessels, and is with most reason to be attributed chiefly to the peculiar structure and inherent properties of the tissue, so called erectile, of which it is mainly formed. The manner in which the greater accumulation of blood in the erectile tissue is brought about is by no means sufficiently clearly explained. Two different opinions prevail as to the cause of this phenomenon; the one, that the flow of blood is retarded in the veins by the contraction and consequent pressure of certain muscles situated towards the root of the penis; the other, that the turgescence of erection is caused by an altered action or condition of the bloodvessels themselves, peculiar to the erectile tissue, in which they are capable of admitting and retaining a greater quantity of blood in the erected than in the collapsed state.

We must refer to the various anatomical articles for an account of the structure of the erectile tissue and the organs in which it occurs; we shall in this place advert to those points only which seem to bear upon the physiological view of their function.

The glans penis, corpus spongiosum urethræ, and corpora cavernosa penis, consist in great

* The following examples of the mixture of species are given by Burdach, but some of them require confirmation.

Papilio Jurtina	unites with	P. Jurtina.
Chrysomela Ænea	,,	C. Alni.
Phalangium Cornutum	,,	P. Opulio.
Cyprinus Carpio	,,	C. Carassius or Gibelio.
Fringilla Carduelis	,,	F. Canaria.
Phasianus Gallus	,,	P. Colchicus.
Anas Olor	,,	A. Anser.
Anas Glaucion	,,	A. Querquedula.
Tetrao Tetrix	,,	T. Urogallus.
Corvus Corone	,,	C. Cornix.
Canis Familiaris	,,	C. Lupus.
Canis Familiaris	,,	C. Vulpes.
Equus Caballus	,,	E. Zebra.
Equus Caballus	,,	E. Asinus.
Equus Zebra	,,	E. Asinus.
Equus Caballus	,,	E. Quagga.
Capra Hircus	,,	C. Ibex.

The examples of genera breeding together are much less numerous.

Rana	,,	Bufo.
Tetrao Tetrix	,,	Phasianus Colchicus.
Capra Hircus	,,	Antilope Rupicapra.
Cervus Elaphus	,,	Bos Taurus ?
Cervus Elapus	,,	Ovis Aries.

part of largely convoluted veins of considerable size; but these veins are differently arranged in the last-mentioned of these parts from what they are in the two first: first in this respect, that in the glans and corpus spongiosum urethræ the tortuous veins are less dilated and more branched than in the corpora cavernosa; so that it is more easy to trace their continuity with one another; and, second, that in the corpora cavernosa the dilated veins are bound together and crossed in various directions by ligamentous fibres and bands,—an arrangement which, while it tends to obscure the connection of one vein with another, and causes their tortuosities to appear rather like cells than continuous tubes, at the same time serves to prevent their distension beyond a certain point during erection, and thus adds to the rigidity occasioned by the accumulation of blood in the venous convolutions or sinuses.

The mode of union of the arteries with the veins in the erectile tissue of the penis is not yet well known; for, although the arteries of the penis have been traced to very small ramifications, corresponding small branches of the veins have not been observed, and consequently anatomists are nearly in complete ignorance of the nature of the small vessels of communication or capillaries of the erectile tissue, and are left to conjecture only respecting the means of passage for the blood from the small arteries into the cells formed by the convoluted veins. Professor Müller, of Berlin,* has lately made an important step in the investigation of this point of structure, by the discovery of a remarkable set of little dilated and ramified branches appended to the terminal twigs of the arteries distributed on the sides and interspaces of the venous cavities in the penis of man and several animals; but so far as we are aware, the exact mode of passage of the blood from these helicine arteries, as they have been termed from their tortuosity, has not been detected, and the operation of these arterial branches in modifying the circulation, or their relation to the process of erection, has not been pointed out; it appears probable that so peculiar a piece of mechanism must have some connection with this process. (See Erectile Tissue and Penis; also *Figs.* 98 and 99, p. 146, vol. ii.)

The principal exciting causes of erection may be referred to the following heads:—

1. Mental emotions relating to sex: in animals, odour of the genital organs, more especially in the breeding season.

2. Nervous affections. Epilepsy, convulsions. Inflammations of the brain, and similar affections.

3. Warmth or other local irritation of the penis and sexual organs.

4. A full state of the testicles, their excretory ducts or vesiculæ seminales.

* See his Archiv. für Physiol. &c. 1835, pp. 27 and 220, and his paper, "Ueber die organischen Nerven der erectilen männlichen Geschlectsorgane," in the Abhand. d. k. Akad. d. Wissensch. v. Berlin für 1835.

5. Irritation of the parts in the vicinity of the penis, as of the urinary bladder by stone, riding, cantharides, savine, alcohol, &c.; of the rectum by strong purgatives; and, in short, every thing which irritates or determines a greater than usual flow of blood to the pelvic viscera or sexual organs.

6. Ligatures, and all other causes of obstruction to the return of blood from the penis.

Erection is an involuntary act; for we have neither the power directly to produce it, nor, when it occurs, to recall the state of collapse. When the penis is in the state of erection, however, the rigidity may be increased by the voluntary exertion of the ischio-cavernosi or erectores penis, and the acceleratores urinæ muscles; and no doubt also by the action of the muscles lately described by Dr. Houston* under the name of compressores venæ dorsalis penis, to the contraction of which, and the consequent impediment produced to the return of blood from the penis, that anatomist has attributed in a great measure the erection of the organ.

The turgescence of erection begins at the root of the penis in the corpora cavernosa, and at the glans in the corpus spongiosum. The glans and spongy body of the urethra may, in general, be made to collapse by pressure, but the corpora cavernosa cannot unless the erectile action itself ceases. The arteries of the penis appear to beat with more than usual force during erection.

The phenomenon of erection is not confined to the penis or such parts as are provided with muscles, but occurs in all situations where that arrangement of the bloodvessels constituting the erectile tissue is to be found. The nipple of the mamma, the cock's comb and wattles, and the turkey's neck are all affected in a similar way; and, although some circumstances seem to shew that erection may in some instances be promoted by muscular contraction, we are inclined to adopt the opinion that it is mainly due to an altered condition of the bloodvessels themselves, and that it may in some degree be analogous to the dilatation of the bloodvessels which occurs in blushing, and some other local determinations of blood.† The large size of the numerous nerves which accompany the bloodvessels of the penis is also in favour of this view.

In many animals the penis is furnished with a bone which adds to its rigidity. This is the case chiefly among Cheiroptera, Quadrumana, Solipeda, Digitigrada, Rodentia, Phoca, and Cetacea. We refer to the articles on Comparative Anatomy for a description of the many varieties in the form of the penis in different animals, and their uses in the act of propagation.

The texture of which the glans clitoridis and corpora cavernosa of that body as well as the nymphæ are formed, is of an erectile kind and strictly analogous to the corresponding

* Dublin Hospital Reports, vol. v.

† See the article Circulation, vol. i. p. 672.

parts* of the penis, to which the clitoris bears a great similarity; and it may be remarked that there is also a functional analogy, as these parts in the female sometimes undergo the change of erection under local irritation or venereal excitement.

The glans penis is endowed with a high degree of sensibility, and is regarded generally as the chief seat of venereal pleasure; but this also belongs to the urethra at the time of emission. The papillous structure of the mucous membrane covering the glans, and the large quantity of nerves distributed on its surface, relate to this high sensory endowment.

The lower part of the vagina and the clitoris in particular are possessed of a similar high degree of sensibility, and in some women, but not in all, are the seat of venereal feelings from excitement; but in many women such feelings are altogether absent; and it is most erroneous to suppose, as some have done, that these feelings are in either sex necessary to insure the fecundating power of the one, or the liability to conception of the other.

With regard to the uses of the hymen we have no conjecture to offer.

The vagina, besides serving to receive the penis in copulation and to conduct the seminal fluid to the uterus, is the passage by which the child issues in parturition.

IV. CHANGES CONSEQUENT ON FRUITFUL SEXUAL UNION.

1. *As regards the female chiefly. Conception.*—The consequence of fruitful sexual union in man and quadrupeds is the dislodgement of one of the ova contained in the ovarium, and the fecundation of this ovum in some part of its passage from the ovarium, where it is formed, to the uterus, in which the fœtus is developed from it.

In now proceeding to treat of the mode in which these further steps of the generative process are brought about, the following subjects present themselves for our consideration. 1st. What changes are operated in the internal female organs after fruitful sexual union, and by what means are the ova dislodged from the ovary? 2d. What changes do the ovaries or their vesicles undergo after the discharge of any of the ova? 3d. What happens to the ovum from the time of its discharge from the ovary until the commencement of the development of the fœtus? 4th. In what part of the female generative system is the change of fecundation effected by the agency of the seminal fluid upon the germinal part of the egg? and lastly, In what does the change of fecundation consist, or upon what properties of the seminal fluid may it be supposed to depend?

These topics comprehend the history of the functions of the male and female internal generative organs, in so far as they relate to the processes of conception and fecundation; under which two heads, as has been already mentioned, it is our intention to bring the remainder of the facts respecting generation which come within the limits of the present article. We shall begin with those facts relating chiefly to the female, or conception.

The immediate consequence of sexual union upon the female internal generative organs is their great excitement, and a turgescence produced by an accumulation of blood in their vessels. When sexual union proves productive, this turgescence lasts for some time after it has taken place, so that in animals opened at this time, the ovaries, Fallopian tubes, and uterus are found to be of a much deeper red colour, and more vascular than in their natural state. In the female Rabbit, for example, opened soon after coition, the internal organs are nearly black from sanguineous congestion.

There also occurs in some of these parts a change of position in regard to one another, which is connected with the discharge of ova from the ovarian vesicles. The fimbriated extremities of the Fallopian tubes are turned towards the ovaries on each side, and embrace these organs closely, so that the infundibular opening is applied against the ovary, and must of necessity receive the contents of the Graafian vesicle when it bursts. In some animals the ovary is inclosed in a sac along with the infundibulum by a reduplication of the peritoneum, so that the ovary is kept always to a certain extent within the infundibulum; but in other animals in which the connection between these parts is not of this permanent kind, there is an equally firm union of them after copulation. In regard to the means by which this approximation and union of the fimbriæ and ovaries are brought about, it may be stated, that in some animals the action seems to be somewhat of a muscular kind; for there are strong fibres, having all the appearance of muscular fibres, which pass from the ovary towards the fimbriated portion of the Fallopian tube; and in these animals, as well as in others even, in which the muscular fibres are less obvious, irritable contraction may be supposed to be a means of bringing the parts nearer to one another. The observations of Hartsœker and Haller, however, would appear to shew that the vascular turgescence which follows copulation, amounting to a state approaching to erection, may also contribute to give rise to the change of position now under consideration, for they found by repeated trials that the forcible injection of fluids into the bloodvessels of the generative organs in the human dead body caused the approximation of the fimbriæ and ovaries. But, although it may be admitted that vascular turgescence may cause this approximation of the parts, we would venture to suggest that some power of the nature of muscular contraction is necessary to give that degree of firmness to the union which it is found to possess some time after copulation.

We must remark, however, that when a

* The glans penis and glans clitoridis, the nymphæ and corpus spongiosum urethræ, and the corpora cavernosa penis and clitoridis are considered anatomically as the respective corresponding parts in the male and female body.

female quadruped is opened immediately after copulation, the fimbriæ are frequently not observed to be in contact with the ovary; and this is found to be the case only when some hours are allowed to elapse between the copulation and the death of the animal. Haighton never found it to have taken place in the rabbit previous to nine hours after union with the male, and De Graaf not even before twenty-seven hours; but observations of this nature upon animals opened soon after being killed, do not make it certain that the action had not taken place; for it may be supposed that the adhesion between the infundibula and ovaries had commenced, but was less firm than it becomes at a subsequent period, and that it was merely disturbed by the violence of the death or rough handling of the body. This is the more probable, seeing that the same change of position has been observed to take place before sexual union in animals in the state of heat, as by Cruikshank in the rabbit, and by Haller in the sheep. In some birds, particularly domestic fowls and ducks, it is well known that when they are well fed all the changes necessary for the formation of an ovum and its discharge from the ovary may take place without the concurrence of the male, and in quadrupeds there is reason to believe that the turgescence and change of position of the generative organs above alluded to may frequently occur independently of fruitful or unfruitful sexual union, as from excitement of the generative organs in the state of heat, or as in the cases observed by Haller, of ewes having connection with wedders or castrated males only.

There is every reason to suppose that the same changes which we have described as occurring in quadrupeds after sexual union, take place in the same circumstances in the human female; that is, that the fimbriated infundibula of the Fallopian tubes are brought near to the ovaries, and are made to embrace them firmly, so as to receive the contents of any vesicles which may burst; and that this change is produced by an action which begins usually during sexual union, but which may also occur without any venereal orgasm.

The ovaries, we have already stated, become unusually vascular during and after sexual union; but the changes in the ovary which most demand our attention, are those connected with the bursting of the Graafian vesicles, and the discharge of their contents. In the unimpregnated female arrived at the age of puberty, the Graafian vesicles of the ovary are of unequal size. Some time after sexual union, one or more of these vesicles, probably those which are at the time farthest advanced, undergoes a greater enlargement, and from its swelling projects beyond the rest of the surface of the ovary, and after various other changes, an aperture is formed in the most projecting part of the coats of the vesicle, through which its contents find an issue. But before proceeding further with this narrative, we must recall to the recollection of the reader the nature of the ovum, which, on the occasion of the rupture of one of the Graafian vesicles, is discharged from its interior.

The ovarian vesicles of man and quadrupeds are filled with fluid, which, viewed by the unassisted eye, appears to contain only a little granular and flaky matter. This fluid is coagulated by heat, alcohol, or acids, as albumen is, and also by exposure to air. The membrane forming the vesicle consists of two layers, an external and internal, and the whole vesicle is covered also by the general peritoneal and vascular envelope of the ovary.

From the earliest times anatomists and physiologists seem to have considered the ovarian vesicles as the source of the offspring; and many, from a sort of loose analogy with oviparous animals, regarded the vesicles themselves as the ova in which the viviparous fœtus is developed. The large size of these vesicles, however, as compared with the Fallopian tubes through which the ova have to pass, and the subsequent observations of De Graaf, Vallisneri, and Cruikshank, as later those of Prevost, Dumas, and others, who found in the first days after copulation ova in the Fallopian tubes of a size considerably less than the vesicles of the ovary from which they had proceeded, proved satisfactorily that the ovarian vesicles and ova are not identical. Various conjectures were in the meantime offered by different authors as to the source of the ovum; some holding it to be formed by a process of secretion, others by an organic union of the male semen with the contents of the Graafian vesicle, and so forth; but no one ever observed the ovum itself of mammiferous animals within the ovary, until Baer made this important discovery in 1827, by the examination with the microscope of the fluid contents of the Graafian vesicle.*

Baer found that, in the centre of a granular layer, placed generally towards the most prominent part of the vesicle, to which he gives the name of proligerous disc or layer, there is fixed a very minute spheroid body, seldom above $\frac{1}{200}$th part of an inch in diameter. The appearance of this body he found to be constant, and on examining it with attention in the vesicles of the ovaries, and after their rupture in the Fallopian tubes, he traced the changes it underwent in the first days after copulation, and established satisfactorily the identity of this body with the ova found by previous observers in the Fallopian tubes and cornua of the uterus; thus proving by actual observation what had before been held only from analogy, that in the mammiferous or truly viviparous, as well as in the oviparous animal, the fœtus derives its origin from an ovum already formed in the ovary before fecundation.†

* Epistola de Ovi Mammalium et Hominis Genesi. Lipsiæ, 1827.

† We have no hesitation in giving the sole and undivided merit of this discovery to the indefatigable and talented Baer, whose observations have contributed, perhaps more than any other single individual of the present time, to extend our knowledge of the early formation of the fœtus. We ought not, however, to omit to mention that Messrs. Prevost and Dumas conceived that in two instances they had perceived ova in the ovarian vesicles of quad-

Some time after sexual union the fluid contained in the vesicles which are about to burst, previously transparent and nearly colourless, now becomes more viscid and tenacious, somewhat turbid and of a reddish colour; and in some animals it is possible in such ripe vesicles to perceive, with the unassisted eye in a favourable light, a whitish opaque spot on the most prominent part, indicating the layer of granules or proligerous disc, in the centre of which the ovum is situated. After a certain time a small opening is formed at the most prominent part of the coverings of the vesicle, the vesicle bursts, and its contents escape through the opening; they are received in the infundibulum, which is now applied firmly against the ovary; and the ovum entering the Fallopian tube is conveyed along it, probably by its slow and gradual vermicular contractions, until it at last arrives in the uterus.

With regard to the time at which the opening of the ovarian vesicles takes place, there are considerable varieties in the same and in different animals. In the sheep, the vesicle has been found burst so early as at two hours after coition. In the dog, Haller found the vesicles burst before the sixth day; in one instance the day after coition; but Prevost and Dumas, not until the seventh or eighth. In the rabbit, Cruikshank observed vesicles burst two hours after coition, while Haighton considers forty-eight hours as the usual time at which the rupture happens in this animal. M. Coste has observed it most frequently between the second and third day in the rabbit.

After the bursting of the Graafian vesicles, there occur in them and in the neighbouring part of the ovary some important changes of structure, which claim our attention in this place as intimately connected with that part of the process of conception which is now under consideration.

If the Graafian vesicle which is enlarged from venereal excitement and is ready to burst, be examined with care, it will be seen that at the most prominent part of its coats the bloodvessels converge towards the point at which the rupture afterwards takes place, and this point is itself comparatively destitute of bloodvessels.*

At the time of the formation of the opening into the vesicle, from the division of some of the bloodvessels, a small quantity of blood is generally mixed with the fluid contents of the vesicle; and after the vesicle has been emptied of these fluid contents, their place is generally supplied by a greater or less quantity of coagulated blood, probably poured out by the same ruptured vessels.

The membranes of the vesicle at this time have become thicker than before: the inner one in particular appears more vascular and uneven, perhaps in part from its being puckered up on the vesicle becoming flaccid and comparatively empty. The wrinkled appearance on the inner surface of the vesicle increases, and there grows gradually out from it a new substance which comes to occupy the whole cavity of the vesicle; and in many instances, as this new substance is formed in greater quantity than can be contained within the limits of the vesicle, it protrudes some way out at the opening of the vesicle, forming a dark red prominence like a nipple, which rises above the neighbouring surface of the ovary. This substance, at the time of its first formation, is of a pink or reddish colour, but as it becomes gradually less filled with blood it acquires a yellowish hue, which is more or less apparent in different animals. In the human species it is of a bright yellow colour, whence the name of corpus luteum applied to this new production of the ovarian vesicles.

The substance of the corpus luteum has a lobular structure; the lobules radiating in a somewhat irregular manner from the centre to the circumference. The central part of the corpus luteum frequently remains hollow for some time after its production, opening exteriorly by a narrow passage from the place where the rupture of the vesicle originally took place; at other times this passage is closed more early, and there remains nothing but an indication of its place in a depression in the centre of the most projecting part of the corpus luteum. The lobules of the corpus luteum, examined with the microscope, exhibit merely a granular structure, and are not formed of acini, as some have described them, so that there is no reason to consider these bodies as of a glandular nature.

The size which corpora lutea attain when fully developed varies much in the same and in different animals. In the human female they become as large as a common hazel-nut; in the cow they are sometimes as large as a ches-

rupeds, (Annal. d. Scien. Nat. tom. iii. p. 135,) but without any certainty or exact knowledge as to their nature. M. Coste, with a spirit of appropriation too common, we regret to say, among his countrymen, has taken advantage of some speculative views and strained analogies brought forward by Baer concerning the bodies which he discovered, in which he compared them (erroneously as we think) to the germinal part only of the ovum, rather than to the whole ovum of the oviparous animal, to take from the merits of Baer in their discovery; but we feel assured that every unprejudiced inquirer who reads with attention Baer's admirable "Epistola de Ovi Mammalium et Hominis Genesi," in which his discovery was first announced in 1827, and compares it with other works on the subject, will be convinced that Baer has no sharer in the discovery, and fully understood the nature of the ovarian ovum of viviparous animals; although it may be the case that subsequent investigations have added considerably to the knowledge of the relations of these ova. We shall return to a more minute detail of this body in considering the process of formation of the ovum in the present article and under the article OVUM.

* The ovarian capsules of the bird, which are obviously the analogous parts of the ovarian vesicles of quadrupeds, present on their most prominent part a remarkable band, extending for nearly one-third of the periphery: towards the margins of this band the small bloodvessels all converge, but they do not pass upon the band itself, so that it is left free from bloodvessels. It is in this non-vascular or less vascular part of the capsule that the rupture takes place when the yolk escapes.

nut; and in the sow or ewe they are somewhat larger than full-grown peas.

The corpus luteum may, by dissection, be easily separated from the surrounding parts and turned out of the ovary; and when this is done, the external membrane of the original vesicle remains lining the cavity left in the ovary. From this it would appear that the corpus luteum is most intimately connected with the inner membrane of the vesicle; and, in fact, Baer* observed that, before the rupture of the vesicle in the dog, the inner membrane had become thickened, rugous, and of a villous structure, as if the corpus luteum grew from that internal membrane itself. This observation also makes it probable that the growth of the corpus luteum may contribute to cause the rupture of the vesicle.

The corpus luteum at first increases gradually in size, remains for a time stationary, and then decreases till it either wholly disappears or leaves only a small mark or cicatrix to indicate its place. The time at which it attains its full size seems to vary considerably. In the sheep two or three days are sufficient for the formation of the corpus luteum, and its cavity becomes obliterated within a fortnight after copulation. Haller found corpora lutea in the dog on the sixth day; Cruikshank observed the corpora lutea to go on progressively increasing till the ninth day in the rabbit; and it is probable that in the human species the corpus luteum is not fully developed till after the second month of pregnancy.

After the corpus luteum has attained its full magnitude, its colour becomes paler and of a clearer yellow; its size then gradually diminishes, its tissue becomes more compact, its cavity is obliterated, and it is converted into a body nearly solid. It generally retains, during utero-gestation, a considerable size, and this remark applies especially to the human species, in which it diminishes much more rapidly in size after than before the birth of the child. In some animals it at last wholly disappears; in others, among which is the human species, it always leaves some mark.

In what has now been said regarding the corpus luteum, that body has been described as it is formed in the place of a vesicle which has been burst after fruitful sexual union; but we may remark that the same series of changes always follows the rupture of an ovarian vesicle from whatever cause that may have proceeded. It is now well known that in some animals the rupture of ovarian vesicles and subsequent changes take place without sexual union merely from the state of heat or venereal excitement of any kind, while in others these phenomena are never observed but as accompaniments of conception. The sow and mare belong to the first of these classes of animals. The rabbit, bitch, ewe, and cow may be mentioned as examples of the second, as also is generally the case in the human female; but in woman, as in some other females, various circumstances induce us to believe that the rupture of ovarian vesicles and the formation of corpora lutea in their place occasionally happen without sexual union from all those causes which excite greatly the sexual organs; and we are not, therefore, inclined to admit the presence of a corpus luteum, taken alone, as a certain sign of sexual union having occurred; though conjoined with other signs, the presence of one or more corpora lutea or the appearance of ruptured vesicles must be regarded as good presumptive evidence.

In some of those animals in which vesicles frequently burst without sexual union, there are occasionally very many corpora lutea in the ovary, so as to alter completely its form, and disguise its natural structure, as may frequently be seen in the sow. In those animals again in which sexual union alone brings about the rupture, we at once distinguish the ovary of the unimpregnated animal from that of the one that has had connexion with the male, and we very generally observe an exact correspondence in the number of corpora lutea and the ova or fœtuses contained in the uterus;* and the same correspondence is very frequently found after conception, even in those animals in which corpora lutea are formed without sexual union.

While the corpus luteum, then, is always to be found in the ovary of a pregnant quadruped, the formation of this body is to be regarded as the uniform consequence of the rupture of the ovarian vesicles, whether that rupture shall have been occasioned merely by excitement of the organs, or by productive or unproductive sexual union; but it is only when conception and pregnancy occur that the corpus luteum attains its full size, and runs through the whole of that series of changes which we have described as peculiar to that body.

We ought not to omit here the mention of a totally different view which has been taken of the corpora lutea, that, viz. of Buffon and Vallisneri,† supported more recently by Sir E. Home,‡ according to which it is held that the corpora lutea exist before the rupture of the vesicles, and are the matrix in which the vesicles and ova are formed.

Two circumstances principally have been brought forward in favour of this hypothesis:—1st, that corpora lutea occur in the virgin state; and 2d, that they frequently contain vesicles. Now the existence of corpora lutea, we have already stated, in the sow (observed by Sir E. Home), and even, we are inclined to hold, in the human female, is not necessarily a proof of sexual union having previously occurred, since the rupture of the vesicles may have

* See Epistola, &c.

* It may be mentioned that more than one ovum have sometimes been found in the same Graafian vesicle, in which case it will readily be understood there might be only one corpus luteum in the ovary and two ova in the uterus, but this is rare. The author has verified the above correspondence in many hundred pregnant ewes, in a considerable number of cows, rabbits, some cats, and other animals.

† Vallisneri, Hist. of the Generation of Man and Animals (Ital.).

‡ Phil. Trans., vol. cviii. p. 256, and vol. cix. p. 59.

followed simple excitement of the sexual organs, and might therefore take place either with or without the male; and in the second place, the occurrence of cavities and vesicular membranes within the corpora lutea is by no means a proof that these cavities are new or forming ovarian vesicles; on the contrary, there is every reason to regard them as unnatural or the product of disease. But though lately revived upon the above-mentioned grounds, it is long since this hypothesis received the most satisfactory refutation, both from the observations of De Graaf and of Haller. Haller in particular traced in the most accurate manner all the steps of the development of the corpus luteum, from the first rupture of the vesicle till its completion: he employed the animals least liable to lead to fallacy in such observations; those, viz. in which rupture of the vesicles and formation of corpora lutea is usually produced only by sexual union; and he always remarked in them an exact correspondence in the number of fœtuses in the gravid uterus with the number of corpora lutea in the ovaries, while at the same time he found the first appearance of these bodies to take place at a fixed period after sexual union, and their size and structure always to bear an exact relation to the period of utero-gestation at which they were observed.*

The uses of the corpora lutea are entirely unknown. The fact that these bodies become larger and remain proportionately of a larger size during pregnancy than when produced in other circumstances (as without sexual union, or after unproductive copulation, or when the product is blighted at an early period of utero-gestation,) would seem to indicate some connexion between the corpora lutea and the development of the fœtus in utero. By those who have regarded the corpora lutea as of a glandular nature, they have been supposed to secrete fluids which assist in the nourishment of the fœtus. We have already stated the reasons for considering such hypotheses as groundless. (See OVARY.)

Descent of the ovum. Its structure and changes during its passage.—The attention of accoucheurs in all ages and countries has naturally been directed to the study of the structure of the human ovum and fœtus in the more advanced stages of utero-gestation, and a great body of facts has been collected from the examination of aborted products or the gravid uterus of women dying during pregnancy, from which scientific men have acquired an accurate knowledge of the structure of the human fœtus and its covering in the ovum during the greater part, and especially in the more advanced period of utero-gestation; but very little is known of the nature of the egg in the first stages or immediately after conception has occurred. We have, in fact, no direct observations which inform us of what happens to the human ovum immediately after its escape from the ovary, and, indeed, for some little time after its arrival in the uterus, when the parts of the fœtus have already begun to be formed in it. This subject has, however, been investigated with considerable success in several mammiferous animals; and although there remain several points which still require elucidation, yet, from the analogy which is known to exist in the structure of the ovum and fœtus of the human species and those of quadrupeds and birds, we are enabled to bring together the detached observations which chance has thrown in our way, and thus to give a connected account of the generative process in man, imperfectly as that process has as yet been observed.

Our design at present is to follow the ovum only as far as into the uterus, or until the commencement of the formation of the fœtus in it. We believe we shall place this part of our subject in the clearest point of view, by prefixing to our remarks regarding the ovum of man and quadrupeds a short sketch of what happens to the egg of the common fowl after its discharge from the ovary.

The substance of the yolk enclosed in its membrane, together with the germinal portion in which after incubation the rudiments of the new animal begin to be formed, constitutes the essential parts of the bird's egg as it exists in the ovary. The ovarian egg, when it has left the place of its formation and passed into the oviduct, receives the addition of various other parts, viz. the albumen, chalazæ, shell and its lining membrane, as it gradually descends through different portions of the oviduct, each of which is destined to secrete one of these newly added parts. These parts may, however, be considered as accessory to the more essential constituents of the egg, which we are inclined to regard as the germinal spot or cicatricula, the granular and oleaginous fluid of the yolk, and the dense transparent membrane with which they are enveloped. To the unimpregnated egg of the ovary we shall give the name of ovulum, and henceforward in this paper apply the name of ovum to the perfected egg, that is, the ovulum to which the accessory coverings have been added, and which has received the influence of the male. The ovarium of the common fowl in the breeding season, or when it is laying eggs, has the form of a bunch of clustering ovula, which are contained in capsules, the more advanced of which hang down from the rest of the ovary by the elongated pedicles of the containing capsules; while the smaller ovula of various sizes, composing the body of the ovary, cluster more closely together. The fully developed ovula only have the deep yellow colour peculiar to the yolk; as the smaller ones are less advanced their colour is paler, and the smallest are nearly colourless and transparent from the absence in them of the oleaginous and granular matter peculiar to the riper yolks.

The little white spot or granular layer which

* The corpus luteum is developed then and becomes perceptible after the bursting of one of the vesicles; but let us not here lose sight of the fact before announced that the first commencement of its formation dates from a short while before the rupture, as indicated by a thickening of the inner membrane of the vesicle.

constitutes the cicatricula or germinal disc is easily seen in the larger ovula, occupying almost always the same position on the surface of the yolk, somewhere near the pedicle of the ovarian capsule. When the cicatricula is examined carefully in the ovulum, a small dark round spot is perceived in its centre, the relations of which to the first production of the fœtus are very important. This little dark spot was discovered by Purkinje to contain implanted in the centre of the cicatricula a minute transparent vesicle filled with fluid. He farther shewed that during the passage of the ovulum from the capsule of the ovary into the infundibulum of the oviduct, this little vesicle disappears, being probably burst, and leaves in its place a thin and tender transparent membrane. The vesicle of Purkinje, as it is called from its discoverer, occupies then the centre of the germinal spot, and it is in the transparent membrane left in its place when the vesicle is dispelled that the first rudiments of the fœtus afterwards make their appearance. Hence the vesicle has also received the name of germinal vesicle, a most appropriate term, since it may be regarded as the more immediate seat of the germ or germinating faculty of the egg.

The Purkinjean or germinal vesicle exists in the smallest as well as in the more advanced ovula of the fowl's ovary, and it is proportionally much larger in small than in large ovula. In the very small ovula it is not, as in the riper ones, situated on the surface of the yolk, but towards the centre of that body; and as the ovulum advances to perfection, the germinal vesicle gradually approaches more near the surface, and becomes more prominent on the surface of the cicatricula. In ovula less than two lines in diameter the vesicle is usually unconnected with the germinal layer or cicatricula, but in those of four lines in diameter it is already placed in the middle of the germinal spot.

In all oviparous animals a vesicle, similar to that now described in the common fowl, occupies the central part of the germinal layer so long as the ovulum remains in the ovary, and undergoes the same rupture and other changes at the time of the discharge of the ovulum from the ovary.*

In turning now to mammiferous or viviparous animals, it may be remarked in the first place, that although the extremely minute size of the body discovered by Baer to be constantly present in the ovarian vesicle prevents us from observing it with ease, and establishing with certainty its analogy to the yolk and its accompanying parts in the egg of the fowl before development begins; yet after the commencement of fœtal formation, the early changes which this body undergoes prove its correspondence with the ovum of birds in a most satisfactory manner. We have already, however, stated the reasons for regarding the vesicle of Baer as the ovulum of mammalia, and need not now recapitulate them. We shall only remark that although the vesicle of Baer and ovulum of birds differ widely in size, that vesicle appears to contain the same essential parts of the egg belonging to birds and other oviparous animals, viz. a fluid granular mass or yolk enclosed by an investing membrane, and furnished also with a more compact granular layer situated on the surface of the yolk, but also enveloped by its membrane, in which the rudiments of the fœtus first appear, and which is, therefore, the germinal layer of the mammiferous ovum.

The membranes of the ovarian vesicle in mammalia and the capsules of the ovary in the fowl are corresponding parts, and the principal difference between the ovarian cavities containing ovula in oviparous animals, and those of viviparous animals, consists in this, that in the latter the ovulum (the vesicle of Baer) is placed in the granular proligerous disc, and has all the fluid of the vesicle interposed between it and the coats of this cavity.

At the time when Baer first discovered the ovulum of mammalia, there was still wanting, in order to complete the proof of its analogy with the ovulum of birds, the observation of the germinal vesicle (vesicle of Purkinje) within it. This additional proof has been supplied within the last few years by the researches of T. W. Jones, Coste, Purkinje, Valentin, and Wagner, which we have ourselves confirmed.

The germinal vesicle of the very small ovulum of quadrupeds is of course a most minute object, and in fact it can only be seen with a good microscope; but in favourable circumstances it is nevertheless quite distinct, and the investigations above referred to, conjoined with analogical evidence, make it highly probable that the little vesicle found within the ovulum of viviparous animals occupies the place in which the fœtus first makes its appearance, and that at the time of the passage of the ovulum from the ovary to the Fallopian tube this little vesicle is burst, and undergoes analogous changes to those which have been noticed in the fowl.*

In birds the shell with its lining membrane forms the external covering of the egg; and in all oviparous animals a similar external envelope (besides the membrane enclosing the yolk) is to be found, though varying greatly in thickness, consistence, and structure in different animals. The ovum of mammalia at the time

* Purkinje's description of this vesicle was first given in his excellent "Symbolæ ad ovi ovium historiam ante incubationem, Vratisl. 1825," and second edition at Leipzig, in 1830. Baer contributed in his "Epistola" many important facts concerning its existence and changes in other oviparous animals. Coste, Valentin, and Wagner have since added several observations. We may state here that the bursting of the vesicle does not occur in all oviparous animals exactly at the time of the escape of the ovulum from the ovary, but nearly about the same time.

* In his "Epistola," published in 1827, Baer compared the vesicle he had discovered within the Graafian vesicles of the ovary to the vesicle which Purkinje had in 1825 discovered in the cicatricula of the fowl's yolk: erroneously as we think; for the facts mentioned above are sufficient to disprove any such analogy. For the sake of clearness we here subjoin a tabular view of the parts which correspond with one another in the bird and quadruped.

when it arrives in the uterus has also a similar external envelope, which has received in man and most animals the general appellation of chorion. Baer is of opinion that the chorion exists ready formed in the ovulum of the ovary; but his observations appear to us as yet insufficient to prove this point, and we feel inclined rather to adopt the view of Valentin, who holds that it is probable that the chorion is added to the ovulum after it has left the Graafian vesicle, that is, during its passage from the ovary to the uterus, somewhat in the same manner as the albumen or shell is added to the egg of the common fowl in its passage through the oviduct. The analogy of all oviparous animals is at least strongly in favour of such a view of the mode of the production of the chorion or external envelope; while on the other hand we ought not to lose sight of the fact that though the external envelope or chorion occupies the same position as the external covering of the eggs of oviparous animals, its structure and functions are very different, for almost in every quadruped the chorion serves important purposes in establishing that more intimate union peculiar to viviparous animals, which is formed between the ovum and uterus in the placenta or analogous structure.

It is only in the dog and rabbit that the ova have hitherto been traced by actual observation in the whole course of their progress through the Fallopian tubes from the ovary to the uterus. These observations we owe chiefly to the careful researches of Cruikshank, Prevost and Dumas, Baer, and Coste. In regard to other animals we have only a few detached observations in some of them, and in the human species the ova have never been observed in the Fallopian tubes, nor indeed for some time after they must have entered the uterus. We do not therefore know, with any degree of certainty, at what distance of time after sexual union the ovum passes into the uterus of the human female. Great difficulties attend the elucidation of this point. In the first place, we are opposed by the impossibility, in the greater number of cases in which we may happen to obtain a pregnant uterus for investigation, of knowing accurately the age of the product or the time at which impregnation has occurred; and in the second place, we are here deprived of the assistance derived in many other parts of our subject from analogical evidence by the wide discrepancies we find among animals in respect to the period of the arrival of the ova in the uterus; for there does not appear to be any exact correspondence yet shewn between the time at which this happens and the length of duration of utero-gestation. It may be well, however, to endeavour to form an approximative opinion. In the rabbit, although ova are known frequently to be discharged from the Graafian vesicles on the second day after sexual union, they are in general not detected in the uterus before the third or fourth day, and frequently not before the fifth or sixth, at which time they appear as vesicles a little more than a line in diameter, lying unattached in the upper part of the cornua of the uterus.*

In the dog ova have been observed in the Fallopian tubes on the eighth day, but they have not been found in the uterus before the twelfth day. In the cat we have found ova of the size of peas beginning to be attached to the uterus at the twelfth day, and in both the cat and dog we think it probable from the size of the ova that they had already been in the uterus for at least one day, so that the tenth or eleventh day may be regarded as the time when ova generally appear in the uterus of these animals.

Haller and Kuhlemann† never found an ovum in the uterus of the sheep till the seventeenth day after copulation, and our own observations on both the sheep and sow agree precisely with theirs. Hausmann never found the ova in the uterus of the sow before the period of four weeks after conception, and those of the bitch before three weeks; but here we must caution the reader against the error of supposing that in the sheep and some other animals, because the ova have not been observed in the uterus, they do not actually exist there previous to a certain date; for the large size of the ovum and its membranes, as well as the state of the fœtus, which though small is already somewhat developed, entitle us to conclude that the ovum of the sheep must have been some time in the uterus. The recent interesting observations by M. Coste have thrown great light upon this subject, he having detected the ova of the sheep so early as five days after conception. In the cow also, in which the period of gestation is nearly twice the length of that in the sheep, the ovum seems to arrive almost as early in the uterus, if we may judge from the state of advancement of the fœtus at an early period.‡

In the Quadruped.	*In the Bird.*
1. The ovary contains	1. The ovary contains
2. Graafian vesicles which are filled with fluid, granules, and the proligerous disc, in the centre of which is placed	2. Capsules entirely filled with ovula, there being no intervening fluid or proligerous disc.
3. The ovulum or vesicle of Baer, consisting of	3. The ovula or yolks, consisting of
4. A yolk, on the surface of which is	4. A yolk.
5. A germinal membrane, in the middle of which is placed	5. A germinal membrane or cicatricula with the
6. The germinal vesicle or vesicle of Purkinje.	6. Vesicle of Purkinje in its centre.

* M. Coste has shewn that there is considerable variety in respect to the time at which the ova descend in the rabbit, and thus very reasonably accounts for the difference one generally finds in the state of advancement of the ova in the pregnant uterus.

† Vide Kuhlemann's Observ. quæd. circa negotium generationis in ovibus fact. Gott. 1753.

‡ Immediately after the arrival of the mammiferous ovum in the uterus it increases in bulk with amazing rapidity, and its membranes being thus suddenly dilated become in consequence very weak and thin; so tender indeed are they, that if they

With regard now to the time at which the ovum first enters the uterus in the human female, let us examine the facts which are before us. The greater number of observations of this kind are made on aborted products; many of these are malformed or diseased, in consequence of which very probably they have been thrown off by abortion; others are injured by the violence of the action which causes the uterus to be emptied of its contents. Our knowledge of the time of conception is generally founded upon the cessation of the menstrual flow on the first occasion when it ought to have recurred after conception has taken place, and conception may in the greater number of instances have taken place at any period of the interval. In a very few cases only have we any means of determining the time of conception, and in still fewer instances has there been an opportunity of examining the uterus in situ at an early period after conception when the period of sexual intercourse was known. In by far the greater number of instances, therefore, there may be an error in the calculation of ten days or a fortnight.

It is by no means rare to see specimens of the human ovum or fœtus in anatomical collections marked as being a fortnight or three or four weeks old; but it is now generally acknowledged that the greater number of these are incorrectly marked. We have seen, however, more than one such ovum, which, both from the history of the cases and from the structure and size of the parts of the ovum and fœtus, we should be inclined to consider as dating between three and four weeks after conception.*

There are some who describe the human fœtus at less than a fortnight old, and even as early as the eighth day, as in the well-known and often-quoted example described by Sir E. Home. But there is some reason to think that Sir E. Home was mistaken in the case alluded to. Either, supposing that conception had occurred eight days before death, the body in question was not the fœtus, or if it was the fœtus, it must have been considerably older than he supposed.

The earliest example of the human ovum with which we are acquainted is that mentioned by M. Velpeau in his work *sur l'Embryologie Humaine;* which, if he was not deceived by the person who gave it to him, he had the best reason to believe was discharged on the fourteenth day after sexual intercourse.

This ovum, the description and drawings of which are very meagre, is described as about the size of a pea; the fœtus was already somewhat formed, though very small; and all points of structure in the fœtus and ovum appear to us (so far as we can judge from the description) to correspond with one another, and to shew that the product was quite natural. This ovum from its size and from the state of advancement of the fœtus must have been in the uterus at least two or three days.

We possess also the recent record of two valuable observations made on the structure of the gravid uterus of females dying suddenly eight days after sexual intercourse; the one by Weber, the other by Professor Baer. No ovum was detected in either of these instances either in the uterus or tubes. We feel inclined to place much reliance on these two observations as being made by persons well acquainted with the various circumstances necessary to be attended to in such a delicate investigation, and with all the advantages of recent knowledge, and though they afford negative evidence only, yet we are disposed to found upon them as proofs that at the eighth day the ovum has not descended into the uterus.

On comparing the degree of advancement of the fœtus in the ovum described by Velpeau and in others with that of the fœtus in the dog, cat, and sheep, at known periods, we would hazard the opinion that the human ovum arrives in the uterus on the eleventh or twelfth day after conception. Valentin thinks the twelfth or fourteenth day, but we are inclined to believe that it cannot be much later than in the dog.

Change of the uterus after conception.—Before the arrival of the ovum in the uterus, a change has already taken place in the interior of that organ preparatory to the reception of the fœtus. An exudation of a substance having many of the characters of organizable lymph

once burst it is impossible to recognize any parts of the ovum, frequently in instances where we are certain it has existed. Baer in a second epistle (published in Breschet's Repertoire, vol. viii. p. 175) mentions these difficulties of manipulation in extracting the ova from the gravid uterus of the dog during the early periods, and advises that, on account of the violent contractions which are apt to ensue in the uterus from its exposure to the air, the animals should not be opened, but left perfectly quiet for eight or twelve hours or more after death. We have frequently pursued this plan advantageously in the rabbit and cat; and have even found it necessary to harden the ovum and uterus in alcohol before being able to extract the former. The same circumstances may account for our never finding the ovum of the sheep before the seventeenth day, for those we examined were all killed at the market, and consequently opened immediately after death while the contractility still remained in the uterus. At earlier periods we have in fact frequently found shreds of membrane, and some of the earliest ova which we found were partly destroyed; but in a very short time afterwards the membranes of the egg and parts of the fœtus acquire sufficient consistence to resist the pressure.

* So common in museums are the specimens of blighted ova which are considered as examples of very early date, that the author confines himself here to the mention of those which he has himself seen, making this general remark, that in all those specimens below the alleged age of six or seven weeks, in which the fœtus and membranes, particularly the amnion, are disproportionate in size, that is, the first very small and the latter large, then the product is unnatural, and we ought to judge of its age more by the extent of the membranes than by the size of the fœtus. We feel inclined to believe that some of the views adopted by Dr. Pockels of Brunswick, in his interesting paper on the early structure of the human ovum and fœtus (to the consideration of which we shall return in the article OVUM), are founded upon the examination of unnatural specimens.

furnishes a soft flaky lining to the cavity of the uterus, and serves to form a covering of the ovum when it afterwards descends into the uterus. This newly formed substance is reflected over the ovum so as to give it a double covering, the two layers of which constitute the two folds of the decidual membrane. The decidua is filled with bloodvessels formed by a process of organization similar to that which occurs in inflammatory adhesion by coagulable lymph. These bloodvessels are continuous with those of the uterus, and as the ovum advances in the progress of development, they are much dilated in some parts so as to form sinuses, which are ultimately intermingled, though by no means continuous with the bloodvessels which pass out of the umbilicus of the fœtus. The placenta or organic connection between the female parent and child, by means of which the respiration and partly also the nutrition of the latter is carried on, is in great part formed in the decidua with which the flocculent chorion is closely incorporated; but the description of these parts belongs to another place.

In a former part of this essay it was remarked that rupture of the Graafian vesicles and discharge of the ovula from them, as well as the formation of corpora lutea, may take place in some animals without the concurrence of the male: there is reason to believe that in some cases the decidua may in part be formed without conception having occurred, as in the cases of moles, &c. When these changes have occurred without conception in Mammalia, it is quite possible that the ova may have been carried down the Fallopian tubes; but as they are unfecundated, they undergo no enlargement, and consequently we do not know what becomes of them.

In many oviparous animals the same is the case, that is, ova are frequently discharged from the ovaries without the concurrence of the male, as happens in the common fowl and other birds, in some reptiles and fishes. But even in those animals in which barren ova are thus excreted by the female, union with the male renders the exclusion of the egg more easy and regular, and it is consequently not uncommon for female oviparous animals which are removed from the males to die at the season of breeding, when the ova are formed in their ovaries or descend from that organ into the oviduct. This is beautifully described by Harvey as befalling his lady's parrot, which he had always taken for a male bird, but which, after being much fondled, died of "a corrupted egg impacted in the oviduct;" and also in a cassowary kept in the royal gardens, which, after being some time there, was excited by being placed in the vicinity of a male and female ostrich, and having laid one egg, died of a second being retained in the oviduct.

In the common fowl indeed, when highly fed, so great is the productive energy both of the ovary and oviduct that they will continue to lay eggs during a whole season without the assistance of the male; but this is well known to be often very pernicious to the bird, as many of those kept without the cock die; and it not unfrequently happens that eggs, or bodies like eggs, are laid by them containing no yolk, but consisting only of the albumen, membrane, and shell, which are the product of secretion from the oviduct, and that in others large masses of imperfectly formed eggs accumulated together are lodged in the genital passages.

These facts exhibit in a strong point of view the powerful productive energies of the female generative organs independently of the concurrence of the male; for it is sufficiently obvious from them that the greater part of the substance of the egg is due to the female, and that ova, to all appearance perfect,* though unfit for reproduction, may be brought forth by the female wholly independent of the male. Some authors also adduce as examples of this independent productive energy of the female, the occurrence of bones, hair, teeth, &c., in close cysts of the ovaries of women and female quadrupeds, but this leads us too far into the regions of vague supposition.

Irregularities in the descent of the ovum.— This appears to be the proper place at which to make mention of a few irregularities that have been observed in the descent of the ovum, which are attended with important modifications of the generative process.

In the bird it not unfrequently happens that the yolk or ovulum which has been discharged from its burst capsule in the ovary, instead of descending through the oviduct, and having added to it the external accessory parts, escapes from the infundibulum or oviduct into the cavity of the peritoneum. This irregularity occurs most frequently among those fowls which are laying eggs without the male, and in which it may be supposed the usual and regular performance of the appropriate motions is not ensured by venereal excitement. These yolks sometimes remain for some time in the cavity of the abdomen, and are afterwards gradually removed by absorption: in other instances they cause death. Upon every occasion when the ovulum is discharged from an ovarian capsule, the oviduct is excited to the secretion of albumen, membrane, and shell, and hence the ova subventanea, which consist only of these accessory parts without the yolk.

In other instances, either from a mechanical obstruction to the passage of the egg, or from a deficiency in the muscular power of the oviduct, the product becomes impacted in the passage, and there are formed large masses of accumulated ova subventanea, with or without yolks in some part of the oviduct or in its vicinity.

In some instances, extremely rarely met with, it is stated by Geoffroy St. Hilaire (Annal. du Museum d'Hist. Naturelle) that ova detained in the oviduct have become slightly developed, and the author owes to the kindness of his friend, Mr. Daniel Ellis, the history of several examples of the same ano-

* We shall have occasion to consider elsewhere more minutely the difference between the fecundated and the unfecundated ovum.

maly; but it may be stated as a general rule that this does not occur in oviparous animals, and more especially in birds, in which a continued supply of fresh air around the shell is necessary to promote incubation, and we do not know of any examples of truly oviparous animals in which the fœtus has been formed in an egg accidentally retained within the body of the parent. In none of those which we have observed was there any appearance of fœtal formation.

It is possible that some irregularities in the position of the ovum of mammalia during gestation may receive an explanation from mechanical disturbances similar to those we have now mentioned in birds; for supposing that in a viviparous animal the ovum does not gain the uterus or usual place of its abode during gestation, development of the fœtus still takes place. In those instances in which a fœtus is formed in the region of the ovary, or in what are termed ovarian conceptions, for example, it is not probable that the ovum is ever developed in the ovary itself without the bursting of the Graafian vesicle: it may be fixed close to the ovary, but it is always independent of that body. After the Graafian vesicle has burst, the ovum may be supposed either not to have been received in the Fallopian tube, or, after having entered that passage, to have been expelled from it by an inverted action of its muscular fibres or other causes. Fecundated by the contact of some of the seminal fluid which has reached so far into the Fallopian tube, the ovum remains in the neighbourhood of the ovary, has a cyst formed round it, and becomes organically united to the ovary or parts in its vicinity by structures similar to those which unite the ovum to the inner surface of the gravid uterus; for the bloodvessels of the mother which run into the cyst enlarge and form a placenta by their union and intermixture with those of the fœtus, and thus for a considerable time (amounting sometimes to four or five months) this ovarian or extra-uterine gestation is carried on.

In other instances of misplaced gestation, the ovum seems to have been arrested in its course when more or less advanced in the Fallopian tube; but here also the parts are susceptible of all those remarkable changes and growth which favour the development of the fœtus in the ovum. We mention these instances of extra-uterine gestation with the view of directing the reader's attention to an inference which may be drawn from them, viz. that all those changes of growth upon which the development of the ovum in viviparous animals depends may be regarded rather as belonging to the ovum itself than as resident in the uterus alone. It is worthy of remark, however, that in ovarian and tubular conceptions the decidua is formed within the uterus, nearly in the same manner as if the ovum had descended in the natural way into its cavity; from which we may infer that the production of the decidua is to be regarded as one of a series of changes induced by conception in the internal genital organs, and occurring independently of one another, rather than as the effect of any stimulation from the ovum, as some have supposed. Such a decidua in fact may be compared to the subventaneous ovum of the bird.

Very little is as yet known as to the physical circumstances (independent of malformation of the organs) which may give rise to misplaced gestation; and this is not a subject which we can hope to have illustrated by observation or experiment. One or two cases are on record, however, from which it might appear possible that a violent disturbance of the body soon after sexual union may be a cause of misplacement of the ovum. Burdach mentions instances of this kind: one of a cow gored by the horns of another soon after copulation, and two instances of the human female in which sudden fright in the same circumstances was followed by ovarian conception.*

In endeavouring to apply such mechanical explanations, we ought not to forget that in by far the greater number of cases sudden motion does not appear to disturb the natural performance of all those actions by which the ovum is securely lodged in the uterus in the natural way.

Circumstances influencing the liability to conception.—The circumstances which influence the liability of the female to conception are so various and so little determined that our remarks on this subject must be very short.

The healthy condition of the female is of course an important circumstance in reference to conception, but we do not know in how far a robust constitution or high state of health is favourable or the reverse to the occurrence of conception. Some women, it would appear, (perhaps those of a spare habit of body and languid powers of constitution) are most liable to fall with child when in their strongest and best state of health, while weakness in others seems to induce conception. Among animals it is known that high feeding sometimes prevents pregnancy, and the same is the effect of the opposite extreme of starvation.

The regularity of the menstrual discharge is one of the most important circumstances which favours the liability of women to conception; perhaps more from its being an indication of the general healthy state of the generative organs than from any influence exerted by the menstrual change itself. Many circumstances, however, seem to render it probable that women are more liable to conception within a few days after the cessation of the menstrual flow than at any other period of the interval, and accordingly there are many accoucheurs who regulate their calculations of the time of birth from this circumstance, dating the commencement of utero-gestation from a period within a week after the cessation of the last menstrual discharge. We do not know with certainty upon what circumstances this influence of the menstrual function depends; but it seems reasonable to suppose that it is connected with that state of excitement and sanguineous congestion in the ovaries and

* See Lallemand's Observat. Patholog. 1818, and Dict. des Scien. Med. xix.; also Grasmeyer de conceptu et fecundatione humana, 1789.

rest of the generative organs which usually attend on menstruation. There seems to be very little reason to believe, as some do, that there is a greater than ordinary liability to conception immediately before the commencement of menstruation.

Lactation in the greater number of women prevents conception for a time, generally for from six months to a year, but in other women seems to have no effect.

It is very obvious that the state of mind of the female has very little to do with conception, as it is well known that conception * occurs where there is no love, no desire, in pain, in sleep, and in the state of insensibility; and it is equally well established that sexual feelings are not necessary for the occurrence of conception, although it is possible that they may in some instances indirectly assist. It is worthy of remark that there are examples of individuals of opposite sex whose marriage has been barren, both having had children with others.

Signs of recent conception in woman.—Before concluding the subject of the changes in the internal generative organs of the female which follow fruitful sexual union, let us recapitulate shortly the principal circumstances which may be considered as evidence of conception having recently occurred in the human female.

In the first place, there is no one point of evidence which is conclusive in the early period of gestation excepting the finding the ovum or fœtus; and here we must be on our guard against confounding the mole, or such productions which occur in the virgin, with the true ovum. The other signs of conception afford little satisfactory evidence singly, though they are important when several are conjoined.

The signs of conception may be distinguished into those which in some measure affect the whole system, which may be called constitutional or general, and those which are more strictly local, or affect principally the generative organs.

The more general signs are—

1. The interruption of the menstrual flow at the usual period when there is no other obvious cause for it.

2. Fulness and enlargement of the breasts, and vascularity of the areola surrounding the nipple.

3. Derangement of the functions of the stomach; frequent nausea and even vomiting, especially in the morning, with depraved appetite, headache, &c.

4. An accelerated pulse, and some febrile symptoms.

The local signs are—

1. A slight enlargement and increased vascularity of the uterus.

2. The closure of the mouth and cervix by a peculiar viscid secretion.

3. The existence of the commencing decidua or substance from which that membrane is formed.

4. A vascular condition of the ovary, with very much enlarged vesicles, a ruptured vesicle or corpus luteum, and an increased vascularity or enlargement of the Fallopian tubes.

Such local signs can only be obtained by the examination of the body after death. When the greater number of them co-exist and have been attended with the more general constitutional signs, there is strong presumptive evidence of conception having occurred. But nothing short of the appearance of the child either passed in abortion or found after death would entitle us to conclude with certainty that conception had taken place, until those more obvious signs, which are found after the period of quickening, make their appearance.

§ 2. *As regards the male organs.*

Fecundation.—In continuing the detail of the phenomena which accompany or succeed to fruitful sexual union, we come next to the consideration of the process of fecundation. We shall begin this subject by a sketch of the nature and properties of the product of the male generative organs, viz. the seminal or spermatic fluid, and afterwards state the more important facts which appear to throw light upon the mechanism of the remarkable influence exerted by that fluid on the ovulum produced by the female.

Properties of the seminal fluid.—The seminal product of most animals is a whitish fluid, which to the naked eye appears homogeneous or nearly so; but in the human species and some of the higher animals, the seminal fluid or substance, ejaculated from the male organs during sexual union, consists of two parts of different consistence and appearance; in the human species, the one being of a pale milky colour and more fluid, the other clearer, semi-transparent, and more of the consistence of thick mucilage.

The seminal product is derived from several sources. A part comes directly from the testicle, some is discharged from the vesiculæ seminales, and with the fluid from these sources is mixed at the time of emission a certain quantity of the product of the secretion of the prostate body and Cowper's glands: but it is by no means well ascertained from which of these organs the two kinds of substance above alluded to are respectively derived. The more fluid and milky portion is first ejected; the gluey or clear mucilaginous parts, frequently collected into small hard masses, are more abundant in the portion which is last emitted.

Several circumstances render it highly probable that a considerable quantity of the fluid emitted during sexual union is derived directly by secretion from the testicle. With a view to the illustration of this, De Graaf performed the experiment of tying the spermatic ducts of a dog immediately before coition, and found, on examining them afterwards, that they were much distended by the accumulation of seminal fluid in the part of the vasa deferentia in-

* See the amusing speculations of the phrenologists on this subject.

tervening between the ligature and the testicle. It may be remarked, however, there are no vesiculæ seminales or reservoirs of semen in the dog, and the result of such an experiment can hardly with justice be applied to the human species. On the other hand, it may be remarked that in man, while the testicle continually secretes a small quantity of semen, and probably a larger quantity during venereal excitement, it is obvious that the vesiculæ seminales serve as reservoirs in which the seminal fluid accumulates; for when in the dead body fluids are thrown into the vas deferens, they pass into the seminal vesicle of the same side and distend it before issuing by the orifice leading into the urethra. The seminal fluid after being secreted probably follows in the living body the same course; and from this circumstance as well as the suddenness of emission, it is reasonable to infer that the greater part of the ejaculated semen, though formed in the testicles, comes in man immediately from the seminal vesicles.

The seminal vesicles we may suppose then always to contain a certain quantity of seminal fluid in the state of health. The accumulation of semen in these vesicles relieves the pressure which otherwise would distend too much the secretory and excretory ducts of the testicle, and the seminal vesicles are themselves relieved either by the sudden evacuation of their contents from time to time, or by the gradual absorption of the seminal fluid by the absorbents or bloodvessels.*

There is also reason to believe that the mucous lining of the seminal vesicles secretes a mucous fluid which is mixed with the prolific product of the testicles. In some animals, indeed, the vesiculæ seminales open separately from the vasa deferentia and discharge by their excretory duct a fluid peculiar to themselves.

The impotence caused by castration or by the ligature of the spermatic vessels sufficiently proves, that the testicles are the only source of that part of the emitted fluid upon which the fecundating power depends.

The properties of the fluid supposed to be derived from the prostatic body and Cowper's glands have not been satisfactorily examined.

The quantity of the seminal fluid emitted during sexual union varies in man from one to two or three drachms. The seminal vesicles are not, however, emptied at one emission, and, according to Haller, when by repetition this comes to be the case, two or three days are required in man to fit them again for reproduction by a new supply of fluid.

Chemical properties of the spermatic fluid.— On cooling immediately after emission, the seminal fluid jellies slightly, but in twenty or twenty-five minutes it becomes more fluid than at first,—a change which does not appear to depend upon the absorption of moisture from the atmosphere, as its weight is diminished rather than increased.

The chemical properties of the seminal fluid have been examined in man and several animals. It is generally considerably heavier than water, has a peculiar odour, which increases on keeping, is alcaline from the first, and gives off ammonia when heated. Left at rest for some time, it deposits crystals of phosphate of lime.

According to the analysis of Vauquelin human seminal l uid consists of the following ingredients:—

Water	90
Animal mucus	6
Free soda	1
Phosphate of lime	3
Peculiar animal principle	—
	100

In the spermatic fluid of the horse, Lassaigne has detected, besides the above-mentioned ingredients, the following substances:—

Muriates of potassa and soda,
Phosphates of lime and magnesia,
Peculiar animal matter called spermatine.

The milt of fishes, particularly that of the carp, analysed by Fourcroy and Vauquelin, contains—

An oily and saponaceous matter,
Gelatine,
Albumen,
Muriate of ammonia,
Phosphate of lime,
——— of magnesia,
——— of potassa,
——— of soda.
Phosphorus in such quantity as to emit light in the dark.

The semen is fluid in almost all animals. In some of the lower animals it is not so, but granular and crumbling. In the greater number of animals the fluid is of a white milky appearance and thinner consistence than in man, presenting in fishes the appearance of an emulsion of yolk of egg in milk.

In respect to its mode of discharge there are also many varieties dependent on the structure of the generative organs. In the lowest animals the testicle alone exists of the genital organs, and the secretory apparatus of this organ possesses a remarkably simple structure, consisting in many of a number of cœca or elongated follicles which pour the product of their secretion into a common duct. In the cuttle-fish a very curious modification exists in the mode of discharge of the seminal fluid; it being inclosed in small parcels in long-shaped transparent firm cases, somewhat like small phials. These cases are about three quarters of an inch in length, and are formed in the course of the vasa deferentia by an apparatus specially provided for the purpose: they are stopped at one extremity, and at the other are closed by

* This absorption of semen into the general circulation is conceived, not perhaps on very sufficient grounds, to cause some of the peculiarities of the male animal at the time of breeding; to render the flesh rank and unfit for eating; more readily putrescent, &c.

a lid somewhat like the cork of a phial, between which and the main body of the case a spiral spring is interposed, so contrived that when the case is immersed in water the spring expands, forces off the top of the case, and allows the seminal fluid to issue from the interior.

We must refer to the anatomical articles for an account of the varieties of structure of the male generative organs in different animals. In some of those in which the vesiculæ seminales are wanting, as in the familiar example of the dog, copulation is necessarily longer than in others. Very little is known as to the uses of the prostatic body or Cowper's glands. See GENERATION, ORGANS OF.

Spermatic animalcules.—The most remarkable circumstance undoubtedly which is known respecting the spermatic fluid, is the almost constant existence in it of an immense number of minute moving bodies of the nature of Infusorial animalculæ,—the well-known and celebrated spermatic animalcules, which, since the time of their first discovery in 1677, have excited the curiosity and speculative fancy of many naturalists.*

The spermatic animalcules have been found, at one time or other, in the semen of almost all the animals in which they have been sought for,† but at that period of their life, and in that season of the year only, when the animals to which they belong are fit for propagation. They are diminished in number, or even entirely disappear, after very frequent emission of the seminal fluid. They almost always exist in the fluid secreted by the testicles, and very often in that of the seminal vesicles, into which they have doubtless been introduced along with the fluid of the testicles.

From these circumstances, as well as others to which we shall afterwards advert, there is good reason to believe, that the existence of seminal animalcules in the male product is in some way or other intimately connected with the integrity of its fecundating property; if not, as some are inclined to hold, the essential cause of it.

The form, appearance, and size of the seminal animalcule are different in almost every different animal, and in each species of the more perfect animals the kind of animalcule seems, like that of Entozoa, to be constant and determinate. While, therefore, these little creatures, by their minute size and their general structure and appearance (so far as these are known), are distinctly animals of the infusorial kind, their residence in other living animals entitles them to be classed among the Entozoa. Baer considers them as most nearly allied to the Cercaria among the Infusoria, and gives them the very appropriate name of Spermatozoa.

In what we have hitherto said of the seminal animalcules, we have drawn our description principally from what has been observed in quadrupeds and birds, but they differ considerably from these in some of the inferior animals. Czermak* holds that these various forms may be referred to three principal heads, viz.:—

1. Cephaloidea, merely rounded bodies without tails, existing in fishes and some Annelida.
2. Uroidea, thread-like, in Mollusca, Amphibia, and some birds.
3. Cephal-uroidea, consisting of a globular and a tail part, in Mammalia, Birds, and Insects.

The first of these kinds of Spermatozoa are like the Monades among Infusoria, the second resemble the Vibriones, and the third, as has been already remarked, the Cercaria.

It is important to remark that, in so far as has as yet been ascertained, the form and size of the spermatic animalcules do not bear any intimate relation to the animal in which they exist, nor to the ova of the female. In respect of form, Messrs. Prevost and Dumas state that the head is usually of a round lenticular shape in quadrupeds, while in most birds it is of a long oval shape; but in some birds the form is the same as in most quadrupeds. The seminal animalcules present nearly the same appearance in man and in the dog. Various markings are represented in the cephalic portion of the animalculæ of some quadrupeds by Messrs. Prevost and Dumas, but these, we are inclined to believe, are not constant, and are appearances which have arisen from accidental circumstances.

In respect to size, there appears to be still a greater want of correspondence. The seminal animalculæ are said not to be larger in the whale than in the mouse. They are very much larger in Insects, Mollusca, and others of the lower animals than in Man. In the snail they are fifty-four times longer than in the dog, and considerably larger in the mouse than in the horse

The following table exhibits approximatively the sizes of the spermatic animalculæ of some

* Haller states as his conviction, that Ludwig Hamm (then a student at Leyden) was the first discoverer of the seminal animalcules in August of 1677. Leeuwenhoek claimed the merit of having made the discovery, in November of the same year, and in 1678, Hartsœker published an account of them, professing to have seen them as early as in 1674. A great deal has since been written regarding them. Needham, Buffon, Der Gleichen, Spallanzani, Prevost and Dumas, and Wagner, may be mentioned as those who have devoted most attention to these curious little animals. Our remarks are taken chiefly from the investigations of the three last authors, as well as from original observations.

† The class of fishes are stated by Messrs. Prevost and Dumas to form an exception to this remark, these observers not having been able to discover any seminal animalcules in the seminal fluid of fishes; but they are stated to have been seen by older authors (see Haller's Elementa, vol. vii. p. 521); and from the latest investigations it appears that they exist, though of a form different from the spermatic animalculæ of most other animals. The author has seen them very clearly in the seminal fluid of the Perch, and one or two other fishes. See Fig. 51, p. 112, vol. ii.

* Beyträge zu der Lehre von der Spermatozoen, Wien, 1833.

of the more common animals in parts of a line:*—

	Parts of a line.
Helix pomatia	·410
Lymneus stagnalis	·300
Aquatic Salamander	·200
Viper	·050
Polecat	·040
Guinea-pig	
Mouse	
Linnet	
Sparrow	
Hedgehog	·030
Anguis fragilis	
Bull	·028
Horse	·025
Ass	
Goat	·020
Ram	
Cat	
Rabbit	
Common fowl	·016
Frog	·013
Dog	·008
Man (according to Der Gleichen)	
Man (according to Buffon)	·006

Gruithuisen states that he has observed the seminal animalcules to propagate by division of their bodies, or fissiparous generation. But we are far from attaching implicit faith to all that has been stated even as matter of observation regarding these bodies.

We ought not to omit in this place to state another and a different view which has recently been taken of the nature of the moving particles of the semen; we mean that of G. Treviranus, who, founding chiefly upon observations made by himself in the lower animals, as Mollusca and Insects, adopted the opinion that these particles are not independent animals, but analogous in their structure and properties to the fibrils and particles occurring in the pollen of plants. Their motion he seems to regard as of the same kind with that discovered by R. Brown to exist in infusions of these and other minute floating particles, and not as of an animal or spontaneous kind. He deduces this conclusion principally from the alleged observation that the motion of the so-called animalcules is not the same as that of ordinary Infusoria, but differs from it in this respect, that it is simply vibratory and constant, and not interrupted by any of those stops or pauses and changes from place to place which are held to indicate spontaneity in the motions of Infusoria.†

Some of the facts already stated by us shew the fallacy of the opinion of Treviranus. Baer, who regards the Spermatozoa as distinct living animals, holds that Treviranus has observed only an imperfect condition of the animalcule, and states in the work of Burdach‡ some additional observations of his own made in the snail, which promise, when pursued further, to remove some of the difficulties respecting the nature of these bodies. Baer states that he has observed the head and tail parts to become separated from one another, and both these parts, but especially the tail, to move about after separation. Baer has observed also that there are various stages of formation and change of the seminal animalcule, during which not only their form but also their motions undergo remarkable alterations, and he supposes that Treviranus must have observed the spermatic animalcule of the snail and mussel in one of these stages only. Observations made* by the author of this article and by Dr. Sharpey in the frog, seem to bear upon this point, and to be in some degree confirmatory of the view given by Baer. We have almost invariably found, in observing the seminal fluid of the frog in the spring or summer, that the animalcules contained in it are not of the kind described by authors in this animal, viz. with both head and tail, but of the thread-like form only. These were collected in bundles in the thick part of the fluid, and generally moved with a continued vibration such as we have previously described. In the thin part of the fluid there were a few round-shaped or monad-like infusoria. Occasionally it happened that when water was added to the thick part of the fluid, and the bundles of the thread-like bodies were artificially broken down, some of them moved progressively through the fluid by the undulatory riggling of one of the extremities; and during their motion we were surprised to see some of those, which, when at rest, appeared to be destitute of any cephalic part, frequently assume the appearance of a head. This phenomenon we remarked to be owing to the circumstance that the end by which the animalcule moved forward was bent backwards on the middle of the body, so as at one time to give exactly the tadpole-like appearance which is represented as a head in their plates by Messrs. Prevost and Dumas. There could be no doubt that this was the case, for in some, in which at one time the end was so closely joined to the body that it could not be seen, at another it loosened from it, and the thread-like animalcule still continued to progress in the fluid with its curve forwards, and the two ends (of unequal length) floating separate and loose. The author has observed nearly the same phenomena in the spermatic fluid of the pigeon. Lastly, the observations of R. Wagner on the spermatic fluid of the Guinea-pig seem to prove more decidedly than any of the previously mentioned facts that the spermatic infusoria are subject to remarkable changes of form at different periods, and that they even go through a regular gradation of development.

The discrepancy of these observations makes

* This table is taken principally from the measurements of Prevost and Dumas given in their excellent account of the seminal animalcules published in the Annales des Sciences Naturelles.

† See a paper in Tiedemann's Zeitschrift, vol. v. part 2, 1835.

‡ Vol. i. second edition.

* These observations were made five years before the publication of this article. For further information respecting the Spermatozoa we refer the reader to the articles ENTOZOA and SEMEN; in the last of which Mr. Wagner, who has investigated their nature with great success, will fully explain his views.

it apparent that we ought in the present state of our knowledge to be very cautious in making any general conclusion regarding the nature of the spermatic animalcules. It appears to be fully proved that some such animalculæ always exist in the seminal fluid of animals when they are fit for propagation; but it is by no means certain that they belong exclusively to the fluids which are the product of secretion in the testicle, for animalculæ very similar to them in general appearance and in motions are to be found in various other fluids and organs of animals. In all those parts of the body in which mucous secretions are accumulated, animalculæ are formed, and in some of the lower animals the Cercariæ of intestinal mucus are hardly to be distinguished from the animalculæ of their seminal fluid.

Nor is it well ascertained that these animalcules belong exclusively to the fluid of the testicle, and do not sometimes occur in the secretions of other parts of the generative organs. They exist no doubt frequently in the seminal fluid of the testicle, but some recent observations seem to shew that they are frequently imperfect in the fluid of that organ, and that in some animals at least they are not fully formed and do not acquire their powers of active motion till some time after the seminal fluid is secreted, and when it has passed from the testicle into other parts of the generative organs. On this account some hold, and with good reason, that they are to be regarded as the product of reciprocal changes of the ingredients of the seminal fluid on one another, rather than as secreted along with that fluid directly from the bloodvessels of the testicle, as others have supposed.

In conclusion, we would remark that in regard to the seminal animalculæ having both the body and tail, such as those that may be seen in the dog, cat, rabbit, or other quadrupeds, and which were described by the discoverers and early observers of the seminal animalculæ, no one who has had an opportunity of observing them carefully with a good lens magnifying three or four hundred diameters can doubt for a moment that they bear a close resemblance to some of the Infusoria, and that both from their structure and motions they are with as much justice as the Infusoria to be regarded as distinct animal beings. With regard to the other kinds above mentioned, or the changes they may undergo in different stages of their existence, farther investigations appear necessary to enable us to form an opinion.

Although the spermatic animalcules, like other Entozoa, are formed only in living animals and may be regarded as dependent for life on those animals in which they occur, yet they retain their life for a time after they leave the body. Thus the spermatic animalcules of the Polecat, which Prevost and Dumas observed with much attention, continued to move for fifteen or twenty minutes on the object-stand of the microscope; and these experimenters state that when the seminal fluid is allowed to remain in the genital organs, the animalcules continue to live for fifteen or eighteen hours after the death of the animal. Their motions cease instantly when a strong electric spark is passed through the fluid containing them.

Immediately after the discovery of the seminal animalcules, they were made the subject of very fanciful hypotheses, and were conceived to throw quite a new light upon some of the obscure parts of the generative process. To the supporters of the theory of pre-existing germs, their discovery opened up the prospect of being able to trace backwards one link more than had previously been done in the chain of life which connects the parent and offspring. By some they were considered as the cause of sexual enjoyment or venereal propensities. By others, the animalculæ were held to be of different sexes, and, according as one or other gained the egg during fecundation, to give rise to a male or female offspring, and thus to determine its sex. They have been supposed by others to form the first rudiments of the fœtus or lay the foundation in the germ of the egg from which the offspring is afterwards developed, and fecundation has thus been resolved into the simple passage of a seminal animalcule into the germinal part of the egg; and finally, one or two of the most fanciful of such dreaming physiologists have (as we had occasion to remark at a former part of our article) not failed to perceive on a sufficiently minute inspection of the animalcule, that it already possessed all the organs belonging to the mature condition of the animal in the seminal fluid of which it existed; compressed no doubt into a very small space, but from which it was easy to suppose the offspring to be formed by evolution.*

Such notions require no refutation. Let us rather pass now to the inquiry of how far observation and experiment have tended to throw light upon the essential circumstances upon which the fecundating property of the seminal fluid depends.

The nature of the change which confers upon the egg the power of production is entirely unknown to us, and we already remarked towards the commencement of this article that this action is to be ranked among those vital operations of the animal economy which are placed beyond the reach of our means of investigation. We should with equal prospect of success proceed to inquire how life originates and is maintained in the parent, as to investigate the secret manner of the transmission of the vital spark from the parent to the offspring. The physiologist who would study this subject must therefore limit his inquiries in this as in other departments of his science to the search after those conditions or chain of circumstances which appear to be essential to the occurrence of the particular change or phenomenon which is the object of his investigation.

Our present object, then, is not to investigate the nature of the change by which the living

* Gaultier, Génération des Hommes et des Animaux. Paris, 1750.

productive power is given to the egg, but to endeavour to establish what are the essential conditions of fecundation.

Difference between the fecundated and unfecundated ovum.—In the first place, in reference to this subject, it would be interesting to know whether any material difference exists between the structure of the fecundated and unfecundated egg.

In the common fowl we have seen that the whole substance of the egg, the yolk and germinal portion, the albumen, shell, and membrane, may be formed in the ovaries and oviduct, and excreted from the body of the hen without any connection with the cock; but such an egg, though apparently the same in structure with that which is laid after connection with the cock, when subjected to the requisite heat, undergoes none of the changes of development which incubation induces in the fecundated egg, but only passes into chemical decomposition like any other dead animal substance.

Did any difference of structure exist between the fecundated and unfecundated egg, we should be disposed to look for it first in that part of the egg which is more immediately connected with the new being, viz. in its germinal portion; but we regret to say that the investigations of naturalists have not as yet pointed out any marked difference in a satisfactory manner. Malpighi, it is true, long ago pointed out a difference in the structure of the cicatricula of the egg of the common fowl which had had connection with the cock, and those of the hen living single, and the observations of this author were afterwards confirmed by Prevost and Dumas. In the impregnated egg the cicatricula is a well-defined whitish spot, with a regularly formed transparent area in its centre; while in the unimpregnated egg there is no regularly shaped transparent area, but rather a number of small irregular clear spaces scattered over the surface of the cicatricula. We fear, however, that this appearance of irregularity exists as well in some eggs that have been laid after connection with the cock, and that the shape or appearance of the cicatricula can scarcely be depended upon as informing us whether an egg has been fecundated or not, since that appearance is much influenced by the state of the nucleus or white matter of the yolk situated below it, as well as by the state of the cicatricula itself. This subject is worthy, however, of the most accurate investigation, as it appears to offer the prospect of affording some information on this very obscure part of the generative process.

In the ovarian ovulum, the vesicle of Purkinje, it will be recollected, occupies the centre of the cicatricula; and this vesicle exists in the ovulum so long as it remains within the ovarian capsule, whether the hen have connection with the cock or not. In the impregnated fowl the germinal vesicle of Purkinje bursts, and leaves the transparent area in the centre of the cicatricula at the time when the ovulum passes from the ovarian capsule into the oviduct; but it remains to be known if the same is the case, or what phenomena ensue upon the escape of the ovulum from the ovarium in the fowl which is entirely separated from the cock.*

We do not know with certainty what befalls the vesicle of Purkinje in the ovulum of Mammalia at the time of its escape from the ovarium. The analogy of all oviparous animals is strongly in favour of the supposition that it bursts in the same manner. M. Coste states that it does not burst, and Valentin supports an opposite view.

While, therefore, we feel disposed to adopt the opinion that the seminal fluid, in fecundating the egg, operates its peculiar change chiefly on the germinal part, and that the bursting of the germinal vesicle is very probably connected with the change of fecundation, it must be admitted that further observations are still wanting to afford a satisfactory proof of the correctness of these hypotheses.

Is material contact of the semen and ovum necessary for fecundation?—No one has ever discovered any of the seminal fluid within the egg: the most minute observation does not detect any appearance of this. A question then naturally presents itself in reference to the subject of our present inquiry, viz. whether it is necessary that a certain quantity of the *substance* of the seminal fluid should be brought into actual contact with the egg in order to cause its fecundation? and if so, in what manner and in what part of the female organs such contact is brought about?

Were we to look no further than to the manner in which fecundation is effected in many of the inferior animals, we might be induced at once to form the opinion that the mere contact of a certain quantity of the seminal fluid with their ova, in whatever way brought about, is all that is necessary for producing their fecundation. Thus, in the greater number of fishes the milt or seminal fluid of the male is shed over the spawn of the female after it is laid in water, without there being any nearer sexual intercourse; the fecundation is external to the body of the female, and we thus know with certainty that the ova and the seminal fluid are the only parts immediately concerned in the process. The same is the case in the common frog, in which there is copulation; for in that animal, although the male and female remain united firmly together during a longer period than any other kind of animal, yet this union is not a means of producing fecundation, but rather of promoting the discharge of unimpregnated ova from the generative system of the female. There is in fact no true sexual union: the spawn is laid by the female unfecundated, and the male (separating then in general from the female) sprinkles seminal fluid on the ova floating in water.

External and artificial fecundation.—The mode of fecundation just now mentioned sug-

* We have long had the intention of instituting a series of observations comparing the changes of the impregnated and unimpregnated ovum in the oviduct, but have not yet had an opportunity, and we recommend it to those who may be anxious to engage in the investigation of this subject.

gested to Spallanzani* the ingenious experiment of artificial fecundation, which he first performed, and which furnished the most convincing proof that could be obtained, that, in such animals as the frog, sexual union is not essential to fecundation, and that, when the ova are ripe and the seminal fluid of the suitable quality, the mere contact of the male and female products is sufficient to confer fertility upon the ova.

Spallanzani opened very many female frogs at the time of propagation, but before they had laid any spawn, and consequently before impregnation could have occurred, and he satisfied himself that the ripest ova extracted from the oviduct, and placed in water, gradually passed into putrefaction without undergoing any of the changes of development; while some of the same ova, upon which he had sprinkled some of the seminal fluid taken from the body of the male, and placed in similar vessels of water, had tadpoles formed from them in the same manner exactly as those which were fecundated by the male frog itself.†

The same experiments were performed by Spallanzani on toads and newts with exactly the same result.

Spallanzani, in order to avoid every fallacy, allowed the female to remain in union with the male, and to lay her spawn in the natural way, preventing only the access of any of the seminal fluid of the male to the ova, by tying up the hinder part of the male's body in oiled silk, and these ova were alike barren, unless he added to them some of the seminal fluid in the artificial mode.

Treviranus‡ mentions the performance of the experiment of artificial fecundation in Fishes, viz. on the spawn of the Salmon, Trout, and Carp, by Duhamel and by Jacobi. Jacobi's experiments were repeated by Dr. Walker of Edinburgh; and very recently it has again been performed on the spawn of the Tench and Bleak by Rusconi of Pavia. (Cyprinus Tinca and Alburnus.)

The very complete series of experiments of Messrs. Prevost and Dumas§ on the frog afford the most satisfactory confirmation of those of the Abbé Spallanzani.

The following appear to be the more important results deducible from these two sets of experiments.

1st. That a very small quantity indeed of the seminal matter is requisite for the fecundation of the ovum.

2d. That dilution of the seminal fluid with water within certain limits does not impede, but rather is favourable to its operation.

3d. That the absorbent power of the albuminous or gelatinous matter which surrounds the black yolk is highly useful in bringing the seminal substance in contact with the yolk, where it is obvious its effect must be produced. This albuminous covering, corresponding to the white of the bird's egg, possesses the remarkable property of absorbing water, somewhat like gum tragacanth, in a determinate quantity, and thus increases greatly in bulk after being laid in water. In the experiments referred to, the absorption of the water by the jelly was fully demonstrated by the immersion of the ova in coloured water, and it was found also that the experiment of artificial fecundation succeeded best when the ova had not been immersed in water for any considerable time previous to the addition of the seminal fluid. The fecundation was less certain the longer the ova were allowed to remain in water before the addition of the semen; and it was shewn that this did not depend simply on the length of time of the separation of the ova from the body of the parent, by the fact that ova taken from the oviduct and kept without moisture retained their susceptibility of being fecundated for a much longer period, as sixteen or twenty hours.

4th. That the seminal fluid of the frog retains its fecundating power for about thirty hours after it has left the body of the male.

5th. Attempts were made by both the experimenters above quoted to ascertain, by way of experiment, whether the seminal animalcules are indispensable to fecundation. Spallanzani came to the conclusion that the seminal fluid did not lose its peculiar powers although deprived of its animalcules, or although the animalcules were dead; but it must be admitted that the means employed by that observer to ascertain the presence or absence of the seminal animalcule were inferior to those we possess in more recent times. Messrs. Prevost and Dumas, who, it has already been remarked, consider the animalcules as the most important part of the seminal fluid in reference to its fecundating properties, state that they found in their experiments, that that part of the seminal fluid which had been subjected to a very careful filtration, and which had thus been wholly deprived of its animalcules, had lost all fecundating power, while the substance which remained in the filter, and which was rich in animalcules when diluted with water, possessed the same powers of fecundation as the pure seminal fluid. We think this experiment requires repetition and some modifications, for other ingredients, besides the animalcules of the seminal fluid, might be retained on the filter.

6th. Both Spallanzani and Prevost and Dumas have attempted to estimate the quantity of seminal fluid required for the fecundation of a certain number of ova, and the latter observers, pursuing their favourite idea to the utmost, have even endeavoured to calculate the number of animalcules which are necessary for the fructification of one or more ova. In Spallanzani's experiments two grains of the semen of the toad fecundated one hundred and thirteen ova. Five grains of semen were mixed with eighteen ounces of water; the point of a needle dipped in this was made to touch an egg for an instant and produced fecundation. The proportion here might be estimated as

* Dissertazioni di fisica animale, &c.

† This experiment the author has more than once performed with a similar result.

‡ Erscheinungen und Gesetze des Organischen Lebens.

§ Annal. des Sciences Nat. tom. i.

semen 1, to egg 1,064,000,000. The addition of a larger quantity of semen, or its remaining longer in contact with the egg, did not, according to Spallanzani, render the fecundation more complete than the instantaneous contact of the wetted needle's point. Prevost and Dumas state that they found the number of ova fecundated by a given quantity of seminal fluid is always below that of the animalculæ which they estimated that fluid to contain; and by a simple process of calculation it was easy to find how many animalculæ served each ovum. A certain quantity of seminal fluid, for example, containing 225 animalcules, served to fecundate 61 only out of 380 ova, to which it was added, so that each ovum required about 3⅔ animalculæ for its fecundation, or making allowance for a few of the animalculæ which went astray into other ova, it may be stated as three in round numbers. It will be long before the vital processes can be traced with the arithmetical precision displayed in this calculation. Unfortunately for the calculations and even the observations upon which they are founded, one of the authors at a subsequent period published the theory which appears to have prompted them to revive an old and fanciful notion that the animalcule forms the rudiment of the new being. The animalcule, according to this hypothesis, makes its way through the stiff jelly surrounding the yolk, gains the centre of the germinal membrane, and esconces itself there in the very centre of that germinal membrane, laying thus the foundation of the primitive streak or the brain and spinal marrow of the fœtus: its position (which is always the same) being no doubt determined by the laws of polarity depending upon the electro-magnetic properties with which, according to equally fanciful theorists, the rudiments of the new being in the egg are endowed.

Hitherto cold-blooded and oviparous animals only have been alluded to; but there are not wanting facts which render it highly probable that in viviparous animals also, contact of seminal fluid with the ovum is the essential part of the fecundating process. Thus, Spallanzani confined a bitch for fourteen days before the arrival of heat, and for twenty-six days after it, so that, during that time, it could have had no connexion with any dog, and at the time of the heat he injected by means of a syringe a quantity of the dog's seminal fluid into the vagina. The bitch brought forth three young exactly at the usual length of time from the period of heat; — an experiment on artificial fecundation, which may in some sort be said to have been performed in the human species is the well-known instance in which John Hunter recommended to a man affected with hypospadiac malformation of the urethra, which rendered intromission of the seminal fluid impossible, the injection, by means of a syringe, of the seminal fluid into the vagina,— an operation which, it is related, was attended with complete success.

While these facts on the one hand tend to shew that no parts of the genital organs and no other agents are concerned in fecundation excepting the seminal fluid and the ova, and on the other hand afford the only *positive* evidence that can be obtained, that actual contact of the one with the other is necessary to induce the change, they have appeared unsatisfactory to some physiologists, who cling to the opinion that, in quadrupeds and birds at least, contact is not necessary, and that fecundation may be effected either by some hidden sympathy (or concurrent action taking place in remote parts) between the external and internal organs of the female, or that this change may be operated by some imponderable influence which emanates from the seminal substance, to which the vague name of aura seminalis has been given.

Course of the seminal fluid within the female organs.—In pursuing our examination of the alleged evidence upon which these and similar hypotheses are founded, it will be necessary to consider in this place another question, respecting which it is difficult in the present state of the inquiry to form a decided opinion, viz. whether, on the supposition of the seminal fluid and ova coming into actual contact, the course of the seminal fluid within the female organs of generation can in any instances be traced, and in what part of these organs it may be supposed to meet with the ova and operate their fecundation.

In the first place the examples of ovarian conceptions, or rather gestations, have been adduced by some as a proof that fecundation necessarily takes place in the ovaries themselves. But from what was said in a former part of this paper, it will be seen that such a belief is founded on an erroneous view of the nature of these misplaced gestations, as well as of the phenomena which occur in the ovary after conception. There is no reason to believe, we may repeat, that ova found developed in the neighbourhood of the ovary have retained their situation within the Graafian vesicle. On the contrary, they must in all probability have been first discharged from the ovary upon the rupture of the vesicle, and their places occupied by corpora lutea; and they may have been fecundated either while loose in the cavity of the peritoneum, or when they have descended some way in the Fallopian tubes, and meeting with the seminal fluid in the course of that tube, have been returned to the vicinity of the ovary by some inverted or unnatural action of the parts.*

Although, therefore, no very decided opinion respecting the place at which fecundation occurs can be formed from the observation of what are termed ovarian and tubular gestations, we are inclined to think that they shew

* We need do no more than mention here a view taken by Sir Everard Home of the uses of the corpora lutea, which he holds to be a means of bringing the seminal fluid into contact with the ovum of the Graafian vesicle. This opinion requires no remark, as it will be at once perceived that it proceeds on the assumption, shewn to be erroneous in a former part of this paper, that the corpora lutea are formed before the rupture of the vesicles.

that this process may take place, in some instances at least, in the upper parts of the Fallopian tube, or even in the infundibulum.

In the second place physiologists have endeavoured to argue respecting the place of fecundation from the well-known fact that, in the common fowl, turkey, and probably some other birds, a single connexion with the male serves to fecundate more than one ovum, as, for example, in the common fowl twelve or twenty ova; and that, as there is usually only one ovum in the progress of descent through the oviduct at one time, we must conclude either that the yolks or ovula are fecundated by the rise of the seminal fluid to the ovary, or that the seminal fluid remains somewhere in the course of the oviduct, to be applied to the ovum as it descends. If we exclude the notions of an aura and sympathetic action, the former of the above-mentioned views appears to us the most consistent with the facts that have already come under our knowledge. The notion entertained by Fabricius and others that there is a receptacle for containing the seminal fluid in the oviduct appears to be incorrect; and we find it difficult to believe that the seminal fluid can remain dispersed through the oviduct, or confined in any particular part of it and retain its power of fecundation, when we consider the manner in which each yolk descends from the ovary and receives in its passage the various accessory parts constituting the albumen and external coverings. Of course, in supposing fecundation to take place in the ovary, there remain two suppositions which may be entertained regarding the mode in which the seminal fluid gains the ovula; for it might either pass directly up the tube of the oviduct, or be absorbed and take some circuitous course.

In the third place, we are inclined to think that in quadrupeds the ova must be already fecundated before their arrival in the uterus, that is, either in the neighbourhood of the ovary or in the tubes, for this reason, that at the time when the ovum first arrives in the uterus, it has already become considerably enlarged, and has undergone some of the changes of development;* and when we consider how very regular and progressive these changes have been observed to be from the time when the ovum first enters the tubes, we shall be disposed to conclude that fecundation very probably takes place before then, or in the upper part of the tubes.

In the fourth place, attempts have been made to trace the seminal fluid in animals opened shortly after sexual union. Most authors agree that much of the seminal fluid frequently flows out of the vagina soon after coition, and Harvey, De Graaf, and Haller were all unable to discover any traces of seminal fluid in the uterus even of various animals killed and opened soon after sexual union. Haller, however, while he states this as the result of his experiments, admits that the means which he possessed of ascertaining the presence or absence of the semen were imperfect, and he himself believed that fluid to have entered the uterus.

Various other physiologists, also, state that they have found seminal fluid in different parts of the female organs. Morgagni and Ruysch had two opportunities of examining the body of the human female very soon after coition, and found, on opening the uterus, a fluid which they regarded as semen. John Hunter states that he observed the same in a bitch, as also did Hausmann. But in all these instances some doubt may be entertained regarding the fluid which was considered as semen.

Prevost and Dumas, trusting to the occurrence of the seminal animalculæ as a certain sign of the presence of seminal fluid, state that they have observed these animalcules, at different periods after coition, both in the uterus and tubes of dogs and rabbits; and it appears to result from the careful series of experiments performed by these physiologists that the longer the time was which had elapsed after coition, the farther the seminal fluid had advanced upwards within the female genital passages. Thus, at twenty-four hours after coition a great quantity of animalcules were found in the cornua of the uterus, but none either in the vagina or farther up the tubes; at forty-eight hours nearly the same was the case: on the third and fourth days there were many animalculæ still in the cornua and some in the tubes, which continued in the dog till the fifth and sixth days; and upon one occasion only they observed a few animalcules near the infundibulum.

Burdach and others, again, are not inclined to place much reliance on these observations, because animalculæ of the nature of Cercariæ have been noticed in the genital passages of female animals which had had no connection with the male.

In the fifth place, experiments on the mechanical obstruction of the uterus, Fallopian tubes, and vagina, appear of considerable importance in reference to this part of our subject. Experiments of this kind were performed first by Haighton,* and afterwards by Blundell; the results of which, making allowance for the more accurate knowledge we now possess respecting the indications afforded by the condition of the vesicles and corpora lutea in the ovary, may be stated as follows:—

1st. That when one of the cornua of the uterus or Fallopian tube of the rabbit is divided within a few hours after coition, and obliteration of the tube has followed, although corpora lutea are formed in both the ovaries

* We do not mean here to state that the parts of the fœtus have appeared, but only that changes in the germinal membrane preparatory to the formation of the fœtus have taken place. Nothing of this kind has ever been found in the unimpregnated animal, no appearance of any ovum, which, considering how often vesicles are burst without sexual union, we think must have been the case had the ovum undergone the same changes in the unimpregnated as in the impregnated animal until its arrival in the uterus.

* Philos. Transact. vol. lxxxvi. p. 173.

(as a consequence of the rupture of vesicles), ova are not to be found on the injured side of the uterus, but pregnancy takes place on the other side.

2d. When the vagina was divided in a like manner at its upper part, although the usual number of corpora lutea were found in the ovaries, pregnancy did not occur. That the mere wound itself locally, or its hurtful effects on the constitution, did not prevent the development of the ova, was proved by the experiment purposely made of dividing the parts in the same way and allowing them to reunite by adhesion without obstruction of the tube, in which case uterine pregnancy occurred nearly as in the natural condition.

3d. In another set of experiments obliteration of the tubes was caused to take place at a later period, probably when the ova had descended and may be supposed to have met with the seminal fluid, and in these animals pregnancy occasionally but not always occurred.

It would appear to follow from these experiments, that the seminal fluid does not rise in the female genital passages immediately upon its introduction, and not for more than a day after coition, and that those circumstances which impede the rise of the seminal fluid prevent fecundation. But they do not warrant the conclusion that impregnation must occur in the ovaries, since the vesicles may have burst, their contents be discharged, and corpora lutea formed without the seminal fluid having had access to the ovary; a fact which is well shewn by the interesting experiment performed by Dr. Blundell, of producing an obliteration of the upper part of the vagina in the unimpregnated rabbit, then allowing coition to take place, and then finding, no pregnancy, but corpora lutea in the burst vesicles of the ovary.

These experiments appear also as of importance in shewing that neither absorption of the semen by the lymphatics or bloodvessels, nor the passage by any other circuitous route, nor indeed any sympathetic action established by sexual union between remote parts of the female generative organs, can be the means of producing fecundation.

There are, no doubt, great difficulties in the way of our understanding by what manner the seminal fluid accomplishes the passage upwards in the genital organs of the female. Thus, the small size of the Fallopian tubes at once strikes us as a powerful obstacle; but in many animals, as, for example, in the Ruminantia, there is an equally great difficulty in comprehending how the seminal fluid gains the uterus itself even; for in these animals the os uteri forms a long and uneven passage, interrupted by many hard cartilaginous projections, and closed in general by a very viscid and tenacious mucus. But yet the seminal fluid must in all probability enter the cavity of the uterus.*

In conclusion, we would remark that we must either suppose fecundation to be the effect of the actual contact of the seminal fluid with the ova in the upper part of the Fallopian tube or somewhere near the ovary, or we are reduced to form the opinion that the action of the seminal fluid on the lower part of the female genital organs may be twofold, viz. first, causing the commencement of the process of fecundation by a sympathetic influence on the upper part of the tubes, and, in the second place, perfecting the change in the uterus when it meets there with the ovum. We feel inclined, in the present state of our knowledge, to give a preference to the first of these opinions.

Nature of the fecundating process. Hypothesis of an aura, &c.—We return now to the consideration of the essential nature of the change of fecundation.

The opinion that fecundation is attributable to the agency of an aura or emanation from, and not to the material contact of the seminal fluid, is founded chiefly upon alleged instances of conception having occurred in individuals (of the human species) in whom, from unnatural formation or disease, no direct passage existed from the vagina or external aperture to the internal organs, as well as upon some of the circumstances above alluded to, as shewing the difficulty of such a passage both in man and animals, even in the natural condition.

No very definite idea, it may be remarked, can be attached to the term "aura," for it has been employed in varous acceptations by different authors; one considering it as of the nature of a gaseous or vaporific exhalation from the seminal fluid, another denying it the nature of a substance even of the most etherial kind, and considering it more as a spiritual or vital principle; and a third regarding it as of the nature of a nervous impression. These discrepancies only shew us that the term aura is to be taken rather as an expression for the unknown agency of the seminal fluid which causes fecundation, than as indicating its modus operandi or the part of its substance more immediately concerned in the action. Some authors have, however, even referred to direct experiment in favour of the agency of an aura. Mondat, for example, (De la Sterilité, 4to. edition, p. 17) states that he witnessed experiments performed by Morsaqui, of Turin, with this view, from which it was found that the bitch could be impregnated when it was impossible, as he states, that the substance of the seminal fluid could in substance pass into the uterus or other parts. Recurved tubes, containing in the closed end a quantity of the dog's seminal fluid, were introduced into the

* Burdach mentions, as supporting the view that the seminal fluid may be absorbed by the bloodvessels or lymphatics, and being carried into the general circulation occasion fecundation when it arrives at the ovary or other parts of the internal organs, Casp. Bartholin, Perrault, Sturm, and Grassmeyer. Dr. Harlan of Philadelphia, in a volume of Experimental Essays recently published, states that he found that the injection of semen into the bloodvessels of a bitch put a stop to the heat sooner than would otherwise have been the case.

vagina of the bitch in such a way that none of the fluid itself could escape, but only an emanation, vapour, or supposed aura rising from it, and in eighteen out of thirty animals on which the experiment was performed, with the subsequent occurrence of impregnation. But until these experiments shall have been confirmed by careful and frequent repetition, we must be allowed to doubt the possibility of performing such an experiment in a sufficiently accurate manner.

Spallanzani, with a view to investigate the powers of a vapour supposed to rise from the seminal fluid, exposed a quantity of the ripe unimpregnated spawn of the frog for some time in the same vessel with a quantity of seminal fluid, the latter being placed at the bottom of the vessel, the ova at the top, and never was any fecundation produced;—an experiment, it is true, from which no more than negative evidence can be derived, but upon the whole more worthy of trust as being subject to fewer fallacies than those of Mondat.

The instances in which it has been alleged that impregnation has taken place in the human female without there being any possibility of the seminal fluid itself passing inwards in the female genital passages, are of a very doubtful nature, and liable to so many sources of fallacy, that we feel little disposed to admit them as grounds of proof of the agency of an aura seminalis. In some of the cases in which it has been found, either in the course of pregnancy or at the time of child-birth, that the female passages are obstructed, there is reason to believe that the closure has been produced subsequent to the occurrence of conception; and the same may be said of those cases of ovarian gestations in which an obliteration of the Fallopian tubes has been observed. In the greater number of such cases, it may also be observed, the malformation of the parts has consisted in the much contracted state of the external orifice or some other part of the passage, rather than in their absolute closure, so that there was merely a difficulty and not an impossibility of the entrance of seminal fluid. But in opposition to such vague and ill-ascertained observations, a variety of circumstances, which it is not necessary to particularize, might be adduced, tending to show how very easily in the human female as well as in other animals all mechanical obstructions to the entrance of the seminal fluid into the uterus tend to prevent conception.

General conclusions respecting fecundation. In conclusion we would remark, 1st, that while we readily admit a very small quantity indeed of the seminal fluid to be sufficient to produce fecundation, we think that what has previously been stated warrants the conclusion, that material contact of a certain quantity, however small, of the seminal fluid with the ovum is necessary to give rise to its fecundation, and, consequently, that the hypothesis of an aura is untenable. And for the same reasons it follows that there are no just grounds for holding the opinion either that fecundation consists in a sympathetic action of a nervous kind, or that it is brought about by the absorption of the semen into the circulatory or lymphatic vessels of the generative system.

2d. It is sufficiently obvious that in quadrupeds there is no exact proportion between the quantity of seminal substance or fluid received by the female or emitted by the male, and its effect in producing fecundation,—a circumstance which points out a distinction which ought always to be borne in mind between that vital change on the female genital system and the whole economy and ovum, and the simple physical re-action which may take place between the semen and ovum themselves.

3d. We may regard venereal excitement of the genital organs and impregnation of an ovum as different phenomena, for though they usually occur together, there are instances in which they take place quite indepeudently.

4th. The action of impregnation is to be regarded as sui generis, or quite peculiar among the vital processes. It is not capable of being imitated by any other substance than the seminal fluid, and neither experiment nor observation enables us to form the most distant conjecture what the nature of that action may be, which, from the influence of the male product, confers upon the ovum a new and independent life, and enables to give birth to a new individual the mass of organic matter in the egg, which, without the change of fecundation, would prove altogether barren and undergo no other changes than those of similar dead matters. The action, however, is in some respects reciprocal, and we cannot determine what part either of the two agents concerned performs in the change of fecundation: we know only this, that unless the seminal fluid be of the suitable composition it is ineffectual, and that ova are susceptible of its influence only when in that period of their evolution when they are ripe. Nor can we with certainty fix on what part of the egg the influence of the male semen more immediately operates. Since the fœtus grows from the centre of the germinal layer, it has been commonly supposed that this is the part of the egg which is most immediately affected by fecundation, but we know nothing of this; and it might be held, on the other hand, that the effect of fecundation operates on the rest of the contents of the egg in enabling them to be assimilated round the germinal centre or rallying point of the development of the new being.

5th. It has not yet been shewn that one part of the seminal fluid is more necessary to impregnation than another. The seminal animalcules form a natural ingredient of the fluid secreted in the testicle at the time when it is excreted for the purposes of propagation; they appear to be invariably present, but additional experiments are still wanting to prove them to be the active or essential agents of fecundation, much more the rudiments of the new being within the ovum.

6th. Like others of the operations of the animal economy, the action of fecundation is known principally in its effects; but it seems to be a question worthy of investigation whether, in the phenomena exhibited during fecundation, or the laws by which this change is regulated, it be in any respect analogous in its nature to the operation of certain poisonous or contagious principles, as for example, the venereal virus, vaccine matter, the contagious principle of small-pox, measles, scarlatina, plague, fevers, &c. The inimitable Harvey thus expresses himself regarding the essential nature of fecundation in different parts of the forty-ninth Exercitation on the efficient cause of the chicken. "Although it be a known thing subscribed by all that the fœtus assumes its original and birth from the male and female, and consequently that the egge is produced by the cock and henne, and the chicken out of the egge, yet neither the schools of Physicians nor Aristotle's discerning brain have disclosed the manner how the cock and its seed doth mint and coine the chicken out of the egge." "This," he says, "is agreed upon by universal consent; that all animals whatsoever, which arise from male and female, are generated by the coition of both sexes, and so begotten as it were *per contagium aliquod*, by a kind of contagion." "Even also," he says, "by a breath or miasma," referring to the fecundation of the ova of fishes out of the body.

"The lac maris, male's milk, propagating or genital liquor, vitale virus, vital or quickening venom," are all names of the seminal fluid of the male. Again, "The efficient in an egge, by a plastical vertue (because the male did only touch, though he be now far from touching and have no extremity reached out to it) doth frame and set up a fœtus in its own species and resemblance." "What is there in generation, that by a momentary touch (nay not touching at all, unlesse through the sides of many mediums) can orderly constitute the parts of the chicken by an epigenesis, and produce an univocal creature and its own like? and for no other reason but because it touched heretofore."

"The qualities of both parents are observable in the offspring, or the paternal and maternal handy-work may be tracked and pointed out both in the body and soul." The first cause must therefore be of a mixed kind. "It is required of the primary efficient in the fabrick of the chicken, that he employ skill, providence, wisdom, goodness, and understanding far above the capacity of our rational souls."

7th. In respect to the part of the female generative system at which fecundation takes place, it appears most probable that in quadrupeds and the human species this change occurs before the ovum reaches the uterus, or some way in the course of the Fallopian tubes; perhaps most frequently in the upper part of them. There is, however, probably some variation among animals and in different circumstances regarding this point. But while we state this as the conclusion most consistent with facts in the present state of our knowledge, we ought not to omit the mention of the more prominent facts by which it is opposed.

In some of the lower animals, fecundation seems to extend beyond the sphere of the ova which are ripe. In the Aphis (as was already mentioned at an early part of the paper) the production of young by the female goes on for several generations (eleven) without any sexual intercourse after that which gave rise to the first. In the Daphnia Longispina this is said also to be the case for twelve generations, and in the Monoculus pulex for fifteen. The queen-bee lays fruitful eggs during the whole year after being once impregnated; and in the instance of the common fowl and some other birds, previously referred to more than once, if we reject the supposition of the seminal fluid remaining in action, it seems necessary to suppose that fecundation must occur in the ovary, since unripe ova are acted on by the fecundating medium at the same time with those which are arrived at maturity and are ready to descend into the oviduct.*

Many physiologists also believe that the influence of the first impregnation extends to the products of subsequent ones. Thus Haller remarks that a mare which has bred with an ass and has had a mule foal, when it breeds next time with a horse, bears a foal having still some analogy with the ass. So also in the often cited instance of the mare which bred with a male Quagga, not only the immediate product, but three foals in subsequent breedings with an Arabian stallion, and these three even more than the first, partook of the peculiarities of the Quagga species.

Instances of the same kind are mentioned by Burdach as occurring in the sow and bitch; and it is affirmed that the human female also, when twice married, bears occasionally to the second husband children resembling the first, both in bodily structure and mental powers.

According to Hausmann, when a bitch has connexion with several dogs (and this is generally the case during the continuance of the heat, sometimes to the amount of twenty,) she usually bears two kinds of puppies at least, and the greater number of these resemble the dog with which she first had connexion.

We feel at a loss to decide what weight ought to be attached to these observations; they appear to bear chiefly on the subjects which are discussed in the next part of this article.

V. MISCELLANEOUS TOPICS RELATING TO THE PRECEDING HISTORY OF GENERATION.

We have deferred until now the consideration of some topics which usually find a place in the history of the generative function, as we have thought it desirable to separate them from the preceding narrative on account of the vagueness of the facts and speculative nature of the opinions with which they are connected. The subject last discussed naturally leads to

* Burdach hazards the opinion that in some quadrupeds the ova may not even be developed at the time of impregnation, as in the Roe-deer, which pair in July and August, but do not bear their young till May, and the Fox, the period of gestation in which is much longer than we should suppose it ought to be, judging from the analogy of others of the Dog genus.

the first of these topics which we shall consider, viz.

§ 1. *Superfœtation.*—In the first section of Part IV. it has been mentioned that in the human female, as soon as the ovum has arrived in the uterus, and even a short while before that period, the passage through the mouth and neck of the uterus is closed by a viscid mucus, which opposes a firm barrier against the entrance of seminal fluid, and thus prevents the occurrence of subsequent or reiterated conception. In some of the lower animals, on the other hand, it would appear that several consecutive conceptions not unfrequently occur, and in some animals this may be considered as the natural mode of generation.

It becomes a point of some interest both in a physiological and in a medico-legal view to determine, whether, as has been supposed by some, the same ever takes place in the human species.

The quadrupeds in which superfœtation (as a second conception during pregnancy is called) is said to occur possess a uterus with two horns, and it may be that in them the product of the first conception has occupied only one of the cornua of the uterus, and that the second conception occurred upon the other or empty side. This may be the case in the hare, for example, which is said to be particularly liable to superfœtation. In woman also, it has been supposed that a double form of uterus, which is present in rare instances as a malformation of that organ, may admit of a second conception on one side in the course of uterogestation confined to the other. But though this may be regarded as possible, we are not aware that any example of the actual occurrence of pregnancy in both cornua of a double uterus affords a satisfactory proof of it.

Great caution is necessary in admitting the evidence of superfœtation, as many circumstances concur to render it very fallacious. Women occasionally bear twins, or two children differing greatly in size and apparent age; and many are apt at once to form the conclusion from thence that the two children must have commenced their existence or have been generated at different times; but it is much more likely in most of these instances, that the different appearance in the size and conformation of the children has arisen solely from a difference in the rapidity and vigour of their growth. In by far the greater number of such instances, the smaller of the children bears obvious marks of being stunted in its growth, and it is often deformed, blighted, or dead and shrunk; and even although this were not the case and the children were both alive, a mere difference of size of children born at the same time must be regarded as very slight evidence indeed of so great a deviation from the usual phenomena of pregnancy as superfœtation.

Those who believe in the possibility of the occurrence of superfœtation found their belief chiefly upon some rare instances of the birth of more than one perfectly developed child at successive periods so remote from one another that both cannot have been conceived at the same time, and it must be admitted that these cases, if correct, go far to prove the possibility of superfœtation.

In reviewing the cases of alleged superfœtation two questions at once present themselves for consideration, viz. 1st, whether a second conception may take place within a few hours or days after the first, or we may say at any period before the ovum is settled in the uterus; and, second, whether this may occur at a later period, as at two, three, four, or more months after the first conception.

The puppies of a bitch, we have already mentioned, generally bear a resemblance to more than one of the dogs with which she has had connexion during the period of heat, and this period may extend to eight or nine days. A mare, which had been covered by a stallion, was five days afterwards covered by an ass, and bore at the usual time twins, one of which was a common foal, the other a mule.*

Women have been known to bear two children of different colour; and in one of these instances the mother is said to have confessed to having admitted the embraces of a black servant a few hours after her husband, who was white.

Facts like these seem to shew that sexual intercourse limited to an interval of a few days (most probably before the uterus has been closed by the decidua) may produce superfœtation. But we would remark that, although it may be that the mechanical obstruction of the decidua opposes an obstacle to the passage of semen upwards, or the descent of a new ovum into the uterus, there is obviously another cause why superfœtation should not occur: we mean that fundamental change in the constitution which is induced by pregnancy, similar to that which continues in the majority of women during lactation. But for such a constitutional change, we conceive continual derangement of the function of utero-gestation would attend that process in consequence of the recurrence of some of the more general symptoms of conception, even although a lodgement of a new ovum in the cavity of the uterus were impossible.

The following cases serve to illustrate the nature of the more important facts on record which do not admit of an explanation, excepting on the supposition that superfœtation has taken place.

1. A woman bearing a full-grown male child had neither lochia nor milk after its birth, and a hundred and thirty-nine days afterwards bore a second child—a living girl, when the milk and lochia came naturally. Eisenmann, who had observed this case, explained the occurrence by supposing that a double uterus existed; but upon the woman's death some time afterwards, no unusual structure was found.†

* Archiv. Gén. tom. xii. p. 125. Another similar instance is related in tom. xvii. p. 89, of the same work.

† See Burdach's Physiol.

2. Desgranges observed another instance in which a woman bore two girls at the interval of a hundred and sixty-eight days in the same circumstances as in the above-mentioned case.*

3. A third case is related by Fournier in which two girls were born at the interval of five months, there being lochia for a few days after the birth of the first.†

4. A fourth instance is mentioned of two children born at the interval of a hundred and nine days.‡

5. Velpeau relates that a Mad. Bigaux had first a living child, and four and a half months, or a hundred and forty days afterwards, a second, also alive.§

We confess that we think these cases, if correctly reported, go far to prove the possible occasional occurrence of superfœtation in the human species. On the supposition that two children born alive at different periods remote from one another have been conceived at the same time, three months appears to be the greatest extent to which the interval between their births could reach, the first being born prematurely at six and a half or seven months, and the second being retained in the uterus till the period of nine and a half or ten months; but this is improbable in some of the instances before us, as both children appeared equally complete, and no mere difference in the rate of their growth could account for their birth at so remote periods.

We are reduced then to the necessity of admitting the possibility, in very rare instances, of superfœtation; but at the same time we may remark that the evidence regarding it is not sufficiently precise, and we are left entirely at a loss to explain what causes may give rise to this variation, and in what manner the seminal fluid may be supposed to pass through the uterus, or the new ovum to gain an entrance there.

§ 2. *Influence exerted by parents on the qualities of their offspring in generation.*— One of the most obvious and important laws of the reproductive function is that by which the specific distinction of animals is preserved. Like produces like; and for the most part an undeviating succession of generations of similar structure and qualities prevents both the extinction of any species and its being blended with or lost in any other. Numerous examples will recur to the mind of every one, of striking family resemblance, which point out in how many respects children frequently inherit their qualities from their parents; but it must be held in remembrance that family or hereditary resemblance is seldom if ever complete, but only of that more general kind which belongs to the species. Thus in one family we recognise numerous minute differences, and in fact it may be said that there are scarcely any two individuals of the same or of different family exactly alike. In respect to sex, the most obvious difference exists: the mother producing male and female; the son is not an exact copy of his father, nor the daughter of her mother, nor are they a mixture of both; but each of them bears certain resemblances to one or other or to both of the parents, into which it may be interesting to inquire,—an investigation which is to be regarded of some practical importance in reference to the breeding of cattle and other stock.

As the female parent furnishes the greater part of the substance of the egg in all animals, and in viviparous animals provides also the materials which serve for the nourishment of the young with which it is intimately connected during utero-gestation, it might, *a priori*, have been supposed that the offspring should be more subject to be influenced by the qualities of the mother than by those of the father; but no general fact of this kind is established, and instances need not here be adduced which shew that the offspring, whether male or female, bears nearly, if not quite, as many points of resemblance to the father as to the mother.

Such influence as the male parent exerts upon the qualities of the offspring must be transmitted and take effect at the period of conception only, and the impression being that of the contact of the seminal fluid with the ovum must be momentary only. A certain part of the female parent's influence is dependent on the original constitution of the ovum formed in her body, while another part of that influence may be supposed to extend through the whole period of utero-gestation.

We shall first consider those instances of the transmission of hereditary qualities which appear to belong to the original constitution of the male and female generative products, and subsequently make some remarks on the influence which the female has been held to exert during the whole of pregnancy.

The general structure of the body, the stature, form, size of the bones, disposition to the formation of muscle, deposition of fat, or the reverse, seem to depend as frequently on the female as on the male parent in the human species. In some animals the male parent more frequently determines the size and general form of the body, as among feline animals, dogs, horses, &c. The bantam cock is said to cause the common hen to lay a small egg, and the common cock causes the bantam hen to lay a larger egg than usual.

An enumeration of all the points of structure which constitute family resemblance would detain us too long, and is unnecessary as they are familiar to every one. It does not appear to be satisfactorily established that the family resemblance is derived more from one than from the other parent, though in one family the influence of the one parent, and in another

* Dict. des Scien. Méd. tom. liii. p. 418.

‡ Ibid. tom. iv. p. 181.

† Stark's Archiv fur die Geburtshülfe, &c. B. iv. S. 589.

§ Traité d'Accouchements, tom. i. p. 345, where cases are referred to by Pignot in the Bull. de la Facult. 4e Année, p. 123, by Wendt, Journal des Progrès, tom. x. and Fahrenhorst, ibid. tom. viii. p. 161.

family the influence of the other parent, may predominate.*

Nor does it appear that any general law has been established regarding the transmission of the nature of the constitution, temperament, state of health, duration of life, &c.; for in the human species at least these qualities of the offspring seem to be inherited from either parent or from both indiscriminately.

The complexion and colour of the offspring has received much attention. In some animals the colour of both parents is sometimes preserved, as in the piebald horse; in others a mixture of the colours of the father and mother appears in the offspring as an intermediate tint. In other animals, and most frequently in the human species, the colour descends from one only of the parents. Thus among white races of the human species, it happens more frequently, when the parents are of different complexion, that the child takes after one or other of them than that its complexion is intermediate between those of the parents; but it does not appear as yet to be ascertained that one parent determines the colour more frequently than the other. The offspring from the union of people of dark and white races of the human species usually has a complexion which is a mixture of or is intermediate between the complexions of the two parents, as in the Mulatto and other degrees of colouring; but it is alleged that in these instances the colour of the father usually predominates over that of the mother. Thus a dark father produces with a white mother a darker child than a white father with a dark mother. Among animals there are infinite varieties in this respect. White colour is said to be more readily transmitted than others. In some animals, however, colour is transmitted with great regularity: thus it has been found that as many as two hundred and five of the product of two hundred and sixteen pairs of horses of similar colour inherited the colours of their parents.

The degree of fruitfulness in bearing offspring, or the opposite, sterility, the qualities of the voice, peculiarities in the degree of delicacy of the external senses, as long or short-sightedness, musical ear, &c., the physical powers of the body as illustrated in the speed or strength of horses, and peculiarities of the digestive functions of the nature of idiosyncrasies, are other familiar examples of bodily qualities usually transmitted in hereditary descent from one or other parent to the offspring.

Lastly, the qualities of the mind are, perhaps as much as the bodily configuration and powers, subject to influence from the hereditary influence of parents upon their offspring. The powers of observation, memory, judgment, imagination, the fancy, and all that belongs to what is usually called genius, the emotions, passions, desires, and appetites, as inborn mental qualities of the offspring, are all liable to be influenced in the act of generation by the parents.*

The hereditary predisposition of man and animals to particular diseases also illustrates in a striking manner the general law now under consideration, and from its importance in reference to life assurance has attracted considerable attention.

Almost all the forms of mental derangement are more or less directly hereditary, one of the parents or some near relation being affected. Of bodily diseases, pulmonary complaints, diseases of the heart, scrofula, rickets, worms, gout, rheumatism, hemorrhoids, hypochondriasis, scirrhus, apoplexy, cataract, amaurosis, hernia, urinary calculi, may be mentioned as examples of diseases more or less directly transmitted as predispositions from parent to offspring. The goitral and cretinous affections combined with deficient intellect are striking examples of the effect of hereditary influence combined with that of the situation in which the cretins live. The union of goitrous persons in particular districts leads to the production of cretins, while the union of a cretin with a healthy person tends to the improvement of the offspring, or its gradual return to the healthy state.

The predisposition to disease may be transmitted to the offspring from either parent, and from the one as often as from the other, but much more certainly when both the parents have been affected with the disease.

We may also mention, in connection with this subject, the transmission to the offspring of various marks and deformities in the structure of the parents or their relations. The cretinism already mentioned is one of these, and there are numerous other cerebral deformities which are so transmitted, as congenital malformations, such as the acephalous and anencephalous states, spina bifida, cyclopia, &c. which run remarkably in particular families. In many instances the hereditary cause of these deformities has been distinctly traced to one or other of the parents. Nævus, moles, growths of hair in unusual places, hare-lip, deficient or supernumerary toes or fingers, have all been traced to hereditary influence, and probably as often to the one parent or his family as to the other. Malformations of the heart, congenital hernia, and indeed most other malformations, are capable of being traced to a similar origin.

Were further illustration of this general law requisite, it would be found in the resemblance of mules or hybrids produced by the union of two distinct races, varieties, or species of animals, which productions also afford an excellent opportunity of observing

* Dr. Walker, in a short essay lately printed for private distribution, has attempted to shew that the upper and back part of the head usually resembles the mother, the face from the eyes downwards most frequently the father.

* In endeavouring to estimate the degree of original resemblance of offspring to parent mentally as well as bodily, but especially the former, great caution is necessary not to overlook that resemblance between them which depends on education, similar habits, pursuits, mode of life, and continual intercourse.

and comparing the amount of hereditary influence exerted by one or other of the parents. The hybrid usually combines to a certain extent the qualities of its father and mother, as in the familiar example of the common mule between the male ass and the mare, or in the product of the tiger and the lion, the dog and wolf, the pheasant and black grouse, the gold and common pheasant, and others. In some mules the qualities of the father predominate, in others those of the mother; but so far as we are aware, the isolated facts regarding this point have not yet been brought under any general law.

It has been asserted that acquired qualities, whether mental or bodily, of the parents are capable of being transmitted to their offspring. Thus the superiority of a civilized over a barbarous nation is said to depend, not solely on the influence of an advanced state of education upon each new comer, but also on the greater natural powers of the children, derived from their parents at the moment of their production, or, in other words, the greater capability of the children to receive the higher mental acquirements and more refined ideas belonging to the civilized condition of society.

Farther, it is asserted that dogs and cats which have accidentally lost their tails have brought forth young ones with a similar deformity. Blumenbach affirms that a man who had lost his little finger had children with the same defect. A wound of the iris and a deformity of the finger occasioned by whitlow are said to have been transmitted. The well-trained pointer of this country produces a puppy much more capable of being trained than the dogs of the original breed. The retriever spaniel and the shepherd's colly are said to do the same. Well-broken horses produce docile foals, and lastly, the young of foxes living in hunting countries are naturally much more circumspect than those living in countries where they are not exposed to the danger of pursuit.

We look upon all these alleged facts with distrust. Many of them are coincidences; others, we suspect, are false. It is obviously insufficient for our purpose to ascertain the qualities of the one generation which is born. We must also know to what circumstances the parent may have owed its peculiarity. We feel convinced that education more than any other circumstance has influenced the superior powers of the animals above alluded to, and there is no proof that the parent did not possess the same capabilities or natural powers as the offspring.

There are, on the other hand, innumerable instances which shew that acquired alterations of structure are not transmitted. How many men are there who have lost limbs and yet have produced children in no respect maimed. A quadruped without the fore-legs has borne entire young. A bitch in which the spleen had been extirpated had young possessing that organ. Men with only one testicle have sons with the usual number; and lastly, the people of nations, the males of which have been circumcised during hundreds of years, have children with foreskins not a bit shorter than those of nations in which no such practice exists.

The breeding of domestic animals of different kinds, suited respectively to the various useful purposes for which they are employed, is a subject connected with the present question of high practical importance; but unfortunately, though some practical men have well understood the proper method to be pursued, it is to be regretted that the facts have never been reduced to general rules, and that the theory has been almost entirely neglected.

It is generally admitted as a fact proven that in the ox, horse, and other domestic animals the purer or less mixed the breed is, there is the greater probability of its transmitting to the offspring the qualities which it possesses, whether these be good or bad. Economical purposes have made the male in general the most important, simply because he serves for a considerable number of females. The consequence of this has been that more attention has been paid to the blood or purity of race of the stallion, bull, ram, and boar than to that of their females; and hence it may be the case that these males more frequently transmit their qualities to the offspring than do the inferior females with which they are often made to breed. But this circumstance can scarcely be adduced as a proof that the male, cæteris paribus, influences the offspring more than the female.

Bad as well as good qualities may be transmitted, and, therefore, it is obvious that in endeavouring to improve any stock by engrafting a good quality, the breeder must choose a male which, besides the requisite good quality, is free from those defects of the female which it is desirable to sink. He must also select a male in the family of which the desired quality has been long resident. He cannot engraft the quality all at once, but must endeavour to introduce it by frequent crossing.

In the horse, for example, the strength of bone and weight of muscle suitable for slow draught, the light frame and prodigious swiftness of the race-horse, and the intermediate or rather combined qualities of the carriage-horse, hack, or hunter, are all capable of being produced by proper attention to purity or mixture of breeds. The pace, speed, action, temper, courage, colour or quality of hair, and almost all other qualities may be increased, diminished, or altered by a judicious admixture of different races. So also the immense weight of beef and fat of the large ox, the flavour of the flesh, the abundance or richness of the milk of the cow, are subject to modification in every different breeding.

The economical breeder, then, while he has settled in his mind the object which he wishes to accomplish in any of his stocks, must hold in recollection that it is only by the combination and continued succession of good qualities that he can ensure a permanent improvement. He must not expect to be able to effect this by crossing the breed of an impure blooded or worn-out female with a male of superior qualities. Bad qualities may become as fixed as good ones, and a judicious selection of the good ones (as adapted for his purpose) ought to be his first and principal object.*

A belief exists with some, founded, it is said, both on common observation and scientific research, that frequent breeding in the same family, or what is commonly called breeding in and in, has the effect of deteriorating a race. There appears, however, much reason to believe that the opinion just now stated is founded in error. In a state of nature it not unfrequently happens, among those animals especially which do not pair, that the strongest males take precedence of the weaker, and naturally select the finest females (as occurs in the deer); but in a state of domesticity this cannot always be the case, and inferior animals coming together give rise to inferior offspring; but, if in the farm-yard sufficient care be taken in the selection of the breeding males and females, it does not appear that near relationship has any effect in deteriorating the race, nor in impeding the transmission of good qualities which may be found in males and females of the same family.

The belief now alluded to has been held in relation to the human species also, and it is affirmed that both the bodily and mental qualities of the offspring suffer gradual and progressive injury from the continued mixture of successive generations of the same family or a small number of families. Hence we find that the marriage of cousins-german, which is according to law in this country, is reprobated as prejudicial by some; and various royal families and aristocratic families are referred to as examples of the bad effect of the restriction of conjugal union to a narrow circle.

It must be remembered, however, that the mutual selection of the parents is not quite the same in the human species as among the lower animals; and in the examples just referred to we feel even inclined to doubt whether, when due allowance is made for the nature of their education, it will be found that kings or princes have become worse or less talented in modern than in ancient times, or whether among that class there is, on an average, a greater proportion of stupid men than in other ranks of society.

The regularity of feature and beauty of the Persian race has been greatly improved by their choice of the most beautiful Circassian and Georgian wives; and there are many examples of particular families in this country in which regular and handsome features and a well-knit and fully developed form of body are hereditary. We shall not pursue the attempt, however, which some have made to apply the principles of cattle-breeding to the human species; for however desirable and necessary an improvement of the breed may appear to some Utopian philanthropists, we fear that the mind, with all its peculiar tastes, prejudices, and passions, has too much to do with the greater number of matrimonial alliances to allow physiological considerations much jurisdiction.

From the different facts now touched upon, it is obvious that the original type of the parents modifies that of their offspring; while, in general, varieties accidentally acquired do not pass in hereditary descent, unless they are of such a nature as to constitute a permanently distinct race or variety.

In the mixture of different races of the human species and of distinct species of animals we recognise a constant tendency in succeeding generations to return to the original type or pure breed; an effect which seems to proceed naturally from the general law already announced, that the purer the breed of either of the parents, or in other words, the more nearly it approaches the original type or unmixed race, the more readily will its qualities descend to the offspring. When the mixed offspring of the black and white races of men unites with either the black or the white, the offspring in successive generations becomes more and more nearly allied to the pure breed with which the cross is made, and at last wholly identified with it. We must look upon this general law of the tendency of all mixed varieties to return to the original type, together with the circumstance that hybrids rarely breed as means adopted by nature for the preservation of distinct species.

The transmission of hereditary resemblance, either as regards the general structure of the body or peculiarities, is not, however, invariable, nor always immediate from parents to offspring. Thus parents with certain deformities may produce all their children naturally formed and healthy; or some of them only (in one case the males, in a second the females, in a third some of both sexes) may inherit the abnormal peculiarity, while the rest of the children are healthy. But these healthy children, from some disposition of their constitution, may transmit to their descendants either in the first or in a subsequent generation the defect which existed in their parents. The varieties in this respect in the human species are almost infinite. Thus, in one family all the children resemble one parent in a striking manner; in another the male children take after the father chiefly, the females after the mother; and in a third the converse holds, the peculiarities of the father descending principally to daughters, those of the mother to sons,—an arrangement of family resemblance which is the most commonly prevalent according to M. Girou, who endeavours to shew that family resemblance frequently passes in an alternating manner from grandparent to grandchild. Thus, the grandchild resembles the grandparent of the same sex, so that a boy whose father is like his (the father's) mother resembles most the grandfather, as in the following plan.

1st Generation.	*Grandf.*	*Grandm.*	*Grandf.*	*Grandm.*
2d ditto	|	Father	Mother	|
3d ditto	Son	Daughter	Son	Daugh.

If it should be proved that a first or earlier

* We refer the reader to the Farmer's Series of the Library of Useful Knowledge. Vols. Horse and Cattle.

impregnation influences the product of a subsequent one, in breeding any particular stock of animals, it would appear of importance that the female should always breed with well qualified males; and farther, that the genealogy of both parents for one step, if not more, backwards, ought to enter as an item into the calculation of the probable qualifications of the offspring.

Much information is, however, still wanting on this subject, which, as it involves the most obscure parts of the generative process, we can hardly expect ever to be able to fathom. It cannot but be a matter of wonder and extreme interest to inquire how, in the unformed germinal spot of the egg of the female at the moment when it receives the vital fecundating influence of the male semen, the disposition to the formation of those minute modifications of structure and function which constitute hereditary resemblances is capable of being retained and transmitted to the future offspring.

The celebrated Darwin and some other fanciful speculators on physiological subjects held an opinion* that the transitory state of the minds of the father or mother at the instant of conception has a marked influence on the mental and physical qualities of the offspring. Thus it has been alleged that children begotten after debauchery or drunkenness are liable to idiocy or weakness both of mind and body; that when the amorous propensities are *too* much excited, the offspring runs the risk of erring in the same way; and in short, that according to the predominance of one or other sentiment, propensity, or frame of mind, the offspring may be a genius or a dolt, a sentimental swain or an unfeeling brute, a thief, a robber, a murderer, &c. Leaving to others the proof or disproof of the alleged facts upon which the above-mentioned belief is founded, we would take the liberty of expressing our doubts as to whether at the particular time alluded to by these theorists any idea but one is usually predominant. Nor shall we here dwell upon the obvious local treatment which is applicable upon the phrenological view of the subject; but as few may be aware of the real importance of that critical period in which life is conferred upon a new being, we have thought it right to put our married readers at least upon their guard against unrestrained yielding to any of the baser feelings or ideas, which do creep into the best-regulated establishments, requesting at the same time that they will communicate to their partners such information as may be considered necessary for the attainment of the grand object in view, viz. the improvement of the population of this kingdom.

The belief now stated as regards the human species has also been applied to animals, and that either parent may thus influence the offspring. Thus it is asserted that the male race-horse when excited by running, if not fatigued, is in the best condition for communicating speed to his offspring. Again, it is related that at the time when a stallion was about to cover a mare, the stallion's pale colour was objected to, whereupon the groom, knowing in the effect of colour upon horses' imaginations, presented before the stallion a mare of a pleasing colour, which had the desired effect of determining a dark colour in the offspring. This is said to have been repeated with success in the same horse more than once. As a similar case, the influence acting through the mother, it is related that a cow belonging to a farmer of Angus, in Scotland, had been grazing in company with an horned ox of a black and white colour for some time before it came into heat. The bull which impregnated the cow had no horns, and differed totally from the ox in colour, as did also the cow itself; and yet, wonderful to ralate, the next calf was black and white, and had horns.

These stories lead us to the consideration of a host of extraordinary relations, from which the general conclusion has been drawn, by no very logical process of induction, that the imagination of the female parent is capable of exerting a powerful influence on the structure and qualities of the offspring either at the moment of conception or during part of the period of utero-gestation.

The effects of the mother's imagination upon the child are so various that we cannot hope to be able to reduce them to any general or complete enumeration. Those which have attracted the greatest share of attention are of the nature of blemishes, spots, wounds, deficient and redundant parts, in short, all unnatural or so-called monstrous formations of the child. The alleged causes of these unnatural formations include all those circumstances which powerfully excite the moral faculties, the fancy, desires, or passions of the mother; sudden surprise, fear, anger, horror or disgust on her being a witness of any unusual or frightful event or object, or the opposite passions of joy, pleasure, admiration, &c. as well as strong longings, desires, and appetites, whether satisfied or not. The influence of the mother's imagination upon the child is not confined in its effects to bodily disfiguration or change, however, for those who carry their belief its whole length hold that the mind of the child may also be similarly modified. Thus it is stated that the ambition, courage, and military skill of Napoleon Bonaparte had their foundation in the circumstance that the emperor's mother followed her husband in his campaigns, and was subjected to all the dangers of a military life; while, on the other hand, the murder of David Rizzio in the presence of Queen Mary was the death-blow to the personal courage of King James, and occasioned that strong dislike of edged weapons for which that crafty and pedantic monarch was said to be remarkable.

We can readily believe that all sudden or violent changes in the functions of the mother, derangements of the general circulation, nervous affections, and other circumstances which tend to disturb the uterine function, must cause or be liable to occasion injury to

* More recently adopted by Mr. Combe, of Edinburgh, in his Work on the Constitution of Man.

the fœtus or its coverings during pregnancy. So also we can understand that any violent affection of the mind of a pregnant woman, in so far as it tends to derange the bodily functions, may produce some effect on the nutrition of the child.

Some contagious diseases pass from the mother to the child in utero. Syphilis and small-pox may be mentioned as those the effects of which have been most frequently observed.* Typhous fever, on the other hand, is said rarely to affect the child. We know also that severe affections of the mother may cause the death of the child, and its premature expulsion or abortion. According to Hausmann, the effect of variations of the external atmosphere is visible in the unusual number of blind colts and hydrocephalic pigs which are born after a wet summer. Malformations of the fœtus of birds have been artificially produced by external injuries and altered position of the eggs during incubation.† The transmission to the child of the effects of chemical poisons taken by the mother has also been observed; but in all the foregoing the effect of the injury has been more or less general; and there is no sufficient reason to conclude from them that a particular impression on the mind of the mother is capable of producing physical injury, or a particular deformity in one or other of the organs of the fœtus.

A vague notion is entertained by some that a certain influence is exerted by the hen or other bird on the eggs that they incubate, by which the qualities of the progeny are modified. But we must observe that hereditary resemblances are preserved in artificial incubation without the hen; and although we are disposed to admit that the female bird incubates its eggs with an instinctive care and perfection that art can rarely imitate, we are exceedingly sceptical as to the possibility of any other secret influence from the oviparous mother to its offspring once the eggs have left the body; and the attempt to support the theory of imagination by this opinion is an explanation of the obscurum per obscurius.

Were it possible to separate the better authenticated from the more fanciful relations of the effects of the mother's imagination, or to select those instances only in which the impression on the mind of the mother had been carefully noted before the birth of the child, we might expect in some degree to be able to free this question from the falsity and prejudice which obscures it. But such a separation we believe to be impossible, and we have therefore resolved to enumerate shortly some of the more remarkable cases taken at random,‡ from which we think the reader will best be able to judge what value or faith is to be attached to the facts now under consideration.

In a certain number of these cases we are told that an injury of an organ in the mother causes a similar injury in a corresponding part of the child's body; as in the following examples.

1. A cow killed by the blow of a hatchet is found pregnant of a fœtus with a bruise on the same place of the forehead.

2. The same was the case with the young one of a hind that had been shot.

3. A pregnant cat which had had its tail trodden on bore five young, in four of which the tail was similarly wounded.

4. A woman bitten on the pudenda by a dog bore a boy having a wound of the glans penis. This boy suffered from epilepsy, and when the fits came on during sleep was frequently heard to call aloud, "the dog bites me!" There are other similar cases on record.

5. A pregnant woman walking with a friend has her head knocked violently against her friend's, and shortly afterwards bears twins, which are joined together by the foreheads.

6. A gentlewoman who was cut for rupture in the groin during her pregnancy, bears a boy having a large scar in the same region, which he bore for thirty years afterwards.

The injuries of others operating on the imagination of the mother may affect the structure of the child: thus—

7. A woman who was suddenly alarmed by seeing her husband come home with one side of his face swollen and distorted by a blow, bears a child (a girl) with a purple swelling covering the forehead, nose, &c. of the same side.

8. A child is born with hare-lip, which was caused by the mother's frequently seeing a child with the same deformity during her pregnancy.

9. A mother seeing a criminal broke upon the wheel, bears an idiot child, of which the bones are similarly broken.

10. A woman seeing a person in an epileptic fit brings forth a child which is subject to epilepsy.

11. A lady in London, who is frightened by a beggar presenting the stump of an arm to her, bears a child wanting a hand.

12. A child is born with its head pierced, in consequence of its mother having seen a man run through the body with a sword.

13. A woman is forced to be present at the opening of a calf by the butcher. She afterwards bears a child with all the bowels hanging out of the abdomen. This woman was at the time of the accident aware that something was going wrong in the womb.

14. A similar misfortune happened to the child of another woman, who was imprudent enough to witness the disembowelling of a pig during her pregnancy.

* In reference to this, it is an interesting circumstance that the child is affected with small-pox some time after the mother, as if the contagion had taken the same time to operate as it does in passing between two persons.

† As in Geoffory St. Hilaire's experiments, which the author has more than once repeated with a similar result.

‡ From Burdach's Physiologie, B. ii. and from a talented Refutation of the Doctrine of the Imaginationists, by Dr. Blundell, of London. Professor Burdach, we may remark, is inclined to adopt the belief.

The mere description of an event may affect the child, as in the following curious case.

15. A woman who had listened with considerable interest to a description of the operation of circumcision bears a child with the foreskin split up and turned back!

16. A woman who sees another affected with prolapsus uteri bears a child affected with the same disease.

The examples of the effect of sudden fright, disgust, anger, joy, &c. are very numerous.

17. A lady absent from home is alarmed by seeing a great fire in the direction of and near her own house; and some months afterwards bears a female child having the distinct mark of a flame on her forehead.

18. A pregnant woman frighted by her husband pursuing her with a drawn sword, bears a child with a large wound in the forehead.

19. A man who had personated a devil (or satyr according to other authorities) goes to bed in his assumed dress, and his wife, being then pregnant, afterwards bears a child having horns, cloven feet, &c.

20. A mother frighted by the firing of a gun has a child wounded as by a gun-shot.

21. A pregnant woman falls into a violent passion at not being able to obtain a particular piece of meat at a butcher's shop; she bleeds at the nose, and wiping the blood from her lip, afterwards bears a child wanting the lip.

22. A woman two months before being brought to bed is alarmed by hearing a report that a neighbour had murdered his wife by a wound on the breast, and bears a child with a similar wound.

23. A child is born with the hair of one side black, that of the other white; competent judges declared at the time that both sides would have been white, but for the circumstance that the mother had carried a heavy sack of coals during her pregnancy.

24. A woman frighted by the sudden appearance of a negro brings forth a child with various black marks.

25. A mother is suddenly frighted by a lizard jumping into her breast, and afterwards gives birth to a child having a fleshy excrescence exactly like a lizard growing from the breast, to which it adhered by the head or neck.

26. A child has a face exactly like a frog's, from the mother having held a frog in her hand about the time of conception.

27. The remarkable resemblance of a woman to an ape was fully accounted for by her mother having been much pleased with one of these animals when with child of her.

The effect of the attentive contemplation of pictures, statues, &c. by pregnant women is worthy of notice.

28. A child is horn covered with hairs in consequence of the mother having been in the habit of beholding a picture of St. John the Baptist.

29. A woman gives birth to a child covered with hair and having the claws of a bear, from her constantly beholding the images and pictures of bears hung up every where in the dwelling of the Ursini family, to which she belonged. It is not stated by the Author of Waverley, whether any thing of the kind ever happened in the Bradwardine family.

30. A woman contemplating, *too* earnestly as it appears, a picture of St. Pius, has afterwards a child bearing a striking resemblance to an old man.

31. The tyrant Dionysius was aware of the effect of pictures; for he hung a beautiful picture in his wife's chamber, in order to improve his children's looks.

32. Two girls (twins) were born with their bodies joined together, their mother having during her pregnancy been in the habit of attentively contemplating two sacred images similarly placed.

33. A child is born with its skin all mottled in colour from the mother having made a visit to St. Winifred's Well, and seeing the red pebbles there.

34. Another child was marked on the face, in consequence of the mother having worn black patches.

The longings and depraved appetites to which pregnant women are liable are occasionally the causes of marks and deformities in their children.

35. There are a great many instances in which the longing of the mother after strawberries, grapes, cherries, peaches, and other fruits has caused the growth of tumours in the children exactly resembling in each the fruit that was wished for,

36. A woman who had *longed* for a lobster brings forth a child much resembling one of these animals.

37. Another woman had a female child, the head of which was like a shell-fish (a bivalve, which opened and shut as a mouth), which proceeded from the mother's having had a strong desire for mussels at one time of her pregnancy.

38. A pregnant woman *longs*, or has a great desire to bite the shoulder of a baker who happens to pass. The husband, wishing to humour this extraordinary fancy, hires the baker to submit to be bitten. The mother makes two bites, but of such a kind that the baker will not submit to more; and some time afterwards she is brought to bed of three children, one dead and two living.

39. A case of spina bifida near the sacrum is explained by the mother's having wished for fritters, and not obtaining them, having applied her hand (we know not with what object) to a corresponding place in her own body.

The impression on the fancy of the mother may be made before conception has taken place: thus—

40 A woman, whose children had previously been healthy, six weeks before conception is suddenly frighted by a beggar who presents a stumped arm and a wooden leg, and threatens to embrace her: the next child had only one stump leg and two stump arms.

The impression on the fancy may extend to the product of several successive conceptions.

41. A young woman frighted in her first

pregnancy by the sight of a child with hare-lip, bears a child with a complete deformity of the same kind: her second child had merely a deep slit, and her third no more than a mark in the same place.

We do not wish to argue against this hypothesis from its prima facie absurdity merely; but we think it will be generally admitted that the greater number of the foregoing cases are ridiculous and incredible; inasmuch as simple malformations of structure well known to anatomists have been regarded as the representations of animals and other objects to which they bear a very distant if any resemblance,—cases, in short, in which it is apparent that the imagination of the bye-standers has been more active than that of the mother.

We shall at once admit that we ought not to reject immediately an explanation of the mechanism of a vital function on account of its obscurity merely; but we assert that the general phenomena of the vital functions are capable of being observed and reduced to fixed and general laws, which is certainly by no means the case with the effects of imagination, which are as various and contradictory as they are absurd and ridiculous. The anatomical connection of the maternal uterus and child is so well known that we may with safety affirm that no such communication exists as would be necessary for the transmission of an impression from the body of the mother to any particular organ of the fœtus, and much less any means of conveying mental impressions only. The longings which are said to be so liable to cause injuries of the child seem to act in the same manner whether the appetite is satisfied or not, &c.

But moral reasons are much stronger against the belief. It is obvious that in much the larger proportion of the cases related, the coincidence of the mental impression on the mother with the injury done to the child is a post-partum observation and discovery. The mother and her friends, or the father, if such a deformity shall belong to his side of the house, are desirous of finding an explanation of the blemish which shall not be a stigma upon them; and in other instances it is to be feared that the idle and talkative women who attend upon child-beds, and even more scientific male accoucheurs, have encouraged the mother's belief in the effect of some alleged previous impression (selected from thousands) on her imagination, in order to hide undue violence employed during the delivery, or perhaps with a less culpable desire to quiet the fears of the mother while in the dangerous puerperal state.

There is no doubt that there are innumerable instances in which the imagination and all the moral and intellectual powers of women have been highly excited during pregnancy without their children having suffered in any respects; and there are not wanting instances of children being born with all kinds of deformity that have been attributed to the effect of imagination, without their being aware of any unusual impression having been made on their minds.

Again, it may be remarked that the stage of the period of pregnancy at which the injury of the child may take place is by no means defined, and that there is no correspondence between the time or advancement of the fœtus and the nature of the injury. Some injuries are said to have occurred or to have had their foundation laid at the very moment of conception, and even occasionally before that time, while others are inflicted only a few weeks before birth.

The monstrous appearances or malformations which constitute by far the greater part of the injuries attributed to the mother's imagination, are now no longer regarded as lusus naturæ merely, or "sports of nature's fancy," as they used to be called; but the times at which many of them must have occurred are known with some degree of certainty, and these times by no means correspond with the periods at which the imagination is said to have been affected. Besides this, nearly the whole of congenital malformations have been accurately anatomised, and their structure is reduced to general laws as regular and determinate in each individual form as the more usual or so-called natural structure. See Monstrosity.

In this question, as in others of a like kind, reference has been made to scriptural authority, in the history, viz. of Jacob's placing the peeled black and willow rods before the ewes which went to drink and afterwards conceived. But any one who pays the slightest attention to the whole of this relation will at once be convinced that the sacred writer, in describing the proceeding of Jacob, exhibits merely that patriarch's belief in the efficacy of such means; for in a subsequent part of the chapter Jacob is undeceived by the angel, who appears to him in a dream and informs him of the real cause of the multiplication of the speckled lambs, &c. viz. the circumstance that the ring-straked, speckled, and spotted males had leaped upon the females, and that the progeny therefore merely inherited their colour from their fathers.

We now leave this unsatisfactory subject, upon which we have perhaps dwelt longer than it deserves. We have introduced the foregoing remarks partly in accordance with custom, and also with a view to shew how little connection exists between the facts of our subject and the vague fancies to which allusion has been made. In doing so we are aware that we are liable to the accusation, on the one hand, of having treated with too much levity facts and observations upon which some are disposed implicitly to rely, and, on the other, of trifling with science in noticing even such vain fancies as belong to pregnant women and their attendant nurses.

We conclude by adopting and expressing the opinion of Dr. Blundell, "that it is contrary to experience, reason, and anatomy to believe that the strong attention of the mother's mind to a determinate object or event can cause a determinate or a specific impression upon the body of her child without any force or violence from without; and that it is equally improbable that, when the imagination is operating, the application of the mother's hand to any part of her own body will cause a disfiguration or specific impression on a corresponding part of the body of the child."

§ 3. *Number of children; and relative proportion of the male and female sexes.*

The simpler animals are, generally speaking, more fruitful than the complicated ones. As examples of great fecundity, may be mentioned some of the Entozoa and Mollusca, which produce hundreds of thousands of ova; among Crustacea and Insects some produce many thousand young. The Perch and Cyprinus genus among fishes produce some hundreds of thousands, and the common Cod, it is said, some millions of ova. Most of the Batrachia produce at least some hundreds. But in the warm-blooded Vertebrata, the necessity of incubation or utero-gestation puts a limit to the number of young; and there are also comparatively few in the Blenny, Skate, Shark, Land Salamander, or such animals as are ovo-viviparous.

In the human female, the number of children altogether produced is limited, first, by the number of Graafian vesicles in the ovaries, which usually amounts to from twelve to fifteen in each ovary; and second, by the length of the time during which a woman bears children, (the greatest extent of which is usually twenty-five years, that is, from the age of fifteen to forty, or twenty to forty-five,) the length of this period again depending upon the rapidity with which the births succeed one another, and the number of children produced at each.

Women most frequently bear every twenty months, but some have children at shorter intervals, as of fifteen or even twelve months. This often depends upon the circumstance that in some lactation prevents conception; in others it does not.

The number of the eggs of birds for one incubation varies from two to sixteen. The number of the young of Mammalia produced in one utero-gestation varies from one to fifteen, and occasionally more.

Woman usually bears a single child. The proportion of twin-births to those of single children is estimated by Burdach as one to seventy or eighty: the proportion of triplet births one to six or seven thousand; quadruplets, one to twenty or fifty thousand. Occasionally five children come at one birth, and there are instances on record of six or even seven children being born at once.

The causes of this greater or less fecundity are not known: they are in all probability various; being not of an accidental nature, but connected with the constitution of one or other of the parents, most frequently perhaps of the mother.

A healthy woman bearing during the whole time, and with the common duration of interval, may have in all from twelve to sixteen children; but some have as many as eighteen or twenty; and when there are twins, &c. considerably more, as in the following remarkable instances. First, eighteen children at six births. Second, forty-four children in all, thirty in the first marriage, and fourteen in the second; and in a still more extraordinary case, fifty-three children in all in one marriage, eighteen times single births, five times twins, four times triplets, once six, and once seven.*

Men have been known to beget seventy or eighty children in two or more marriages, but the tendency of polygamy is generally believed to be to diminish rather than to increase the number of the whole progeny.

According to Marc, not more than two or three children are born from two thousand prostitutes in the course of a year,—a circumstance depending in part on their want of liability to conception, and in part on frequent abortion.

The proportion of children born in each marriage varies much in different countries. The following statement of the average number is taken from Burdach: Germany, 6—8; England, 5—7; France, 4—5; Spain and Italy, 2—3.†

In reference to the average proportion of male and female births, it appears from very extensive data that in this and most other countries the number of males usually exceeds that of females; in this country in the proportion of four or five in a hundred.

The circumstances which influence the preponderance of male births are not known. The accompanying table shews how very constant it is in different countries.

Table of the proportional number of males and females born in different countries; the females being taken as 100.

Great Britain	104.75
France	106.55 103.38
Prussia	106.94 105.90
Sweden	104.72
Wurtemburg	105.69
Westphalia and Rhine	105.86
Bohemia	105.38
Netherlands	106.44
Saxony and Silesia	106.05
Austria	106.10
Sicily	106.18
Brandenburg	106.27
Mecklenburg	107 07
Mailand	107.61
Russia	108.91
Jews in Prussia	112.
—— in Breslau	114.
—— in Leghorn	120.
Christians in Leghorn	104.

It has been found, on the other hand, that the first children of a marriage consist of a greater number of females and fewer males, in the proportion, according to Burdach, of fifty-three male births to a hundred females. A similar preponderance of females is said to exist among illegitimate children; but the difference is

* See Fournier, Dict. des Scien. Méd. tom iv.

† According to Burdach, one marriage out of fifty is unfruitful; there is one birth on an average for every twenty-five of the population of a place; and taking the whole population of the world at six hundred and thirty-three millions, about fifty-one children are born every second!

much less, not amounting to more than four or six in one hundred.*

Malformations are said to occur more frequently among illegitimate than legitimate children; and malformed children are more frequently of the female sex. This, together with the circumstance that illegitimate children are oftenest first born, may in some degree account for the greater number of females among them.

The data upon which it has been attempted to found an explanation of the cause of the formation of a male or female offspring are very slender indeed; nor are we likely ever to obtain knowledge which shall enable us to form a satisfactory theory regarding the cause of the determination of the sex. Some men beget always male children, others always females, in more than one marriage. The same seems sometimes to depend on the mother. In other marriages children of one sex are born for a time, and subsequently those of the other; or the male and female children may alternate, &c. &c. without our being able to point out any circumstance which has given rise to the production of one or other sex.

Accordingly many vague opinions have been entertained regarding this subject, as for example the following:

1. That the wishes or ideas of the parents at the time of conceptions may influence the sex of the offspring.

2. The nature of the food of the parents, particularly of the mother during pregnancy.

3. The use of various medicines: hence the numerous charms and recipes for begetting children of either sex.

4. The quantity of oxygen absorbed during development.

5. The manner in which the spermatic artery is given off from the aorta, and

6. The older and equally groundless notion that male children come from the right testicle or ovary, and females from the left; upon which hypothesis was founded the celebrated advice of Hippocrates: "Ubi femellam generare volet (pater) coeat, ac dextram testem obliget, quantum id tolerare poterit, sed si marem generare appetat, sinister testis obligandus erit."

A belief has long prevailed that the greater the strength of either of the parents in proportion to the other, the more of its own sex will be generated. M. Girou de Buzaraignes has paid considerable attention to the influence of age, strength, mode of life, &c. of the parents on the sex of the offspring, and has made a series of experiments on the domestic animals, from which, should they be confirmed, some important results may be expected.

According to M. Girou,† male fathers among the domestic animals which are either too old or too young, produce with mature and healthy females more female than male offspring; while female parents that are too old or too young in proportion to the males bear most males. This would appear to be the case in the human species also from the observations of Hofacker at Tubingen, and of Saddler on the English peerage: the children of a husband considerably younger than his wife being nearly in the proportion of ninety sons to a hundred daughters; while those of the husband considerably older than the mother are in the proportion of a hundred and fifty or a hundred and sixty sons to a hundred daughters; the intermediate ages being found to give a proportionate scale.

Burdach states that those women who are most fruitful bear many more boys than girls, as in the following examples:—

	Boys.	Girls.
1st woman bore	26	6
2nd ditto, in first marriage	27	3
in second ditto......	14	0
3rd ditto	38	15

According to Girou, female domestic animals bear more females when well nourished and left in repose than when much worked and on spare diet; and it has been alleged that the sexes of plants are influenced by their nourishment or soil in which they grow; diœcious plants having seeds which propagate more males in dry ground exposed to the sun, more females in moist, well manured, and shady ground; monœcious plants bearing more of the staminiferous or pistilliferous flowers in corresponding circumstances.

The explanation of the cause of this variation of the sex as well as of the original sexual difference, it has already been remarked, is beyond the reach of investigation. Very interesting observations have, however, brought to light the different steps of the process by which the generative organs of either sex are gradually formed during the development of the fœtus; and a series of facts has thus been established of great interest and importance as tending to elucidate the nature of those numerous remarkable malformations of the reproductive organs generally comprehended under the term Hermaphrodism. We refer the reader to the article upon this subject, and to that of OVUM, for a history of the process now alluded to, and shall not do more than merely mention in this place some of the more important results which have been obtained.

1st. It appears that in the earliest stages of fœtal life, the sexes (or what may become afterwards either male or female, that is, all the young) are perfectly alike in structure.

2nd. That there exists in all a common matrix or rudimentary organ or set of organs, which at a later period is converted by development into the male or female organs.

3rd. That the early type of the sexual organs is to be regarded as common and single, rather than double, as some have considered it.

In conclusion, we may remark that we must confess ourselves equally unable to fathom the nature of the original bias or determination given by the parents, in consequence of which a male or a female child is produced, and to ascertain the manner in which any other hereditary influence, quality, or conformation is transmitted from the parent to its offspring. At the same time it appears not improbable

	France.	Prussia.	Hamburg.	
	Boys.	Boys.	Boys.	Girls.
* Illegitimate Children . . .	104·	102·	94·	} 100
Legitimate ditto	106·	106·	105	

† Sur la Génération.

that the nature of the sex may in some degree be modified by circumstances affecting the female at an early period of utero-gestation. In reference to this subject we ought not to omit the mention of a fact which is well established, viz. that when the cow bears two calves, one of which is a male, the other, exteriorly resembling the female, has its reproductive organs internally imperfectly formed, being of that kind of hermaphrodite formation usually called the Free Martin.*

Bibliography.—*Hofmann, G.* De generatione et usu partium, &c. 8vo. Altorf, 1648. *Harvey, Guil.* Excercitationes de generatione animalium, 4to. Lond. 1651. *Malpighi,* De formatione pulli in ovo, 4to. Lond. 1673; *Ej.* De ovo incubato, ib. 1686. *Bartholinus,* De form. et nutrit. fœtus in utero, 4to. Hafn. 1687. *De Grauf,* De virorum organis generationi inservientibus, 8vo. Lugd. Batav. 1668; *Ej.* De mulierum organis, ib. 1672. *Hartmann,* Dubia de generatione viviparorum ex ovo, 4to. Regiom. 1699, in Haller, Diss. Anat. t. v. *Trelincourt,* De conceptione adversaria, 12mo. Lugd. Batav. 1682. *Garden,* A discourse on the modern theory of generation, Phil. Trans. 1691. *Taury,* De la génération et le nour. du fœtus, Paris, 1700. *Nigrisoli,* Consid. intorno alla generazione de viventi, 4to. Ferrara, 1712. *Valisnieri,* Istoria della generaz. dell'uomo, Venet. 1721. *A. Maitre Jean,* Obs. sur la formation du poulet, 2mo. Paris, 1722. *Leuwenhoeck,* in Phil. Trans. for 1693, 1699, 1701, 1711, and 1723; Opera om. 4to. Lugd. Batav. 1722. *Brendel,* De embryone in ovulo ante conceptionem, Gotting. 1740. *D. de Superville,* Some reflexions on generation, Phil. Trans. 1740. *Bianchi,* De naturali, &c. generatione historia, Turin. 1741. *Needham,* A summary, &c. on generation, Phil. Trans. 1748. *Buffon,* Decouverte de la liqueur seminale, &c. Mém. de Paris, 1748. *Haller,* Ad Buffonii de generatione theoriam adnot. in *Ej.* Op. anat. minor. t. iii. *Buffon,* Œuvres de, t. i. and in Mém. de Paris, an 1753. *Parsons,* Philos. observ. on the analogy between the propagation of animals and that of vegetables, Lond. 1752. *Haller,* De quadrupedum utero, conceptu et fœtu, in *Ej.* Op. anat. min. t. ii. *Wolff,* Theoria generationis, Halæ, 1774. *Spallanzani,* Saggio d'osservazioni microscopiche concernenti il systema di generazione de Sig. Needham e Buffon, Modena, 1765. Memorie sopra i muli di varii autori, Modena, 1768. *Sandifort,* De ovo humano, in *Ej.* Obs. pathol. lib. iii. *Senebier,* Expériences pour servir à l'histoire de la génération, &c. de Spallanzani, &c. &c. Genev. 1785. *Blumenbach,* De nisu formativo Comm. Gottiog. vol. viii. p. 41. *Denman,* Collection of engravings, Lond. 1787. *Zroeifel,* Uber die Entwickelungstheorie. ein brief an H. Senebier, Gotting. 1788. *Mohrenheim,* Nova conceptus atque generationis theoria, Königsberg, 1789. *Grasmeyer,* De conceptione et fecundatione, et Supplementa, Gotting. 1789. Speculations on the mode, &c. of impregnation, Edinb. 1789. *Fontana,* Lettera ad un amico sopra il systema degli coilluppi, Firenze, 1792; Transl. into Reil's Archiv. Band. ii. *Haighton,* On the impregnation of animals, Philos. Trans. 1797; Transl. in Reil's Archiv. Bd. 3d. *Ludwig,* De nisu formativo, Lips. 1801. *Vicq d'Azyr,* Anat. et phys. de l'œuf, in Œuvres, t. iv. *Pulley,* On the proximate cause of impregnation, Lond. 1801. *Oken,* Zeugung, Hamb. u. Wurzb. 1805. *Prevost et Dumas,* Nouv. théorie de génération, in Annales des Sciences Naturelles, 1825. The various systems of Physiology, but especially Treviranus, Burdach, vol. i., and Haller's Elementa.

(Allen Thomson.)

* See John Hunter's well known paper on the Free Martin in his Animal Œconomy, new ed. by Owen, 1838.

GLAND,

Gr. ἀδὴν; Lat. *Glandula;* Fr. *Glande;* Germ. *Drüse.*

*An organ whose office is to separate from the blood a peculiar substance, almost invariably fluid; constantly provided with an excretory duct; formed of a process of the mucous membrane or of the skin, disposed either in the form of a sac or of a ramified canal; which sac or canal in all cases is closed by a blind extremity; and which, although amply supplied with blood, is never directly continuous with the bloodvessels.** It is absolutely necessary to give this definite explanation of the meaning which is attached to the word *gland* in the present article, inasmuch as there is no term in anatomy that has been more vaguely, and as it appears to me more incorrectly employed.

It is not necessary to point out the absurdity of applying this word to certain parts of the brain, or to the masses of fat contained in the joints, which were called by the older anatomists glands; in these instances the fallacy is immediately apparent; but there are other errors which, although less striking, are, I conceive, no less injurious in their effects. Thus in the glandular system many continental authorities include not only the liver, kidneys, salivary glands, and other organs, which are universally acknowledged to belong to this class; but likewise the lymphatic glands, the thyroid, the thymus, the spleen, the supra-renal capsules, and the ovaries.† It is con-

* The only real exception to this law is the testicle of fishes, in which no excretory duct seems to exist.

† Bichat, after condemning the application of the term to the thyroid, the pineal gland, the lymphatic glands, &c. states, "we ought only to call those glands, which pour out by one or several ducts, a fluid which these bodies separate from the blood they receive by their vessels." Anat. Gén. tom. ii. p. 598.

Meckel, on the contrary, objects to the opinion that an excretory duct is essential to a gland. According to his definition the glandular system comprises, 1. the mucous glands; 2. the sebaceous glands; 3. the liver, the salivary glands, the pancreas, the lachrymal glands, the tonsils, testes, the ovaries, the prostate, Cowper's glands, the kidneys; 4. the lymphatic glands, the thyroid, the mammary glands, thymus, spleen, supra-renal capsules. Man. d'Anat. tom. i. p. 511.

It is surprising that so admirable a physiologist as Meckel should adopt this opinion.

Professor Müller has also a classification, which seems to me objectionable; for he has admitted among the glands the spleen, thyroid, lymphatic glands, &c. It must not, however, be supposed from this arrangement that this profound anatomist considers these particular bodies as real glands. His classification is as follows. (Handbuch der Physiol. des Menschen, Coblenz, 1834, p. 418.)

I. Glands without a duct.	A. *Ganglia sanguineo-vasculosa,* the spleen in the digestive organs—the supra-renal capsules in the genital and uro-poïetic viscera — the thymus and thyroid in the respiratory apparatus—glandula choroidalis in the eye—the placenta in the fœtus. B. *G. lymphatico-vasculosa,* the lymphatic and mesenteric glands.
II. True glands with an excretory duct.	Liver, salivary glands, testis, &c.

tended by these writers that the last named bodies elaborate from the blood certain fluids, and that as far as the real function of a gland is concerned, it matters not whether the secreted fluid escapes by a proper excretory duct, or is taken up by the lymphatic vessels; it is, indeed, supposed by Haase that these bodies, like the true glands, possess excretory ducts, but this opinion has received little support.

This method of viewing the subject appears to be very injudicious; because it is based on the assumption that certain organs secrete fluids from the blood, but of which secretion we have no evidence; and further, because organs are classed together, between which there is no similarity either of structure or of function.

In establishing a well-founded distinction between parts which, in their general form and outward appearance, bear a resemblance to each other, it is proper to seek for some leading and obvious character, concerning which there can be no dispute. In applying this rule to the present case, we shall find that the special distinction of a true gland, as contrasted with those organs with which it has been assimilated, is the possession of an *excretory canal or duct;* and taking this as the essential characteristic, there is no difficulty in perceiving that the glandular system in the human body ought to be restricted to the following parts:—

Mucous glands, comprising, *a*, simple mucous glands or follicles, dispersed over the whole extent of the various mucous surfaces, either insulated or collected together, as the glandulæ Peyeri seu aggregatæ. *b*, *Compound mucous glands*, (g. agglutinatæ,) formed of the preceding, collected into masses, and slightly modified in their structure, comprising the molar, labial, palatine, and buccal glands, the lachrymal caruncle, tonsils, Cowper's glands, prostate, and seminal vesicles. *c*, *Sebaceous glands*, consisting of those of the skin, the ceruminous glands, the Meibomian glands. *d*, *Conglomerate glands*, (g. conglomeratæ;) these, which are the most complex of the glandular organs, consisting of the salivary glands and pancreas, the mammary glands, the testicle, the kidney, and the liver.

These glands may be classed according to their functions in the economy as follows:—

I. For lubrication and protection; *a.* mucous glands in all parts of the body; *b.* sebaceous glands; c. lachrymal gland; *d.* lachrymal caruncle.

II. Connected with digestion; *a.* salivary gland; *b.* pancreas; c. liver.

III. Connected with generation; *a.* testis; *b.* prostate; c. seminal vesicles; *d.* Cowper's glands; *e.* mammary gland.

IV. For excretion; *a.* kidney; *b.* liver.

By extending the principle that all glands are in reality nothing but processes of the mucous membrane ending in cul-de-sac, the lungs have, by some writers, been included amongst the glandular organs, the trachea, it is said, performing the office of an excretory duct. It is certain, as we shall subsequently show, that the lungs present, both in their formation and functions, a close approximation to the true glands.

The particular description of the above organs and the modifications of the general glandular structure they present, will be found in the articles KIDNEY, LACHRYMAL APPARATUS, MAMMA, &c.

Situation.—The principal glands are placed in the head and abdomen; in the extremities, with the exception of those of the skin, they are totally absent. In general they are protected from external injury by being lodged deeply in the cavities of the body; but to this rule there are several important exceptions, as the mammæ, testes, parotid glands, &c.

Organization.—In the whole range of Anatomy, whether Human or Comparative, there are probably no organs which, on account of the complexity of their structure, the number and variety of forms which they present, and the importance of their functions in the animal kingdom, are more interesting than the glands, or the structure of which, until within a very recent period, was more imperfectly understood. Even at the present time the prevailing ideas respecting the essential characters of the glandular organization are in general so vague and indefinite, and but too often positively erroneous, that I feel myself called upon to enter more fully into the investigation of this subject, than would otherwise be necessary. Much of this uncertainty has arisen from the fact that, whilst the views of the immortal Malpighi, founded as they are on truly philosophic grounds, have never attracted that investigation to which they are so justly entitled, the theoretical opinions of Ruysch, being received with all the eclat inspired by his unrivalled skill in vascular injections, have been generally adopted. It is true that, on many minor points, Malpighi was in error; and that the vagueness of his descriptions, and his infelicitous comparison of the ultimate divisions of the glands with clusters of grapes or *acini*,* greatly assisted in preventing his opinions being generally admitted or even comprehended. But those distinguished anatomists who have, by their recent inquiries, at length decided the long-disputed theories of Malpighi and Ruysch, have proved that in all essential points the conclusions of the former great authority are founded in truth.

Minute structure.—The investigation into the structure of the glands, when conducted in accordance with the enlightened principles of philosophical anatomy, shows that the laws which regulate their formation are simple and definite; and that, although Nature has displayed here, as in all her other works, immense fertility in modifying the forms and characters of the several glands, so as to render them efficient to the performance of their varied offices, yet in no single instance is there a departure from that structure, which constitutes the type of the whole glandular system. The unifor-

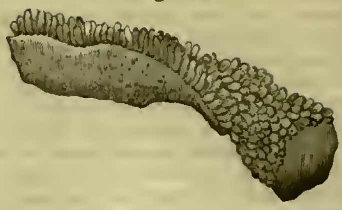
* This term, so much employed in descriptions of the glands, yet so indefinite in its acceptation, has caused such confusion and misconception, that it is most desirable to abolish it from the nomenclature of Anatomy. In the descriptive part of the present article, I shall therefore scrupulously avoid employing this expression.

mity which, with the aid of Comparative Anatomy, has been so satisfactorily demonstrated in the development of the nervous and osseous systems, is equally evinced in the glands; for whatever diversities may be presented in their form and appearances—whatever varieties may be remarked in the internal disposition of their component parts, as in contrasting a simple follicle with a conglomerate gland, or the tubular biliferous organs of insects with the apparently solid liver of the Mammalia; whether, in short, they appear solid, cellular, or tubular, every glandular organ is nothing else than a modification of a simple closed sac. This important truth is distinctly announced by Meckel in the following passage. "The most simple mucous glands, which are only simple sacs, present the type of the glandular formation. If we picture to ourselves this sac as being prolonged and ramified, and interlacing its branches between those of the bloodvessels, we shall at length arrive at the most compound gland, without there ever being a direct communication between the bloodvessels and the excretory ducts."* We have here briefly but clearly expressed the great principle, in obedience to which the various glands are developed; but that which Meckel only figuratively expressed, has since been realized in all its bearings and intricate details, by the extensive and laborious researches of several distinguished anatomists, and especially by Professor Müller of Berlin.

As it would be in vain to attempt to demonstrate the essential characters of the glandular formation, and to prove the uniformity which pervades the whole system, by selecting, as has been generally done, the most intricate organs; I propose, in the first place, to describe the most simple form of gland, and, seizing this as a clue, to trace its gradual development throughout the whole series of glandular organs, so as to convey a general, but, it is hoped, comprehensive account of this interesting branch of anatomy.

With this object in view, the simple follicles of the skin and mucous membrane may be advantageously selected; because by tracing the successive development of these bodies, the gradual transformation of a simple sac into a tube, a ramified canal, and even a conglomerate gland, may be very distinctly demonstrated. In fishes, whose aquatic mode of life renders an abundant defensive secretion necessary, the cutaneous follicles are more developed than in other animals, and constitute tubes or canals, which being carefully examined are found to end in cœcal extremities. A similar formation is seen in the bulbus glandulosus of most birds, where the mucous crypts are prolonged into short tubuli (*fig.* 209); whilst in the Ostrich (*Struthio camelus*) the follicles present an appearance of cells. (*Fig.* 209, *b*). In some Amphibia, *Salamandra maculata* for example, the glands of the external integument being very much developed, it is seen that each of

Fig. 209.



a. Conglomerate follicular gland, *Struthio rhea*; c. same, *Meleagris*; *d.* same, *Anser*;* the upper drawing shows the cylindrical follicles in a young falcon.

those bodies is composed of a small flask-shaped pouch of the skin, which at one extremity becoming enlarged into a base, there terminates in a blind sac; whilst at the other end being contracted, it opens by a short neck on the external surface. (See *fig.* 210.) A microscopical view of the cœcal canals in the simpler glands is appended. (See *fig.* 211.)

Fig. 210.

Flask-shaped cutaneous follicle or gland magnified=110.†

Fig. 211.

The simple sacs and tubes just described are very often collected together, giving rise to *aggregate* or *compound follicles*, the arrangement and degree of complexity of which are very various. In some instances these sacs unite so as to form a gland with a single orifice or excretory duct, of which the Meibomian glands of the eye-lids are an example; or again, the aggregate follicles may themselves be joined together with various degrees of complication, in the form of a cluster, from which several excretory ducts proceed, as in the caruncula lachrymalis, the labial, buccal, and other mucous glands of the mouth, the tonsils, &c. In all these instances there is nothing but an evolution of the original sac, so that in the same manner as this is formed from the mucous membrane or skin, are the tubes and canals prolonged from the third pouch, by which contrivance the surface subservient to secretion is, within a given space, greatly increased. The conversion of a sac or tube into a granular mass is also in this manner rendered very apparent; and thus it is easy to understand how a ramified canal may produce the apparently solid

* Man. d'An. i. p. 515. Béclard has a similar comparison: "it is true that a gland, like a follicle, consists of a canal closed at the extremity." Anat. Gén. p. 424.

* Home, Lect. on Comp. An. ii. tab. 46.
† Berres.

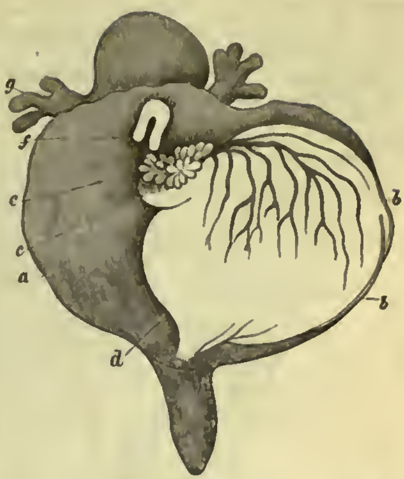
granules (the so much talked of *acini*) of the liver and other conglomerate glands.

Such, then, are the more simple forms of the glandular organs; and if we proceed to those which are more complex, no difficulty is experienced in proving, by the aid of comparative and developmental anatomy, that the structure, although it becomes more and more developed, is in character essentially the same. The inquiries of the anatomist in this respect are greatly facilitated by the existence of an universal law connected with the process of organization, in accordance with which it happens that, whenever any particular gland first appears in the animal series, it presents invariably the simplest form of the glandular structure, although this same gland may subsequently attain in the higher classes the most intricate formation. It is for this reason the salivary glands are so simple when they first appear in birds, the pancreas in fishes, and the liver in insects.

Ample confirmation of this gradual transition from simple to compound, which is in fact only another instance of the great laws which regulate the formation of the whole animal creation, is afforded by following any of the more intricate glands through the several stages of their development. Thus, if the pancreas be examined in its rudimentary state, it will be perceived that, like the mucous follicle, it is composed either of a fluid sac or of a tube more or less complicated. In the class *Cephalopoda*, the individuals of which are so remarkable by the complexity of their internal organization, the pancreas consists either of a simple sac opening into the intestine near the gizzard, (see *fig.* 219, *p*, *fig.* 220, *f*, vol. i. p. 533), or of a spiral canal, (*fig.* 221, *f*, p. 535,) the secerning surface being increased by a number of laminæ. In most fishes there are numerous fluid appendages placed near the pyloric extremity of the stomach, (*appendices pyloricæ*,) which are with propriety regarded as constituting a rudimentary pancreas, (*fig.* 212,) and which, in the in-

Fig. 212.

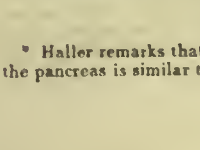
Fig. 213.



stance of the Sturgeon and Swordfish are aggregated into a glandular mass.* (See *fig.* 46, vol. i. p. 115.)

The liver is certainly the most intricate structure of all the glandular organs when examined in the higher animals; and yet, if we descend to the lower classes, which present, as it were, a natural analysis of the various parts of the animal machine, the texture becomes sufficiently simple. One of the most simple forms of this organ is probably furnished in the *lumbricus terrestris;* at least I have seen in that animal, in a few instances, a beautiful appearance of cœcal tubuli composing the yellowish substance which coats the intestine, and which is thought by some authorities to constitute the liver. In many insects, Crustacea and other Articulata, the biliferous organs consist of fluid sacs proceeding from the stomach or intestine, and often assuming the appearance of tubes, but always closed at their distal extremities. In some instances these tubuli are very simple, (see *fig.* 37, *d*, vol. i. p. 111,) but in other cases they are more complicated, and present a ramified arrangement; and in this manner the structure evidently approaches that of the most compound or conglomerate glands. The liver of the Lobster presents an excellent illustration of the cœcal tubuli which constitute the secreting structure of so many species of glands. By cutting out a portion of this organ, and slightly unravelling the tubes by moving the section in water, the canals ending in cul-de-sac are beautifully seen, and if slightly magnified, it is found that they closely resemble the pyloric appendages of fishes. The

Fig. 214.

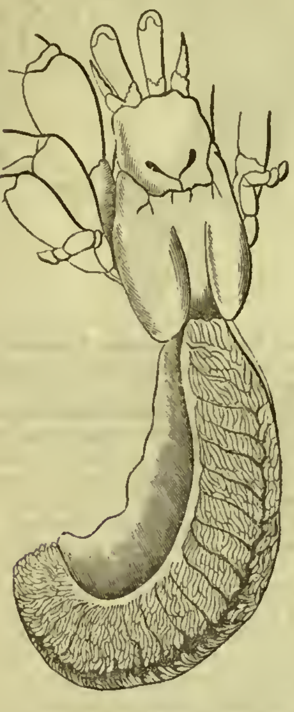


* Haller remarks that, in the Skate and Shark, the pancreas is similar to that of higher animals.

adjoining figure (*fig.* 214) conveys a very accurate representation of this structure as it exists in the biliary organs of the *astacus fluviatilis*, the digital tubuli (*c*) being depicted as they appear when partly unravelled.

In another of the Crustaceans, *pagurus striatus* (*fig.* 215), the same kind of structure is

Fig. 215.



observed, constituting a very complex liver. In the *squilla mantis* that organ is so remarkably intricate that Cuvier supposed it formed an exception when compared with the other genera of the Crustacea, which, as we have seen in the instances above, possess biliary organs composed of blind tubes, by being lobulated and solid like a conglomerate gland.* It has, however, been ascertained that the lobules are excavated in their whole extent, and communicate by openings with the intestine, which runs through their spongy mass, so that the secreting surface is wonderfully increased in extent.†

That the liver consists of a blind pouch, originating from the intestinal canal and becoming more and more complicated, is further shown in many of the Mollusca, in which the excretory ducts are so large that they appear like branches of the intestine, and thus present a structure which is somewhat analogous to those curious cœcal diverticula observed in certain of the Annelida, well seen in the *aphrodita aculeata*, and which are by some anatomists regarded as forming a rudimentary liver.

The evolution of the liver in the embryo affords an additional proof of the disposition of the secreting surface or membrane in the interior of the compound glands. In one of the Gasteropods (*Limnæus stagnalis*) the liver is first produced as a pellucid sac from the intestine. In an amphibious animal (*bufo campanisonus*) a prolongation in the form of a sac is seen in the intestinal membrane, which constitutes the first appearance of the liver; as the development proceeds, the hepatic duct is formed, and becoming ramified, produces at length a number of branching tubes, which present a granulated form. The evolution of the liver in the green lizard (*lacerta viridis*) is very similar, the organ first appearing under the form of a hollow sac proceeding from and communicating with the cavity of the intestine, and subsequently having branches of ramified tubes added.*

If from the investigation of these more simple forms, which might be multiplied almost *ad infinitum*, we proceed to the conglomerate glands of Mammalia, it will be observed that, although the component parts of these highly organized bodies are so closely packed together as to present a solid and granular appearance, yet by a careful inspection it may be satisfactorily determined that the true secreting structure consists of tubuli with cœcal ends. For this purpose the testicle may be advantageously selected: if this organ without any previous injection be divided, the section at first sight seems to consist of a great number of small roundish bodies or granules; but if, as occasionally happens, the tubes are distended with semen at the time of death, by a more cautious examination it is immediately apparent that these little bodies are composed of a very fine tube coiled up or convoluted. By injecting the tubuli seminiferi with mercury, the formation of the little grains is rendered more evident; but the most successful mode of displaying the whole internal formation of the testis is by filling the tubuli with a coloured size injection.†

It was remarked by Ferrein‡ that the kidney is a tubular organ, and the extensive researches of Müller as well as those of Huschke have proved that the secreting or cortical part is made up of an immense number of serpentine tubes of an equal diameter throughout, ending in blind sacs, and becoming continuous with the straight canals placed in the cones of the organ. This structure is seen in *fig.* 216, where a magnified view of the cortical ducts of Ferrein, the secerning apparatus, and the straight excretory tubes is given as the parts exist in the *sciurus*. This structure offers a close resemblance to the tubuliform liver of some insects.

* Leçons d'An. Comp. t. 4. p. 152. It is proper to observe that Cuvier, in thus alluding to a *solid* conglomerate gland, appears to have fallen into the common error respecting the nature of the minute granules, or acini as they are called.

† Müller de Gland. Secernent. Struct. p. 70, § 5.

* Müller l. c. tab. x. *fig.* 13.

† Sir A. Cooper on Testicle.

‡ Mém. de l'Acad. Roy. des Sc. 1749, p. 489.

(See the biliary organs of *Melolontha Vulgaris, fig.* 38, vol. i. p. 111.)

In the liver of Mammalia and Man, both in the embryo and after birth, it is much more difficult to demonstrate the ultimate tubes with their cœcal extremities; indeed the existence of such canals is rather deduced from the analogy of the liver in the lower animals than from actual observation. Müller states that the blind free extremities of the biliary ducts are visible on the surface of the liver with the microscope in the embryo of Mammalia; but that owing to their compact arrangement they are less distinct than in birds, so that their internal connexions cannot be perceived.* In a few Mammalia, however, as the squirrel, (*sciurus vulgaris,*) he observed with the microscope the blind cylindrical extremities of the biliary ducts on the surface of the liver, presenting a branching and foliaceous appearance. (*Fig.* 217.) The exact mode of termination of the biliary tubuli was still more distinctly seen in a portion of liver considerably magnified, taken from an embryo of the quail, (*Tetrao coturnix,*) about one inch long (*fig.* 218). From the published account of Mr. Kiernan's valuable observations on the minute structure of the liver, it does not appear that the actual terminations of the biliary tubes in blind extremities were perceived, although that such is their disposition is rendered very probable from what was seen with the microscope, and especially because it was found that much greater difficulty was experienced in injecting these tubes than the bloodvessels, on account, as it was surmised, of the bile contained within them having no exit.*

Fig. 216.

Fig. 217.

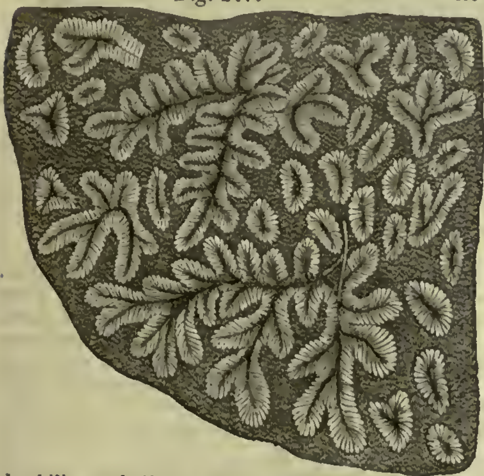


Fig. 218.

Lastly, in tracing the minute texture of these complex glands of the Mammalia, it is necessary to call the attention of the reader to a circumstance which of all others has been the most fertile source of error, so much so indeed as to have misled the great majority of anatomists. It is this: in many glands small rounded or berry-shaped corpuscles seem to be appended to the commencement of the secreting tubes, so that a deceptive appearance is produced, as if cells or little bags were placed between the terminal bloodvessels and the small excretory ducts. This appearance of cells or even of solid rounded corpuscles is dependent on two causes: in some glands the secreting canals are so coiled up that, as is seen in the human testis, when a section is made in the uninjected state an apparently granular texture is presented, (*fig.* 219;) but a second influential circumstance is that in many instances each of the secreting tubes swells out at its cœcal end into a slightly enlarged cul-de-sac (*pedunculated tubes*), so that when they are viewed in an aggregate form, the semblance of roundish-shaped granules is seen, (*fig.* 220.) As these and all other varieties which are presented in the glandular formation are

* L. c. p. 80, § 21, 22.

* Phil. Trans. 1833, p. 741.

Fig. 219.

considered in the several articles on the individual glands, it is only necessary to state in this place that what are called indifferently *lobules*, *glandular grains*, *vesicles*, *acini*, &c. are in every instance composed simply of the secreting canals variously disposed and arranged

It is, however, very remarkable that whilst those glands which arise from the alimentary canal present an immense variety in the arrangement of their secreting texture, the essential glands of the genito-urinary apparatus, the kidney and the testicle, have a most uniform structure, consisting of serpentine tubes of the same diameter throughout their whole extent.

The details into which I have thought it requisite to enter prove that the true secreting structure consists in every gland of nothing else than a vascular membrane, on the surface of which the glandular fluid is poured out; and consequently that in those complex organs, as the liver or kidney, in which the vascular se-

Fig. 220.

Peripheral ramification of the parotid duct, with some of the vesicular terminations, magnified = 110.*

creting membrane is, for the sake of convenience, disposed in the form of extensively ramified tubes, it is most important to recollect that the glandular fluid is poured not only into the cœcal extremity or commencement of each tube, as is the commonly received opinion, but along *the whole extent of the tube.* For the establishment of this fact, certainly the most important in the history of the glands, we are principally indebted to Professor Müller.

Excretory duct.—Although the essential seat of the glandular function is now ascertained, some difficulty exists in determining the actual extent of the secreting surface in the various organs; or in other words, at what precise point the mucous canals ceasing to secrete, become mere excretory passages.† An attempt to decide this point is, however, necessary, because until this time the majority of anatomists have signified by the term *excretory duct*, not only the canals which simply bear away the secreted fluid, but likewise those tubes which constitute the true secreting apparatus, and which, it is evident, are at the same time both secreting and excreting canals, as they not only secrete, but likewise carry to the larger and non-secreting ducts the fluids poured out by their parietes.

In the simple sacculi or follicles, it is evident that the secreting structure is co-equal with the extent of the bag itself, so that the little orifice becomes the excretory duct; in the tonsils, prostate, &c. there are several such orifices or ducts. But at what point does secretion cease in the compound glands? Mr. Kiernan states,* that in the liver the secreting portion of the organ is confined to what he calls the lobular biliary plexuses, or to those tubes which are placed within the lobules; so that here the excretory apparatus is very complex, consisting of the interlobular tubes, those

* Berres, l. c. pt. 5, tab. ix. *fig.* 2.

† I allude here of course to the peculiar secretions, as the bile, urine, milk, &c. and not to the secretion of mucus, which we know is poured out along the whole extent of the excretory ducts.

* Phil. Trans. 1833, p. 741.

of Glisson's capsules, and, lastly, of those which quit the organ. The limitation thus established, and which I have no doubt is strictly correct, may be applied to all those glands, such as the salivary, mammary organs, &c., which, like the liver, possess distinct lobules. In the kidney the true secreting structure is probably restricted to the serpentine tubes contained in the cortical texture, (*canales corticales*, or ducts of Ferrein,) the straight canals (*tub. Belliniani*) constituting the cones, which bodies, in a minute injection of the bloodvessels, are nearly colourless, being merely for excretion.* The testis, with its appendix the epididymis, presents an intricate arrangement; it is probable, however, that the principal secreting part consists of the seminal tubes which form the lobules, and that the vasa recta and efferentia are merely excretory in their office; in the upper part of the epididymis a second secreting structure is met with, constituting the coni vasculosi, whilst the lower part containing the convolutions of the vas deferens is of the excretory character.

It is proper to observe that the process of secretion is incessantly going on; but with the exceptions of the mucous, sebaceous, and a few other glands, the fluids produced are destined to be poured out only at stated intervals; it is, therefore, evident that some contrivance is required, by which the several secretions may be retained, till the moment arrives when it is necessary they should be discharged. The liver may be selected to illustrate this principle: one of the most essential functions of that organ being the decarbonization of venous blood, its constant action is no less indispensable, indeed considering the whole animal series, is even more indispensable than that of the lungs themselves; and yet the product of that action, the bile, is only designed to be poured into the duodenum during the process of digestion. In order to obviate the irritation of the bowels that would result from the incessant discharge of the bile, and at the same time to economise that fluid, the gall-bladder is provided, which, receiving the secreted fluid in the intervals of digestion, fulfils all the conditions required. The absence of the gall-bladder in several classes of animals can scarcely be admitted as being incompatible with this explanation; for the majority of these instances of deficiency occur in non-ruminant vegetable feeders, in several genera of the Pachydermata and Rodentia for example, in which it is evident that as the process of digestion must occupy a considerable period, a prolonged flow of bile is requisite, and a special reservoir is less necessary; in addition to which it is known that in some of these cases, as in the horse and elephant, the principal trunk of the biliary ducts is very large, and may in some degree supply the place of a gall-bladder.*

The urinary bladder is a provision rather of convenience than of necessity, enabling the animals that possess it to retain the urine as it flows from the ureters, until a considerable accumulation takes place. These are the only instances in the human body of a distinct reservoir being provided;† but every gland, by retaining its secretion in the excretory ducts, has a power of emitting the fluid, under certain circumstances, in larger quantities than usual, as in the case of the salivary and lachrymal glands; a similar accumulation must take place in the seminal tubes and prostatic ducts, and especially in the lactiferous tubes and their terminal sinuses. In animals the examples of distinct reservoirs are too numerous to be here enumerated.

Structure of the secreting canals and excretory ducts.—It is now certain that all these tubes are composed essentially of a prolongation of the mucous membrane. The former, according to Müller, consist only of a single coat, but it must be presumed that they possess in addition a tunic, having, independently of elasticity, a power of contraction by which their contents are propelled often in a direction opposed to gravity, and in obedience to the application of a mechanical stimulus to the surface on which the ducts terminate. In the excretory ducts the internal membrane is surrounded by a fibrous structure, which is very apparent in some of the larger canals, and probably exists in all. The fibres of this coat are of a greyish white or brownish colour, and are often so fine and compact that they are distinguished with great difficulty. The real character of this structure is not known; in appearance there is little or no resemblance to proper muscle; the action, however, of the excretory canal seems to require a contractile power; and Meckel states that he has distinctly perceived circular fibres in the vas deferens, which tube is said to be distinctly muscular in the bull.

Bloodvessels.—If it be recollected that the arteries carry to the glands the materials of their various secretions, and if the large quantity of fluid formed by those viscera be called to mind, we shall not be surprised to find that with a few exceptions, such as the lungs and the brain, there are no organs so abundantly supplied with arterial blood. This supply is in proportion to the activity of secretion, rather than to the size of the gland; thus the kidneys,

* It is stated by Müller that all his researches induce him to conclude that the serpentine tubuli of the cortical part constitute the true secreting texture; an opinion which is corroborated by a very curious preparation contained in the museum of the Webb-Street School of Anatomy, in which a sac has been formed on the outer surface of the kidney, containing a number of small calculi, and having no connexion whatever either with the straight tubes or with the infundibula.

* Carus, Traité Elem. d'An. Comp. ii. p. 269. It may be proper to state that the Otter, according to Daubenton, possesses the above dilatation of the duct in conjunction with a gall-bladder.

† Some anatomists conceive that the vesiculæ seminales are merely receptacles of the semen; but this opinion has been to a great extent abandoned in England since the observations of Hunter. See the works of Hunter, edit. by Palmer, vol. iv. p. 20. Note, p. 26.

furnishing about four pints of urine daily, receive, in proportion to their bulk, more blood than the pancreas, where the secerning process is less active. That this is the principle which regulates the supply of blood is also evidenced in the vessels of the mammæ, which receive a more ample supply of blood during lactation than at other periods.

The sanguiferous vessels, like the secreting canals, present many varieties in their disposition in the several glands, the varieties of form in each class being, however, definite in their character, and doubtless having a reference to the different kinds of fluids which are required to be separated from the circulating blood. Those organs which are provided with a distinct envelope, as the testicle, the kidney, and liver, usually possess but one artery, which enters at the same fissure as the excretory canal; other glands, presenting a more distinctly lobulated texture and having no proper capsule, the tonsil, pancreas, and mamma for instance, receive an indefinite number of arteries, which enter irregularly on all parts of the surface; lastly, in the most simple form, as the mucous crypts, the secreting vessels constitute a delicate plexus on the surface of the little bag.

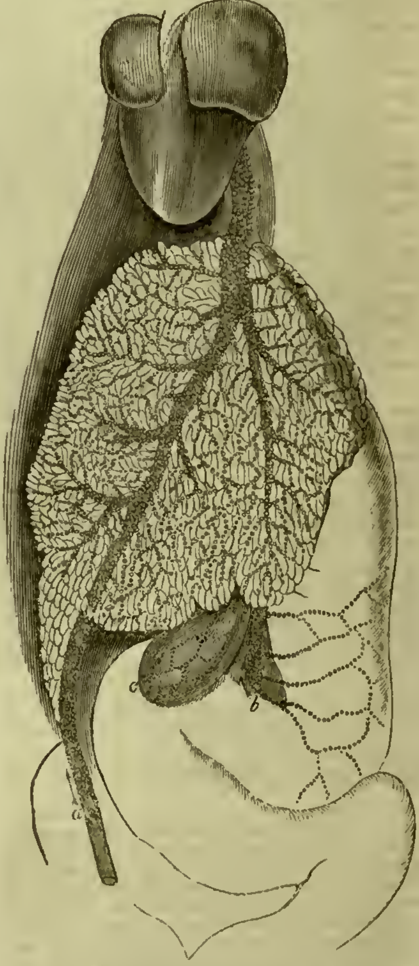
In all those instances where the gland is large enough to receive one or more arterial trunks, it is found that the vessel having entered begins to divide into smaller branches, which penetrate between the masses of the gland, and these becoming smaller and smaller at length furnish an intricate plexus, the branches of which, as in the case of the simple bag or follicle, ramify on the surface of the blind secreting canals.

It is only necessary to observe with respect to the veins, that when compared with their arteries, they are smaller than elsewhere; and also that in common with the veins of the splanchnic cavities, they are devoid of valves, so that in the kidney, liver, &c. they may be beautifully displayed by the aid of a successful injection, even to their ultimate ramifications.

Arrangement of the minute bloodvessels.— In considering the intimate texture of the glands, it is essential to state the manner in which the last divisions of the sanguiferous vessels are disposed. By the aid of minute injection these vessels may be demonstrated, though with difficulty, as far as their termination; and they may also be observed in a few instances during life and whilst carrying on the circulation.

An opinion to which we shall subsequently recur has been entertained by many anatomists, that the little arteries are either directly continuous with the excretory ducts, or, as we should rather call them, the *secreting canals*, or, at all events, that some kind of direct communication exists between the terminal arteries and the secreting canals. The most cautious and apparently successful researches, however, do not corroborate this opinion, but, on the contrary, show that no direct communication of any kind exists. In the lungs, which organs are formed and developed in exact accordance with the glandular structure, the ultimate divisions of the pulmonary artery, after freely ramifying over the surface of the air-cells, are known to terminate by direct continuity in the radicles of the pulmonary veins. Now, that which is demonstrated in the lungs equally applies in the case of the glands. In the simple lacunæ of the mucous membrane the arteries are disposed over the surface of the pouch, but they end in the returning veins without opening on the secreting surface. Müller states that on examining with a sufficient power the larva of the *triton palustris*, he observed streams of blood, traversed by single globules, running between the elongated secreting canals of the liver, and, further, that the last arteries pass immediately by a reticulate anastomosis into the small hepatic veins. This disposition is seen in the adjoining figure, which represents the circuit of the blood in the larva of the triton fifteen lines in length.

Fig. 221.



a, vena cava; *b*, vena portarum; *c*, minute currents of blood in the gall-bladder.

Müller expressly says, *that in no organ are the free extremities of the bloodvessels seen, but that the arteries always pass by a reticulate anastomosis into the veins;* that the blood circulates between the secreting canals of the liver, and at length on their surface, so as, as it were, to soak their coats with blood, but it does not pass into the canals themselves; or, in other words, that the sanguiferous vessels are not continuous with the biliary tubes.*

The important investigations of Kiernan respecting the minute anatomy of the liver, have shewn that the vena portæ having divided so as to constitute an intricate plexus in each lobule of the organ, and having ramified on the secreting canals, terminates in the hepatic vein.† In the section on the development further evidence is furnished in corroboration of these observations.

In all these instances, then, it is proved that there is no continuity between the arteries and the secreting tubes; and as the smallest secreting canals are always considerably larger than the smallest bloodvessels, the proportion varying in different glands, it may be assumed that in the whole glandular system, the arteries, having divided to a great degree of minuteness, and having ramified freely on the surface of the secreting canals, terminate directly in the returning veins.

Although in former times such a disposition of the bloodvessels as that now described would have been regarded as incompatible with the process of secretion, yet since the interesting researches of Dutrochet on Endosmose and Exosmose,‡ there is no difficulty in understanding that fluids may readily pass from the interior of the arteries into the secreting canals without there being any direct communication between these two orders of tubes. Not only may this passage take place, but even it is rendered probable by the experiments of Magendie§ that the bibulous matter constituting the glandular texture, and presenting, as we have found, so many varieties in its physical characters, may separate fluids, varying, according to the gland employed, from the diversified substances mechanically mixed together and suspended in the blood.

Lymphatic vessels.—Notwithstanding these are readily traced in the larger glands, their disposition, and especially their origin, are not known; a connexion, however, has been rather generally admitted in certain glands between their ducts and the lymphatics. In one instance Cruikshank filled the absorbents of the mamma from the lactiferous ducts; and both Walter and Kiernan contend that the absorbents of the liver may be injected from the biliary ducts. Müller, on the contrary, denies this communication, and states that the lymphatics are much larger than the smallest secreting canals. He also contends as to the results of injections, that the arguments drawn from them have no greater weight than all others derived from the fortuitous passage by rupture of fluids from one into a different order of vessels.

Nerves.—In proportion to their size the glands, like the other organs of the vegetative functions, receive very small nerves, which are, with some few exceptions, derived from the system of the great sympathetic. The nervous fibrils surround and accompany the branches of the arteries, till, in the interior of the gland, they become so minute that it appears impossible to detect their exact termination. Müller states that they never separate from the bloodvessels, and, consequently, that they do not supply the proper glandular substance. But in such a case as this the evidence afforded by microscopical inspection alone should be received with great reserve, especially when it is recollected that in opposition to the doubtful information thus acquired must be placed the unquestioned fact that the mind is capable of influencing the contraction of the secreting and excreting tubes, as is instanced in the flow of the saliva, of the tears, and of the semen under certain mental impulses. But perhaps a still more striking illustration of the control of the nervous system is afforded by the discharge of several glandular fluids resulting from impressions acting on comparatively remote but associated surfaces—the pouring forth of the saliva for example, in consequence of the contact of various substances with the tongue; of the bile and pancreatic juice from the application of food to the surface of the duodenum; of the semen from the stimulation of the glans penis. In all these and similar instances it must be presumed from analogy that the effect of the physical impression is conveyed through the only known media of conduction, the nerves.* The facts here adduced respecting the influence of the nerves merely relate to the contraction of the secreting and excreting canals; how far the nervous energy is essential to the process of glandular secretion itself belongs to another division of the subject. (See SECRETION.)

Interstitial cellular tissue.—A considerable portion of every gland is made up of the connecting cellular membrane, which, as in all other organs, enters the interior, where it fills up all the minute fissures and angles that intervene between the tubes and lobules, and at length, penetrating between the most minute of the secreting canals, it constitutes a nidus for the lodgement of the constituent parts.

The investing membrane is in many instances

* De Gland. Struct., p. 74, § 12. Phys. des Menschen, 1 Band, p. 441.

† Phil. Tran. 1833, p. 745. Mr. Kiernan infers that the hepatic artery terminates, not as is usually supposed in the vena hepatica, but in the vena portæ. Müller, however, thinks it is not probable that this is the true disposition, because the preparations of Leiberkuhn show that the capillary branches of the venæ hepaticæ can be as readily injected from the hepatic artery as from the hepatic vein. Notwithstanding these objections, analogy would induce us to suppose that Mr. Kiernan is correct in his supposition.

‡ Nouv. Recher. sur l'Endos. et l'Exosmose, 1828.

§ Lect. on the Physical Conditions of the Tissues, Lancet, 1834-35.

* I have in another place entered more fully upon this question: Obs. on the Struct. and Funct. of the Spinal Cord, p. 136, et seq.

simply formed by the condensation of the connecting cellular tissue, but in the larger glands a proper fibrous capsule is provided, which adheres more or less intimately to the proper glandular texture.

General conclusions respecting the minute structure of glands.

1. That throughout the whole range of the animal kingdom and in every species of gland there is one uniform type, from which the glandular formation in no instance deviates.

2. That every gland consists of a membrane derived either from the skin or mucous membrane.

3. That this membrane is disposed either in the form of a pouch or of a tube more or less ramified, and terminates in every instance, without an exception, in a blind extremity.

4. That the secreting canals are most diversified in form, being simply sacculated, branching, pennitifid, nail-shaped, or enlarged at the commencement, cellular, berry-shaped, serpentine.

5. That granules or acini in the hypothetical sense of writers do not in reality exist.

6. That whatever may be the variety of form it is always subordinate to the grand principle which the whole glandular system displays,—namely, that the largest possible extent of secreting surface is contained in the smallest possible space.

7. That there is no immediate connexion or continuity between the secreting canals and the sanguiferous vessels.

Hypotheses respecting the minute structure of glands.—I was desirous in the first part of this article to convey to the reader a comprehensive view of the glandular structure, unincumbered by any reference to the opinions of anatomists on this subject; but the hypotheses of Malpighi and Ruysch have so long divided the world of science, that it is necessary to ascertain how far the doctrines advocated by those celebrated men are in accordance with the above-stated conclusions. In doing this, however, much difficulty is experienced, especially in considering the opinions of Malpighi, inasmuch as his comparisons of the minute structure of the liver, of which organ he principally treated, are very vague and obscure, and being for the most part unaccompanied by illustrative plates, it is almost impossible in many of his descriptions to detect the meaning he wishes to convey. But, notwithstanding these obstacles, it is evident, on studying his account of the liver and kidney, that justice has not been done to his researches; for he not only corrected many of the then prevailing errors, but also ascertained several important points connected with this interesting branch of anatomy.

Malpighi compares the minute lobules of the liver and other conglomerate glands to a bunch of grapes, these lobules being joined to the neighbouring lobules by intermediate vessels. His words are, "for as an entire bunch of grapes is formed of small bunches by a communion and tying together of vessels, which small bunches are themselves formed into a mass by appended grapes *(acini)*; so the whole liver is formed by lobules many times folded, and which are themselves formed of glandular globules."* It is thus observed that Malpighi describes in the liver larger and smaller lobules; and it is to these latter that the celebrated but vague term of *acini* appears to be more particularly applied. He observes that the lobules are of various forms in different animals; in fishes having the shape of a trefoil, in the cat six-sided, &c. The interlobular spaces are noticed as being distinct in fishes, but as obscure in the more perfect animals.

With respect to the intimate structure of the small lobules, or acini, Malpighi conceived that each of them consisted of a hollow vesicle, receiving the secreted fluid from the small arteries and conveying it into one of the roots or branches of the hepatic duct; or, in other words, that the structure of the acinus was the same as that of the simple mucous follicle. Owing, however, to the imperfect means then possessed of prosecuting such inquiries, it is certain that Malpighi did not detect the ultimate structure; for more exact observations have proved that the last divisions of the secreting canals, although they constantly terminate in cœcal extremities, do not always end in follicles, but that they may consist of serpentine tubes, as in the kidney, or of pennatifid canals, &c. It also has been determined that what he regarded as the last divisions of the ducts, or acini, are themselves composed of smaller canals. But his observations on the developement of the liver in the chick shew that he was acquainted with the essential facts connected with the structure of that organ, and with the mode of its formation; for among other interesting remarks, he says that on the seventh day of incubation the liver of a yellowish or ashen colour presents granules of rather an oblong form, and "as it were blind pouches, appended to the hepatic duct."†

This hypothesis, founded as it is on so large a body of evidence, was generally received; but the discovery of the art of minute injection, which seemed to afford ocular demonstration of the fallacy of Malpighi's theory, induced the majority of anatomists to adopt the ideas rather pompously announced by Ruysch. This celebrated anatomist, rejecting the hypothesis of Malpighi, contended‡ that he had proved, by injection, that the arteries are directly continuous with the excretory ducts; or that the little ducts proceed from the minute arteries, like lesser from larger branches; and that each acinus consists principally of bloodvessels, but contains also an excretory duct.§

In considering the merits of these two hypotheses, it becomes apparent that Ruysch supported his opinion by evidence of a most insufficient character; for in investigating the

* De Viscer. Struct. cap. iii. p. 18.

† De Format. Pulli in Ovo, p. 20.

‡ Opuscul. Anat. de Fabric. Gland. Opera omnia, t. iii.

§ Loc. cit. p. 56, *fig.* 2.

most complicated glands he relied solely on his vascular injections, to the exclusion of the evidence afforded by the much more satisfactory researches of comparative and developmental anatomy. If, as Professor Müller has observed, Ruysch had carefully examined his injected organs with the microscope, he would have found that between the most delicate plexuses of the bloodvessels there is always an additional substance destitute of vessels; although these organs, when seen by the naked eye, appear to be stained in every direction with the coloured injection.* But even admitting what frequently happens from a too forcible injection, that the matter thrown into the arteries is found in the ducts, this does not prove that the small bloodvessels are continuous with the excretory canals; for after the sanguiferous vessels are filled, they easily become ruptured, and so allow their contents to escape into the ducts. It may further be objected, that in all the glandular organs which have been carefully inspected the commencements of the excretory ducts are larger than the least arteries;† indeed, Ruysch's own account of this imaginary continuity is very vague, and the plates designed to illustrate his theory, especially that of the kidney, are any thing but satisfactory. As Ruysch did not employ the microscope, it is impossible he could have *seen* that continuity which he so confidently described; indeed, as Haller remarks,‡ it is difficult, or rather as we should say impossible, to demonstrate, with the aid of the most powerful lens, the connexion of the last arteries with the coats of the ducts.

Not only did Ruysch adopt a most insufficient mode in prosecuting his inquiries, but he assumed as a fact what was in reality a mere hypothesis, that secretion can only take place from the *open mouths* or orifices of the secerning arteries. The only point, therefore, which he discussed was, whether the passage of the arteries into the excretory ducts takes place gradually and insensibly, or suddenly and by the intervention of a follicle; for it never occurred to the anatomists of those times, or even to Haller and his contemporaries, that canals closed at their end by cul-de-sac, and without open arterial mouths, could secrete.§

But the true opinions of Malpighi did not refer to the exact mode of termination possessed by the arteries; nor did he imagine that any particular machine or follicle was interposed between the arteries and the ducts: his observations were rather directed to the more important circumstances relative to the disposition, formation, and extent of the true secreting canals.

In concluding these remarks on the hypothesis of Malpighi, it is due to the character of that illustrious cultivator of anatomical science to state that his views are highly philosophic, and in a general manner correct—that they are supported by numerous observations made on the glands of the lower animals, as well as on the development of the liver during incubation—and that he had thus the sagacity to adopt the mode, which experience has shown is alone capable of resolving this difficult question.

It would be superfluous to enter into a detailed account of the opinions advanced by later anatomists, as they are for the most part simply modifications of the hypothesis either of Malpighi or of Ruysch. A few general observations will therefore suffice.

Ferrein has the merit of being the first writer who pointed out in a more distinct manner than had been done by Malpighi, the great importance of what are erroneously called the excretory ducts, but which constitute, as we have already shown, the true secerning structure. He remarks* that the cortical part of the kidney is composed of a collection of white cylindrical tubes, variously folded on themselves (*canales corticales*, or ducts of Ferrein,) and he thought he had seen the same tubes in the liver. The serpentine cortical canals have been seen in birds by Galvani, to be filled with cretaceous urine after the ligature of the ureter. Although the researches of Ferrein are very important, yet they want that support from comparative anatomy, by which means alone they could have been made subservient to establish any general principles.

To Rolando belongs the honour of having demonstrated the mode in which the glands are developed from the alimentary canal. By carefully conducted observations on the incubated egg, he discovered that each of these organs in the first instance consists of an elevation or tubercle of the intestine, which subsequently becomes hollowed and forms a canal directly continuous with that of the intestine. He also distinctly announced what has since been demonstrated in all its details, that the lungs are formed, like the glands, by a *pushing out* of the upper end of the intestinal tube; and he further describes the mode in which the bronchi and their subdivisions are developed. The error of those writers who contend

* Loc. cit. p. 8, § 4.

† *Diameter of secreting canals.*

	Line
Parotid gland . . .	0·0099 (Weber).
Kidney	0·0166 (Meckel).
Ditto	0·0180 (Weber).
Testis	0·0564 (Müller).
Ditto	0·0648 (Lauth).
Liver (in rabbits) . .	0 0140 (Müller).

Diameter of capillary bloodvessels.

	Line		Line
Parotid . .	0·0030	to	0·0039 (Weber).
Kidney . .	0·0044	to	0·0069 (Müllor).
Testis . . .	0·0030	to	0·0035 (Weber).

Burdach Physiol. Fünfter Band. p. 38. For measurements in other glands, see Müller De Gland. Struct. p. 112; Valentin Handb. der Entwickelungs-geschichte, p. 535 et seq.

‡ El. Phy. t. ii. p. 378.

§ The existence of open mouths in the arteries of the serous membranes, where they are generally called *exhalants*, has never been proved; on the contrary, on examining, with a powerful microscope, the circulation of the peritoneum in rabbits, I have repeatedly observed that the small arteries, after ramifying in a very complicated manner, become distinctly continuous with the little veins.

* Mém. de l'Acad. Roy. des Sc. 1749, p. 492.

with Ruysch that the bloodvessels and the secreting canals are continuous with each other, is clearly shown; in short, Rolando was the first modern anatomist, who, following in the footsteps of Malpighi, pointed out the manner in which the inquiry ought to be prosecuted, and thus laid the foundation of those laborious and interesting researches for which science is principally indebted to the German anatomists, and by which, within the last few years, the subject of the glandular organization has been so strikingly elucidated.*

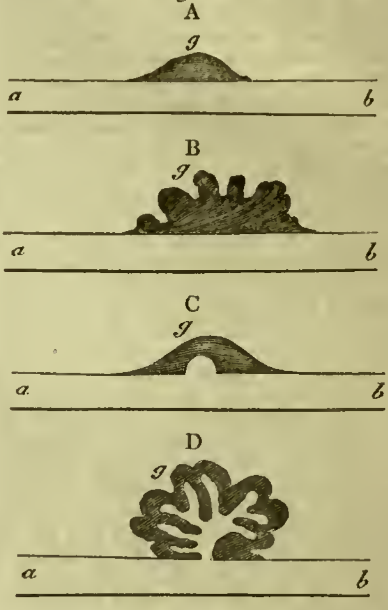
Development.—The investigations of Harvey, Malpighi, Rolando, Weber, Meckel, Bär, Valentin, Rathke, Müller, and many other anatomists, have very satisfactorily determined the manner in which the glands are in general developed. It is, however, necessary to premise that these observations principally *relate to those glandular organs which are appended to the alimentary canal*, especially the salivary glands, the pancreas, and liver; for as regards the development of those glands that are subordinate to the secretion of urine and to generation, comprising essentially the kidney and the testis, much uncertainty still prevails, although it is rather generally believed that the corpora Wolffiana, or false kidneys, are in some way or other connected with their primary formation.†

From the researches that have been made with so much care, we learn that, although there are many modifications of the formative process in the different classes of the glandular organs, there are yet certain fixed laws in obedience to which they are produced. As the development of the individual glands is, however, considered in the several articles on those organs, it is only requisite to describe in this place in a general manner, and without noticing the modifications of the general rule, the process of formation. In prosecuting this inquiry two different objects present themselves for examination,—the primitive substance in which the gland is developed, and the internal component parts, consisting essentially of the secreting tubuli and the bloodvessels.

1. Every gland is formed from a portion of the primary plastic and amorphous mass (*blastoderma*) of which the body of the embryo consists.

2. This mass is at first gelatinous, extremely delicate and diaphanous; it subsequently becomes thicker and less transparent. In the beginning it is solid, and in the case of those glands which are appended to the alimentary canal,—that is to say, the salivary glands, the liver, and the pancreas, (and the same laws are observed in the formation of the lungs,*) it appears as a projection on the mucous membrane. (*Fig.* 222, A.)

Fig. 222.



A plan designed to show the first origin of the glands.

a, b, alimentary canal; *g,* gland. (The letters have the same signification in A, B, C, D.)

3. In a short time this rounded mass begins to project on its external surface, and thus forms a number of lobes, or, as it were, little islands, which, by the continuation of the same process, become more and more numerous and smaller in size; and thus, according to the character of the gland examined, are at length formed all the minute lobes of which it consists. (*Fig.* 222, B.)

4. Simultaneously with this development of the outer surface of the plastic mass, but quite independently of it, a metamorphosis is going on within, by which the internal canals, which subsequently become the secreting tubes, are formed. In the first instance a hollow or cavity is noticed communicating with the tube of the intestine, and which subsequently becomes the principal or excretory duct. When it first appears it is a simple sac, (*fig.* 222, C,) but in proportion as the projections or lobes are formed on the external surface, lateral branches are added to the principal duct; and these again become more and more ramified, till an indefinite number of tubes are formed. (*Fig.* 222, D.)

* Journ. Comp. des Sc. Méd. xvi, p. 54, p. 57. P. 63. The honour of discovering the mode in which the glands appended to the alimentary passage are formed by *pushings-out* of that tube has been by Burdach improperly attributed to Rathke.

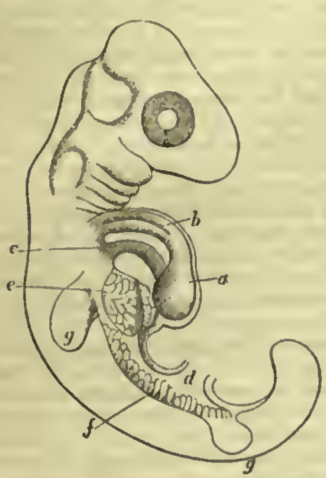
† It would be inconsistent with the perfection of the formative process to conceive that either the kidney or the testis requires the aid of any other glandular organ for their development; besides which it may be mentioned that there is no actual connexion between the above glands and the corpora Wolffiana. Rathke observes. " Although they (corpora Wolffiana) are not organically connected with the kidneys and genital organs, they appear to be, in an early period of the life of the embryo, the precursor or representative of the kidney." Burdach, II. Band. p. 646.

* Rathke, in Burdach's Phy. II. Band. p. 580, edit. 1837. Valentin, l. c. p. 501 et seq.

This development of cœcal tubuli is seen in the liver of *Limnæus stagnalis* in the embryo state, (*fig.* 223). In the embryo of *Lacerta viridis*, (*fig.* 224,) the rudimentary liver with its blind secreting canals (*e*) are observed; the elongated heart (*a*) furnishing the aorta (*b*) dividing into its right and left trunks, together with the principal venous trunk (c), are represented; *d* is the intestine, *f* the rudiment of the corpora Wolffiana, and *g g* the rudiments of the upper and lower extremities.

Fig. 223.

Fig. 224.



One of the most remarkable differences observed in the development of the several glands relates to the proportion between the mass of the primary plastic substance, and the extent and number of the contained tubes; thus, in the evolution of the liver there is seen a thick layer of the primitive matter; whilst, on the contrary, the parotid gland in the embryo of a calf two inches seven lines long, consists of a tube visible to the naked eye, and not at all covered by parenchyma.

5. The mode in which the secondary tubes are developed has been observed with great care; and it is distinctly established that *they do not proceed as mere elongations of the primary cavity*, but are formed in an independent manner. One of the latest writers on the development of the body, Valentin * has given a very exact account of the process in all the glands. He states that in the neighbourhood of the chief duct or of a branch of it, small oblong accumulations of the plastic mass are formed, which become hollowed in the interiur, and these hollows, *at first independent of the principal cavity*, subsequently communicate with it. It is also observed by Müller that in the kidney of Batrachian Amphibia, the secreting tubes first appear as vesicles which are formed before the ureter, and therefore independently of the principal duct.* As the tubes become more developed, the plastic substance around them, by acquiring greater firmness, constitutes their walls, and thus determines their exact form and limits. It is necessary to state that in every instance without an exception, the newly-formed canals end in cœcal extremities, which are often rather swollen, presenting a pedunculated appearance.

6. In proportion as the canals become formed in the substance of the plastic mass, this latter gradually diminishes in quantity, till ultimately, when all the tubuli are formed, it is so much reduced that it merely fills up the interlobular fissures, and is in fact converted into the interstitial cellular tissue.

7. At the same period of time that the tubes are thus being formed, the bloodvessels are being developed; and, as Müller and Valentin remark, a very close parallel is presented in the generation of these the essential parts of the gland. As in the case of the tubes, there are at first little masses, or islands, of the plastic substance, which subsequently join together, and their interior becoming liquified, a number of little channels are formed containing a circulating fluid, and which channels, by the subsequent consolidation of their walls, are at length formed into perfect bloodvessels. Like the tubes these vessels are at first independent; they afterwards open into larger trunks and ultimately into the heart. It is proper to remark that, although there is such a correspondence in the process of development in each instance, the bloodvessels are formed quite independently of the canals; that they occupy a different part of the plastic mass; and that they never present that continuity which ought at this epoch to have been very apparent, if the theory of Ruysch had been founded in truth.

8. The several glands are not developed equally early, some having their organization much more advanced than others; thus at the time when the pancreas is so far formed as to contain an immense number of canals, the parotid presents only a single duct or a few ramifications.† The principle which regulates the relative degree of development has evidently reference to the importance of the organ during the fœtal life; and in this respect the liver is most remarkable, for that body being, as I conceive, *the true decarbonising organ in the animal kingdom*, and therefore its functions being doubtless necessary in the fœtus, very quickly acquires a high degree of organization, so much so that, as we learn from all observations, it very speedily fills the greatest part of the abdomen.‡

* Loc. cit. p. 521, et alibi.

* De Gland. Struct. p. 87.

† Rathke in Burdach's Phy. II. Band. p. 576. Valentin, l. c. p. 225.

‡ In the embryo of a sheep five lines in length, Valentin has found the liver filling half of the abdominal cavity; and in the embryo eight lines long, that organ constitutes three-fourths of the bulk of the viscera contained in the peritoneum:

Lastly, The laws in obedience to which the glands are developed, are as universal as to their existence in the animal kingdom, as those which regulate the formation of the nervous, osseous, and vascular systems; and thus it may be noticed that the complex glands of man and the mammalia, such as the parotid, the pancreas, and the liver, pass, in the various epochs of their development, through those forms, which in the lower animals, and especially in the invertebrated tribes, constitute the permanent structure. It may also be stated, that when any particular gland first appears in the animal series, it presents the most simple structure, although the same gland in the higher classes acquires the highest degree of complexity. Thus, the liver in insects is tubular, and in many of the amphibia excavated into large cells; the pancreas in fishes consists of separate tubuli; the salivary glands of birds are extremely simple; so also are the mammary glands in the Cetacea, and the prostate glands in many of the Mammalia.

BIBLIOGRAPHY.—*Malpighi*, De visc. struct. cap. iii. p. 18, et alibi; De format. Pulli in ovo, p. 20. *Ruysch*, Opera omnia. tom. iii. *Haller*, Elem. Phys. ii. *Ferrein*, Mém. de l'Acad. Roy. des Sc. 1749. *Cuvier*, Leçons d'Anat. Comp. tom. iv. *Rolando*, Journ. Comp. des Sc. Méd. tom. xvi. The Treatises of *Bichat*, *Meckel*, and *Béclard* on Gen. Anat. *Müller*, De gland. secernent. struct. penit. Handb. der Phy. I. Band. p. 418. Trans. of ditto by Baly, vol. i. p. 441. *Burdach*, Phy. II. Band. edit. 1837, pp. 258, 264, 287, 376, 375, et alibi. This volume contains a large collection of the most important facts relative to the development of the several organs, V. Band. p. 36 et seq. *Kiernan* in Phil. Trans. 1833. *Valentin*, Handb. der Entwickelungs-geschichte, pp. 495, 514, 521, 533. *Baer*, De ovo Mammal., and in Burdach's Phy. *Carus*, Anat. Comp. par Jourdan, tom. ii. *Grant's* Lect. on Comp. Anat. in Lancet, 1833-34. *Blumenbach*, Man. of Comp. Anat. by Coulson. *Berres*, Die Mikroskopischen Gebilde des Menschlichen Körpers.

(R. D. Grainger.)

GLOSSO-PHARYNGEAL NERVE (*nervus glosso-pharyngeus*; part of the sixth pair of Galen and the older anatomists; part of the eighth pair of Willis; the ninth pair of Soemmerring and some of the modern anatomists). The glosso-pharyngeal, par vagum, and spinal accessory nerves were long considered as forming a single nerve. Willis first clearly pointed out the origin and course of the spinal accessory, separated it from the par vagum, and termed it the nervus accessorius. The glosso-pharyngeal appears to have been generally described at the time of Willis as a branch of the par vagum. The term glosso-pharyngeal was not applied to it until the time of Huber.* Previous to the time of Willis, however, some anatomists, more particularly Fallopius,† Eustachius,* Bauhinus,† had shown that this nerve was really not a mere branch of the par vagum. The same thing was stated, more or less strongly, by many subsequent anatomists, more particularly by Winslow,‡ Haller,§ and Vicq D'Azyr.‖

Soemmerring¶ and Andersch** were, however, the first who fairly separated the glosso-pharyngeal from the par vagum, and ranked it as a distinct nerve. The glosso-pharyngei form the ninth pair of Soemmerring's classification of the encephalic nerves, and were termed the eighth pair by Andersch. There can be no doubt that if we adopt the numerical method of naming these nerves, the glosso-pharyngei properly form the ninth pair. To avoid, however, all the misunderstanding which is apt to arise from the use of numerical names when applied to these nerves, the best designation for the nerve at present under our consideration is the glosso-pharyngeal, derived from its being principally distributed upon the tongue and the pharynx. I need scarcely state that, under the term eighth pair, as it is most generally used in modern writings, is included the glosso-pharyngeal, par vagum, and spinal accessory nerves.††

Origin.—The glosso-pharyngeal nerve arises by from two to six filaments from the restiform body of the medulla oblongata, closely upon the groove which separates the restiform from the olivary body. At its origin it is placed immediately above and in the same line with the par vagum nerve, and between it and the portio dura of the seventh pair. Its lower margin is generally separated from the upper margin of the par vagum by a few small bloodvessels.

From its origin it first proceeds outwards along with the par vagum and spinal accessory to reach the foramen lacerum posterius. Through the anterior and inner part of this foramen it escapes from the interior of the cranium, and is enclosed in a strong and separate sheath furnished by the dura mater.‡‡ In its passage through the foramen lacerum it is placed anterior to the par vagum and spinal accessory and the commencement of the inter-

(l. c. p. 517.) Similar observations have been made in other animals and in the human embryo by Meckel.

* Epistola Anat. de Nervo Intercostali, De Nervis Octavi et Noni Paris, &c. p. 17. Goet. 1744.

† Opera quæ adhuc existant omnia, p. 455. Francof.

* Explicatio Tabularum Anatomicarum Eustachii, tab. xviii. Bat. 1744.

† Theatrum Anatomicum, cap. xxiii. p. 659. Francof. 1605.

‡ Exposition Anatomique de la Structure du Corps Humain, tom. iii. p. 106. Amstel. 1743.

§ Elementa Physiol. tom. iv. cap. xxix. p. 231-2. Laus. 1562.

‖ Traité d'Anatomie et de Physiologie avec des planches coloriées, etc. No. iii. p. 56. Paris, 1786.

¶ De Basi Encephali et Originibus Nervorum, &c. in tom. ii. p. 97. Ludwig. Script. Neurol. Sel. Min. 1792.

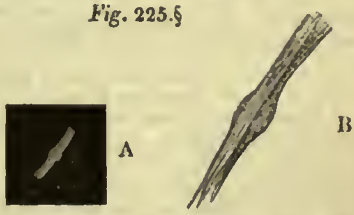
** Fragmentum Descrip. Nerv. Cardiac. in tom. ii. Ludwig. Sc. Neur. Sel. Min. p. 113.

†† Those who may wish to examine at greater length the literature of this nerve may consult Soemmerring Oper. Cit. p. 97, and more particularly Kilian Anatomische Untersuchungen über das neunte Hirnnervenpaar oder den Nervus Glosso-pharyngeus, p. 1-62. Pesth, 1822.

‡‡ According to Morgagni (Adversar. Anat. vi. Animad. xii.) and Wrisberg (De Nervis Pharyngis, in tom. iii. p. 52 Ludwig. Script. Neur. Sel. Min.) this septum separating the glosso-pharyngeal from the par vagum is sometimes osseous.

nal jugular vein, which lie in the order here enumerated. As the nerve issues from the lower part of the foramen lacerum it forms a small rounded chord, close to, but still quite separate from the par vagum, and is situated between the internal jugular vein and internal carotid artery. It now leaves the trunk of the par vagum, proceeds downwards, inwards, and forwards, passing in front of the internal carotid artery and behind the styloid muscles, and joins itself to the stylo-pharyngeus muscle. It runs at first along the lower margin of this muscle, and rests on the superior constrictor of the pharynx which separates it from the tonsil; it then mounts on the anterior surface of the stylo-pharyngeus muscle, and passes between it and the stylo-glossus to reach the base of the tongue, upon which it is ultimately distributed. Occasionally, instead of turning over the lower edge of the stylo-pharyngeus, it perforates this muscle. In following the course here described, it forms a slight curve, the convexity of which looks downwards, and it sends off several branches, which are principally distributed to the pharynx and isthmus of the fauces. These branches vary very considerably in size and in number in different subjects, but the general distribution of the nerve is in all cases nearly the same. When the branches are few in number, this is compensated for by their increased bulk, and when they are more numerous they are of diminished size. This nerve generally anastomoses with the par vagum within the cranium by a pretty distinct branch.* As the nerve lies within the foramen lacerum it presents two swellings or ganglia upon it, and gives off some small branches. The superior of these two ganglia is considerably smaller than the inferior, and has been termed the *ganglion jugulare* by J. Müller, (*fig.* 225). It is described by Müller† as generally present, though small, placed upon the posterior or external side of the nerve, and situated at the cranial end of the foramen lacerum. It can only be distinctly seen after the dura mater has been removed, and the upper margin of the opening chiseled away. I have repeatedly observed this ganglion jugulare in the human subject. In one case which I lately dissected, where it was comparatively large, very distinct, and presented undoubtedly all the appearance of a true ganglion, it appeared to me, after careful examination, that this swelling does not include the whole of the nerve, but is confined, as Müller states, to the posterior filaments. These posterior filaments do not seem to differ otherwise in appearance from the anterior. This ganglion was first pointed out by Ehrenritter, and mentioned by Soemmerring on his authority.‡ Very little attention seems to have been paid to this ganglion, so that when it was lately re-described by Müller,§ it was supposed that its existence in the human subject had been hitherto unknown.* Mayer, of Bonn, had, previous to this (1833), described two small swellings upon the root of the glosso-pharyngeal in the ox, but he failed to detect any similar ganglion in the human species. No nervous filaments either leave or join that part of the trunk of the nerve upon which the ganglion jugulare is placed. The inferior ganglion (ganglion petrosum, ganglion of Andersch) is considerably larger than the superior, is of an oblong shape, and includes all the filaments of the nerve. It is described by Andersch† as about five lines in length, and commencing about four lines below the place where the nerve perforates the dura mater. No doubt, if we include all that portion of the trunk of the nerve which appears to be somewhat increased in size, it may sometimes measure five lines, but the true gangliform enlargement is considerably less. As Wutzer‡ remarks, it is rarely found to exceed two lines in length. This ganglion lies in a distinct depression in the petrous portion of the temporal bone, which Andersch terms receptaculum ganglioli petrosi.

Fig. 225.§



Natural size. *Magnified about four times.*

Some branches both proceed from and join that portion of the nerve occupied by this ganglion petrosum. The most important of these is a small branch which proceeds from the ganglion into the tympanum (*ramus tympanicus nervi glosso-pharyngei;* nerve of Jacobson). The course and distribution of this branch were partly known to Schmiedal, Andersch, Ehrenritter, and Comparetti,‖ but were more fully

* Op. cit. p. 114.

† Handbuch der Physiologie des Menschen. Erster Band, p. 589.

‡ Arnold in Tiedemann's Zeitschrift für Physiologie, vol. ii. p. 175, and J. Müller, in his Archiv. für Anat. und Phys. &c. 1837. No. ii. p. 275.

§ In Vergl. Jahresbericht Von 1833, Archiv. für Anatomie und Physiol. 1834, p. 11.

* I find that Wutzer, in his Monograph "De Corporis Humani Gangliorum Fabrica atque Usu," p. 92, after describing the inferior ganglion of the glosso-pharyngeal, says, "secundarium ganglion quod nonnumquam adesse Ehrenritter contendit mihi non sub oculos cecidit."

† If Andersch is not to be considered the discoverer of this ganglion, it cannot be denied that he first gave a full and clear description of it. (Op. cit. p. 115.) Kilian (Op. cit. p. 30 and 75) contends that the existence of this ganglion was known to Winslow. In evidence of this he quotes the following sentence from his Exposit. Anatom. tom. iii. "les deux portions (nervus glosso-pharyngeus et nervus vagus) sont édroitement collées ensemble et communiquent de part et d'autre par des filamens qui grossissent un peu la petite portion (glosso-pharyngeal.)"

‡ Op. cit. p. 91.

§ [This figure is taken from a dissection by Mr. Walker in the Webb-street School of Anatomy. The Editor is indebted for it to the kindness of his friend Mr. Grainger.]

‖ Vide Müller's Archiv. für Anat. und Physiol. &c. No. ii. 1837. p. 281.

described by Jacobson.* The nervus tympanicus enters a canal in the petrous portion of the temporal bone, and there anastomoses with the Vidian and the carotid plexus of the sympathetic. The orifice of this canal is placed between the jugular fossa and carotid canal, and external to the termination of the aqueduct of the cochlea. The ramus tympanicus is figured and described by Arnold† as dividing into six filaments: 1. a filament to the fenestra rotunda; 2. one to the fenestra ovalis; 3. one which anastomoses with the sympathetic; 4. one distributed upon the Eustachian tube; 5. one, which he terms nervus petrosus profundus minor, anastomosing with the spheno-palatine ganglion; 6. one, the nervus petrosus superficialis minor, which anastomoses with a branch from the otic ganglion or ganglion Arnoldi. The nerve of Jacobson thus forms an anastomosis among the glosso-pharyngeal, the second and third branches of the fifth pair, and the superior ganglion of the sympathetic.‡ A small branch arises from the ganglion petrosum, as delineated by Arnold,§ which unites itself to the auricular branch of the par vagum.‖

Two other filaments are generally found connected with that part of the trunk of the nerve occupied by the ganglion petrosum. These are a communicating twig between the ganglion petrosum and ganglion of the par vagum, and an anastomosing filament of the sympathetic. As these filaments are very minute, and lie in a dense fibrous sheath, they can only be displayed by an exceedingly careful dissection. The communicating filament between these two ganglia of the glosso-pharyngeal and par vagum is short, and passes directly from the one ganglion to the other. The communicating filament from the sympathetic comes from the superior cervical ganglion, mounts up between the trunks of the par vagum and glosso-pharyngeal, and divides into two portions,—one of these connecting itself to the ganglion petrosum, the other to the ganglion of the par vagum. The course and mode of termination of this communicating filament of the sympathetic is represented differently by Wutzer¶ from the description here given. I have adopted that given by Arnold,** since it exactly agrees with my own dissections. Another branch has been described as arising from the ganglion petrosum immediately below the ramus tympanicus, and passing backwards behind the styloid process, to anastomose with the trunk of the facial after its exit from the stylo-mastoid foramen.* We here see that the anatomy of that portion of the glosso-pharyngeal nerve which lies within the foramen lacerum is very complicated, but it must be at the same time obvious that it embraces considerations of great interest in a physiological point of view.

What the true nature of these two ganglia is, we cannot at present venture positively to decide. I may mention, however, that Müller† states that he is satisfied, that the superior ganglion or ganglion jugulare resembles the Casserian ganglion upon the trigeminus or fifth pair, and those upon the posterior roots of the spinal nerves, for while one portion of the nerve swells into a ganglion, the other passes by without assisting in its formation. On the other hand, he believes that the inferior ganglion differs decidedly from those upon the posterior roots of the spinal nerves, and resembles the swelling which is occasionally found upon a nerve where it is joined by branches from the sympathetic. The ramus tympanicus, according to his view, belongs to the sympathetic system of nerves.‡

On escaping from the foramen lacerum the glosso-pharyngeal occasionally forms direct anastomoses with the par vagum, spinal accessory, and superior ganglion of the sympathetic; at other times it only anastomoses with these through its branches.

Digastric and stylo-hyoid branch. — The origin of this branch is far from being regular. It frequently arises from the external side of the nerve soon after its exit from the foramen lacerum. It ramifies, as its name implies, in the digastric and stylo-hyoid muscles. The filaments of this nerve anastomose in the substance of the digastric muscle with the digastric branch of the portio dura.§

Carotid branches are two or more in number, and pass from the convexity of the nerve or from some of its pharyngeal branches, and proceed upon the surface of the internal carotid, where they form a very evident anastomosis with the sympathetic, with the pharyngeal, and other branches of the par vagum, and assist in forming the plexuses around the carotid arteries. They have been traced downwards for a considerable extent, and found to anastomose with the superior and even with the middle cardiac nerves.

Pharyngeal branches.—The nerve next furnishes the pharyngeal branches, which are from two to four in number. The largest of these proceed downwards, and their ramifications can be traced over the whole of the pharynx, but more particularly over its upper and middle

* Acta Reg. Soc. Havniensis Medic. tom. v. Copen. 1818.

† Icones Nervorum Capitis, tab. vii. 1834.

‡ Cruveilhier (Anatomie Descriptive, tom. iv. p. 952, 1835) states that, in one subject he found this ramus tympanicus formed by two branches, one from the par vagum, the other from the glosso-pharyngeal. In another subject it was formed by a branch from the auricular of the pneumo-gastric united with one from the glosso-pharyngeal.

§ Op. cit. plates iii and v.

‖ It appears that the ramus auricularis of the par vagum was described even to both its branches by Comparetti, p. 129, De Aure Interna, &c.

¶ Op. cit. fig. vii.

** Op. cit. tab. iv.

* Cruveilhier, op. cit. p. 953. He looks upon this twig as the rudiment of a considerable branch of the facial, which he found in one case partly to replace the glosso-pharyngeal. See also tom. iii. p. 424.

† Archiv. für Anat. &c. No. ii. 1837, p. 276.

‡ Handbuch der Physiol. Erster Band.

§ Mr. Swan, in plate xvii. *fig.* 2 and 3, of his "Demonstrations of the Nerves of the Human Body," figures this communication as formed by a filament of the digastric branch of the facial going to join the trunk of the glosso-pharyngeal.

portions. One or generally more of these pharyngeal branches perforate the stylo-pharyngeus muscle, and can be traced partly downwards upon the middle constrictor, partly upwards upon the superior constrictor and mucous membrane of the fauces, and also partly forwards upon the surface of the tonsils. I have traced one of these pharyngeal branches through the posterior part of the hyo-glossus muscle into the mucous membrane at the side of the posterior part of the tongue. These pharyngeal branches, by their anastomoses with the pharyngeal branches of the par vagum and pharyngeal branches of the sympathetic, form what is called the *pharyngeal plexus of nerves.** A distinct swelling is frequently found over the internal carotid artery, formed by the confluence of the principal pharyngeal branches of the glosso-pharyngeus, of the superior pharyngeal branch of the par vagum, and the pharyngeal branches of the superior ganglion of the sympathetic. This swelling varies considerably in size and appearance. Hubert† describes a small ganglion in the pharyngeal plexus. Haase‡ shortly describes this swelling as a gangliform enlargement. Wrisberg§ states that a ganglion, of the size of the ophthalmic, is placed at the confluence of these nerves. Scarpa|| describes and figures it as a gangliform plexus more particularly connected with the pharyngeal branch of the par vagum. Wutzer¶ states that he has been unable to detect this pharyngeal ganglion. Kilian** and Arnold,†† but more particularly Kilian, figure it as a plexus. Though I would not deny the occasional existence of a small ganglion in this region, yet I believe it will be found that this swelling is generally formed by the cellular tissue binding together these branches as they anastomose with and cross each other.‡‡

Lingual branches.—After the trunk of the nerve has furnished the pharyngeal branches, it sends off from its concave side some small twigs upon the surface of the tonsils. It then forms the lingual portion of the nerve, passes into the base of the tongue below the stylo-glossus and posterior margin of the hyo-glossus muscle, where it divides into three or four branches. The superior of these is principally distributed upon the posterior part of the sides of the tongue, and sends some twigs backwards upon the palato-glossus muscle and mucous membrane of the fauces, where they anastomose with the other tonsillitic twigs. The middle part of the termination of the nerve passes through the lingualis and hyo-glossus muscles to reach the mucous membrane and papillæ at the side of the base of the tongue. The remainder of the nerve perforates the genio-hyo-glossus to reach the mucous membrane and papillæ in the middle of the base of the tongue. The distribution of these twigs is confined to the mucous surface at the base of the tongue, and do not extend beyond an inch in front of the foramen cœcum. They pass through the muscles of the tongue without giving any filaments to them.*

Tonsillitic twigs.—The different twigs of this nerve which we have described as passing to the tonsils, form an intricate plexus, posterior to and around these bodies, which has been called the *circulus tonsillaris.* These tonsillitic twigs are ultimately intermixed with the ascending filaments of the pharyngeal branch of the par vagum, and pass in considerable numbers to the isthmus of the fauces and soft palate. They anastomose also with the posterior palatine branches of the second branch of the fifth pair, and, according to Wrisberg,† with a filament from the third branch of the fifth.

In repeated dissections, both upon the human subject and the dog, I have found, in tracing the branches of this nerve to their ultimate distribution upon the pharynx and fauces, that those branches of the glosso-pharyngeal which do not anastomose with the pharyngeal branch of the par vagum are principally distributed upon the mucous membrane, and that comparatively a small number of these filaments seem to terminate in the muscular fibre. The uncombined twigs of the pharyngeal branches of the par vagum are, on the other hand, distributed entirely to the muscular fibre. In a dissection of this kind care must be taken to select those twigs only which proceed to their distribution without exchanging filaments with any other nerve. It can be made more favourably in the dog than in the human species. The glosso-pharyngeus is still distributed upon the tongue in birds, in the frog, and certain of the amphibia, while this organ receives no branch from the fifth pair, and from this circumstance it has been considered the nervus gustatorius of these animals.‡ In fishes there is a branch of the par vagum called glosso-pharyngeal, which escapes from the base of the cranium by a separate opening, and is distributed upon the gills, and also upon the tongue as far as the skin of the mouth.

Physiology.—It is only to the labours of anatomists and physiologists within the last few years that we are to look for any thing

* A small twig from the hypo-glossal nerve can sometimes be traced into this plexus. As the superior pharyngeal branch of the par vagum is partly formed by the spinal accessory, this last nerve must assist in the formation of this plexus.

† Op. cit. p. 18.

‡ De Nervo phreoico dextri lateris duplici, &c. Ludwig, tom. iii. p. 115.

§ Op. cit. p. 58.

|| Tabulæ Neurologicæ, plate 2.

¶ Op. cit. p. 91.

** Op. cit. tab. ii. fig. 5.

†† Op. cit. tab. iv.

‡‡ The glosso-pharyngeal in the dog is generally considerably increased in size where the principal pharyngeal branches are given off.

* In tracing these nerves, it has appeared to me that a few minute filaments terminate in the muscles of the tongue, but these are exceedingly few and small. The statement of Wrisberg, that the deep branches of the lingual portion of the glosso-pharyngeal are distributed to the muscles of the tongue, is opposed to the observations of the best anatomists, who have since his time examined the ultimate distribution of this nerve.

† Op. cit. p. 51.

‡ Handbuch der Physiologie, etc. Erster Band, p. 590, 772.

like accurate data in enabling us to judge of the functions of this nerve. Its deep situation, its proximity to important parts, and the consequent difficulty of exposing it in the living animal, have until very lately deterred physiologists from making it an object of experimental investigation. Some have supposed that it supplies the nervous filaments upon which the sense of taste at the root of the tongue depends, while the third branch of the fifth pair furnishes those of the anterior part of this organ. Mr. Mayo* states that "when this nerve is pinched in an ass recently killed, a distinct convulsive action ensues, apparently including and limited to the stylo-pharyngeus muscle and upper part of the pharynx." He concluded from this that the glosso-pharyngeal is in part, probably, a nerve of voluntary motion; and from its distribution upon the surface at the root of the tongue, that it is also partly a nerve of common sensation. Sir C. Bell believes that this is the respiratory nerve of the tongue and pharynx, associating the movements of those organs with the muscles of respiration in speech and in deglutition. And we find it stated by Mr. Shaw † that its power of combining the movements of the tongue and pharynx in deglutition "has been shown by several experiments, the results of which were very curious, and corroborative of the views deduced from comparative anatomy." Panizza ‡ has undertaken an experimental investigation into the functions of the nerve, and obtained very unexpected results.

From these we are led to believe that when this nerve is pricked in a living animal, this is attended by no indications of suffering and no convulsive movements; that section of both nerves is followed by loss of taste, while the tactile sensibility of the tongue and the muscular movements of deglutition and mastication remain unimpaired; that section of the fifth pair is on the contrary followed by loss of common sensation without any apparent effect upon the taste. From these and other experiments upon the nerves supplying the tongue, he concludes that the glosso-pharyngeal is the nerve upon which the sense of taste depends, and is therefore the true *gustatory nerve.* Dr. M. Hall and the late Mr. Broughton § had, from experiments performed previous to the publication of those of Panizza, arrived at the conclusion that this nerve is not a nerve of common sensation. These gentlemen likewise reported at the meeting of the British Association for 1836 an experiment, the results of which were in exact accordance with those obtained by Panizza upon this nerve, but no details of these experiments have yet been published. Mr. Mayo* has stated several objections to these conclusions of Panizza. He rests his grounds of dissent principally upon the fact that the distribution of this nerve is confined to the posterior part of the tongue; while the sense of taste, he maintains, is also present in the anterior part of that organ, and consequently it cannot, in that part at least, depend upon the glosso-pharyngeal. The persistence of the sense of taste after section of the fifth pair may, Mr. Mayo supposes, depend upon the palatine twigs of the second branch of the fifth pair distributed upon the palate and isthmus of the fauces. Mr. Mayo attempted to decide the matter by experiment, but he did not carry this sufficiently far to obtain any satisfactory results. Dr. Alcock † has also lately examined into the functions of this nerve experimentally, and has arrived at conclusions at direct variance with those of Panizza; for according to Dr. Alcock, when this nerve is exposed and irritated in the living animal, it excites pain and spasmodic contractions of the pharynx and muscles of the throat. When divided on both sides, the animal's taste, "to say the least of it, did not appear to be much affected." He believes that the sense of taste enjoys "two media of perception, and that these are the glosso-pharyngeal nerve and the lingual and palatine branches of the fifth." He also states that the muscular movements of deglutition are very much impaired after section of the nerve on both sides. He concludes, then, that the glosso-pharyngeal are sentient nerves, and also influence muscular motion. He, however, is doubtful in what manner these muscular movements are excited by irritation of this nerve, for though "disposed to regard the result in question as the effect of a sentient impression excited through the nerve, and referred to the interior of the pharynx," from the fact that this movement extends to muscles not supplied by this nerve, and forms an associated movement, he admits "that the circumstance may be as well explained by an exalted degree of muscular excitement, or by a higher one than that necessary to produce the simple starting." Professor Müller ‡ believes that an examination of the position of the ganglion jugulare will decide that the glosso-pharyngeal is a mixed nerve, and he maintains that the distribution of this nerve, partly for sensation (mucous membrane of the root of tongue), partly for the movements of muscles (stylo-pharyngeus and pharynx), exactly resembles that of the two roots of the nervus trigeminus. Unable amidst these discordant statements to come to any satisfactory conclusions upon the proper functions of this nerve, I entered into a lengthened experimental and anatomical investigation for this purpose. The experiments were twenty-seven in number, and were performed upon as

* Anatomical and Physiological Commentaries, n. ii. p. 11. 1822.

† London Medical and Physical Journal, vol. xlix. 1823.

‡ Edinburgh Medical and Surgical Journal, Jan. 1836, and Medical Gazette, Sept. 1835.

§ Fourth Report of British Scientific Association, and Mr. Broughton, in vol. xlv. of Edinburgh Medical and Surgical Journal.

* Medical Gazette, Oct. 1835, and 4th edit. of Outlines of Physiology, p. 314.

† Dublin Journal of Chemical and Medical Science, Nov. 1836.

‡ Archiv für Anat. und Physiol. etc. n. ii. 1837, p. 276.

many different dogs. Seventeen of these were upon the living animal, with the view of ascertaining if this nerve were to be considered both a nerve of sensation and motion, and what are the effects of its section upon the associated movements of deglutition, and on the sense of taste. The other ten were performed on animals immediately after they had been deprived of sensation, for the purpose of satisfying myself to what extent it was to be considered a motor nerve. The most remarkable effect witnessed in these experiments was an extensive convulsive movement of the muscles of the throat and lower part of the face on irritating this nerve in the living animal, provided the irritation was applied to the trunk of the nerve before it had given off its pharyngeal branches, or to one of these pharyngeal branches separately. These movements were equally well marked upon pinching the cranial end of the cut nerve after it had been divided at its exit from the foramen lacerum, as when the trunk of the nerve and all its branches were entire. In some of these experiments we observed a remarkable difference between the effects of irritating this nerve before and after it had given off its pharyngeal branches, which is valuable on this account, that it may explain the discrepancies between the results obtained by Panizza, Dr. M. Hall, and the late Mr. Broughton on the one hand, and Dr. Alcock on the other. For though I do not mean to affirm that pinching the lingual portion of the nerve is never followed by indications of suffering, (for from the irregularity in the origin of the pharyngeal twigs, and the difficulty of judging at the bottom of a deep wound in the living animal at what particular part these are all given off, it is generally impossible to decide where the lingual portion may be said to begin,) yet I have no hesitation in saying that if in several of these experiments we had operated only on that portion of the nerve which first presented itself, and not proceeded to dissect it backwards towards its place of exit from the cranium, we should have gone away with the impression that the irritation of this nerve was followed by no convulsive movements, and little if any indications of suffering.

From a review of all the experiments which I have performed upon the glosso-pharyngeal nerves, I am inclined to draw the following conclusions:—

1. That this is a nerve of *common sensation*, as indicated by the unequivocal expression of pain by the animal, when the nerve is pricked, pinched, or cut.

2. That mechanical or chemical irritation of this nerve before it has given off its pharyngeal branches, or of any of these branches individually, is followed by extensive muscular movements of the throat and lower part of the face.

3. That the muscular movements thus excited depend, not upon any influence extending downwards along the branches of the nerve to the muscles moved, but upon a reflex action transmitted through the central organs of the nervous system.

4. That these pharyngeal branches of the glosso-pharyngeal nerve possess endowments connected with the peculiar sensations of the mucous membrane upon which they are distributed, though we cannot pretend to say positively in what these consist.

5. That this cannot be the sole nerve upon which all these sensations depend, since the perfect division of the trunk of the nerve on both sides does not interfere with the perfect performance of the function of deglutition.

6. That mechanical or chemical irritation of the nerve, immediately after the animal has been killed, is not followed by any muscular movements when sufficient care is taken to insulate it from the pharyngeal branch of the par vagum. And we here observe an important difference between the movements excited by irritation of the glosso-pharyngeal and those of a motor nerve, for while the movements produced by the irritation of the glosso-pharyngeal are arrested as soon as the functions of the central organs of the nervous system have ceased, those from irritation of a motor nerve such as the pharyngeal branch of the par vagum, continue for some time after this, and when all connexion between it and the medulla oblongata has been cut off by the section of the nerve.

7. That the *sense of taste* is sufficiently acute, after perfect section of the nerve on both sides, to enable the animal readily to recognize bitter substances.

8. That it probably may participate with other nerves in the performance of the function of taste, but it certainly is not the special nerve of that sense.

The sense of thirst which is referred to the fauces and pharynx does not appear to depend entirely upon the presence of this nerve. The animals in which it was divided lapped water of their own accord. I observed one of those in which the nerves were found satisfactorily divided, rise, though feeble, walk up to a dish containing water, lap some of it, and return again to the straw upon which he was previously lying.

In all experiments upon the glosso-pharyngeal nerve in the dog, too great care cannot be taken to avoid the pharyngeal branch of the par vagum, which is sometimes situated in immediate contact with it, at other times one or two lines below it, and is frequently united to it by a considerable communicating branch, so that it may readily be mistaken for a large pharyngeal branch of the glosso-pharyngeal. This precaution is the more necessary, as I am confident that these two nerves differ from each other in function, and this must consequently seriously affect the results. I attribute the difficulty of deglutition after section of this nerve in the living animal, and the muscular movements on irritating it in the animal recently killed, observed by two of the preceding experimenters, to a want of sufficient precaution in separating these nerves from each other. These results were only observed by me when the pharyngeal branch of the par vagum was implicated in the experiment.

With regard to the argument in favour of the motal properties of this nerve, drawn by Müller from its anatomy, it appears to me that this analogical mode of investigation, valuable though it is, must be permitted to yield to the more positive observations obtained from experiment. And though it may be granted that the apparent limitation of the ganglion jugulare to the posterior filaments of this nerve causes it here to resemble closely the double roots of the spinal nerves, yet we must be wary in drawing analogies between the glosso-pharyngeal and spinal nerves, since we have another ganglion situated immediately below this, viz. the ganglion petrosum, which involves the whole of the nerve, and to this assuredly we have no analogical structure in the spinal nerves. No doubt Müller supposes that this inferior ganglion differs from those placed upon the posterior roots of the spinal nerves, and that it belongs to the sympathetic system. But as nothing like conclusive proof is advanced in support of this opinion, we may in the mean time reasonably suspend our belief as to the probable influence which this lower ganglion may exert upon the functions of the nerve.

Of course the fact that some of the filaments of the glosso-pharyngeal terminate in the muscular fibre, is no proof that these filaments are motal, for the muscular bundles have their sensitive as well as their motal filaments.

(John Reid.)

GLUTÆAL REGION, (Surgical Anatomy.) (Fr. *region fessiere.)* The glutæal region may be defined with tolerable precision to be all that space external to the pelvis which is covered by the glutæi muscles of each side. Its boundaries seem naturally to be the crista of the ilium above; behind, the mesian line as low down as the point of the coccyx; before, a line drawn from the anterior superior spinous process of the ilium to the trochanter major; and below, a line drawn from the point of the coccyx to the insertion of the glutæus maximus; in fact, the inferior margin of this muscle forms the boundary line. These limits, better defined than those of most of the anatomical regions, separate this tract from the lumbar and iliac regions above, from the superior anterior region of the thigh in front, from the perineal and posterior regions of the thigh below, and from the corresponding part of the opposite side at the posterior mesian line. This space, which does not comprise many points of importance in surgical anatomy, is yet not without interest. Here are the glutæal and ischiadic arteries, also the commencement of the course of the great sciatic nerve. The internal pudic artery also skirts along the inferior edge of the glutæal region, but this will be best considered as part of the region of the perineum.

The first thing that strikes us in the examination of this region is the great density and thickness of the integuments; they are inferior in this respect only to the sole of the foot. This density is, however, found greater proportionally in the true skin than in the cuticle, which retains much of the softness and pliability of the same covering in other parts of the body, and the end of this is evident, since whatever the pressure may be upon the glutæal parts, a dense state of the cuticle in any degree similar to the sole of the foot would, in the varied positions and movements of the trunk, be quite incompatible with comfort. On the other hand, the true skin, though pliant, is remarkably dense and strong, its fibres almost tendinous in structure, interlacing each other in every direction, and united underneath to a strong but rather loose cellular tissue which connects it to the glutæus muscle. It is to the laxity of this cellular connexion that the integuments of this part are partly indebted for that pliability which enables us to rest with ease and comfort upon surfaces of various degrees of hardness and inequality. It contains a considerable quantity of fat, which adds to the softness and elasticity of this cushion, and is very different from the granular hard fat found in the plantar region. The density of the integumental covering of the glutæal region varies somewhat in different parts. It is greatest where it covers the tuber ischii, and gradually diminishes on all sides except on the side next the perineum, where the change is very abrupt from its characteristic density to the extreme thinness and delicacy of the perineal covering. The peculiarity of structure of the integument covering the glutæi should be borne in mind by the surgeon in the treatment of diseases of this part. Abscesses should on this account be earlier opened from the obstacle thus presented to their pointing. It is on this account also, probably, that we so generally find abscesses here accompanied with sloughing of the cellular tissue, which is best obviated by an early opening.

The fleshy fibres of the glutæus maximus are covered by a somewhat denser stratum of cellular tissue, forming an aponeurosis distinct from the fascia lata of the thigh, though continuous with it at the anterior edge of the muscle, where the fascia lata lies upon the anterior half of the glutæus medius. The great glutæus is composed of coarse and loosely connected fasciculi, running in a direction downwards and forwards. It commences by a somewhat semicircular line of origin from the posterior two-thirds of the crista ilii, from the side of the sacrum and of the coccyx. From this origin the fibres run somewhat converging towards the great trochanter and upper part of the linea aspera. This direction of the fibres should be borne in mind in connexion with all remedial manipulations on this part, that the position in which the limb should be placed may be chosen most favourably for the relaxing of the muscle. The other muscles which are in this neighbourhood, and all of which move the thigh-bone, are so much smaller than this great muscle that the relaxing of this is of the first importance, and the position must be chosen with reference almost entirely to this.

On reflecting the glutæus maximus the following parts are brought into view:—1st, several large branches of arteries and veins, which were divided in reflecting the muscle, and which passed into the substance of the great glutæus muscle; these are from the glutæal and ischiatic arteries, and appear principally at the upper and posterior part of the glutæus medius; 2d, the whole of the glutæus medius, the posterior two-thirds of which had been covered by the larger muscle; 3d, at the posterior edge of the glutæus medius is the pyriformis muscle partly concealed by it, and coming out of the superior sacro-sciatic foramen; 4th, next below the pyriformis lie the two gemelli, with the tendon of the obturator internus between them, and below these is the quadratus femoris, having underneath it the strong tendon of the obturator externus; 5th, the great sciatic nerve is seen emerging from the superior sacro-sciatic foramen near the sciatic artery. Sometimes it comes out entirely below the pyriformis; sometimes it descends in two branches, one of which perforates that muscle, and they then unite. The trunk passes directly downwards, crossing the rotator muscles of the hip, and passing between the projecting tuberosity of the ischium and the trochanter major. In this part of its course it is accompanied by the sciatic artery, which is seen about half an inch to the internal or sacral side of the nerve, and sends one considerable branch to supply the nerve, and runs tortuously imbedded in its neurilema. The course which the nerve and artery here take will be represented by a line drawn from the posterior superior spinous process of the ilium to a spot midway between the tuber ischii and trochanter major. Lastly, in this view are exposed the bursal sacs, of which there are several between the glutæus maximus and the subjacent parts. The most considerable is found between it and the external surface of the trochanter major. A considerable but smaller one is placed between its broad tendinous expansion and the upper part of the vastus externus, and two smaller ones commonly between the muscle and the os femoris at the upper and back part of the thigh. The ischiatic artery at the commencement of its course is smaller than the glutæal, and comes down over the pyriformis muscle, and makes its exit from the pelvis through the lower part of the sciatic notch, between the pyriform and levator ani muscles, above the lesser sciatic ligament, and in front of the sciatic nerve; it sometimes passes between the roots of this nerve. On the dorsum of the pelvis the sciatic artery is covered by the glutæus maximus muscle, and may be seen by a similar dissection to that which exposes the glutæal artery, excepting that it is found about an inch and a half lower down than the last-named vessel.

The glutæal artery comes out of the pelvis at the upper part of the sciatic notch in company with the superior glutæal nerve and vein. It immediately winds upwards upon the dorsum ilii, keeping close to the bone, and shortly after its arrival upon the dorsum it divides into branches principally distributed to the glutæal muscles. To expose this artery and its branches in dissection, it is necessary to proceed as in the dissection of the glutæus maximus muscle. Next divide this muscle in a line from the posterior superior spine of the ilium to the tuberosity of the ischium. In making this dissection several large arteries and veins must be injured. If the edges of the muscle be now separated and the subjacent cellular membrane removed, the glutæal artery, accompanied by one or two large veins and by the glutæal nerve, may be seen escaping from the sciatic notch above the pyriform muscle, between it and the glutæus medius. This artery, as it escapes from the pelvis, lies three inches and a half from the mesian line, or from the spinous processes of the sacrum.

The glutæal and ischiadic arteries, as we have seen, are covered by the glutæus maximus muscle, and lie at such a depth from the surface that they are not very liable to injury. Wounds, however, of this part do occasionally implicate these vessels, either in their large branches or even the trunks themselves, and they have been affected with aneurism, an instance of which is mentioned by Mr. J. Bell,* and which attained a considerable size. In the case of a wound, its direction will lead us to the situation of the artery; and in the instance of aneurism just mentioned, Mr. Bell ventured to lay open the sac and thus reach the mouth of the glutæal artery, which he secured by ligature, and this perhaps might be accomplished in a very emaciated person; but generally speaking the artery lies so deep, and the vessels which must be wounded in making the necessary incisions would by their bleeding so obscure the operation, that the most experienced surgeons do not recommend the attempt under ordinary circumstances, but prefer the operation of tying the internal iliac.† As a guide, however, to the situation of the glutæal artery, whether in the examination of a wound or in operating upon it, its position on the dorsum of the pelvis may be ascertained by drawing a line from the posterior spinous process of the ilium to the middle of the space between the tuberosity of the ischium and trochanter major. If this line is divided into three, the glutæal artery will be found emerging from the pelvis at the juncture of its upper and middle thirds.‡

To return to the consideration of the anatomical structures which we expose in succession. We are struck with the difference in texture of the three glutæi muscles. The fibres of the two smaller glutæi are of moderate size and strength, while those of the larger glutæus are remarkable for their coarseness and large dimensions. The relative situation of the three muscles is also important. The position and direction of the glutæus maximus is just in that line in which the greatest vigour of action is required to erect the body by drawing the back part of the pelvis towards the trochanter major. In this operation it is assisted by the position of the glutæus medius and minimus,

* Principles of Surgery, vol. i. p. 421.

† See Med. Chir. Trans. vol. v. Also Guthrie on Diseases of Arteries, p. 364.

‡ See Harrison's Surgical Anatomy of the Arteries, vol. ii. p. 100.

the posterior fibres of which are covered by the glutæus maximus. These anterior fibres have a different action, varying in the different positions of the body in relation to the thigh, and, according to this, consisting either in rotation inwards, abduction, or flexion of the femur, or, this bone being fixed, assisting in the various anterior movements of the pelvis upon the thigh.

At the posterior edge of the middle glutæus is the pyriformis coming out of the upper opening of the sciatic notch. Here, as we have seen, the glutæal artery is also emerging from the pelvis and winding round the upper edge of the notch. This, therefore, will be the situation of an aneurism of this artery, and a pulsating tumour being detected in the situation just indicated by measure, as the seat of this vessel, will be a very strong ground for deciding both as to the disease and the vessel diseased. A case lately came under our notice of a very obscure character in which a swelling was situated precisely in the position of the glutæal artery, but without pulsation or any other symptom of aneurism. The swelling was at first indistinct, but as the surrounding parts wasted under the effect of disease it became more prominent. It was firm to the touch and rather moveable, and about the size of a hen's egg. But the principal part of the disease showed itself within the pelvis in a tumour consisting almost entirely of coagulum, as was proved by puncture, situated behind the rectum, and pressing it forward so as to occupy nearly the whole pelvis, and obstructing the passage both of fæces and urine. As there was no decided symptom of aneurism no operation was attempted for the relief of the case, and as the girl, who is eighteen years of age, still lingers, the nature of the disease is not yet cleared up. But this part also occasionally gives exit to a hernial tumour, part of the intestines or even the bladder or ovary becoming thus displaced and being lodged in the sac.* The superior opening of the sciatic notch is bounded above by the notch of the ilium, before by the descending ramus of the ischium, and below and behind by the superior sacro-sciatic ligament; and so large is the opening thus left that we might expect to find the protrusion of some of the viscera of the pelvis much more frequently than we do. Yet so completely is this part covered and defended by the pyriform muscle, the plexus of nerves, the glutæi maximus and medius, that this form of hernia is an extremely rare occurrence. When it does occur in the adult, the diagnosis is very difficult while the hernia is small, owing to the great depth at which it is situated. When, however, it is congenital, the nature of the swelling is larger in proportion to the size of the surrounding parts, and the depth of the superjacent parts less; yet even here Professor Schreger did not at first detect the nature of the swelling. In fact nothing but the actual feeling of the guggling of the gas of the intestines under the finger seems sufficient to discriminate the case, and this is of course not to be expected when the gut is strangulated. Indeed, in Dr. Jones's case* the symptoms were not at all referred by the patient to the true seat of the disease, and the surgeon was in consequence never led to make any external examination of this part. It may be well to state here the anatomical relations of the hernial sac in this case, which was carefully dissected. "A small orifice in the side of the pelvis, anterior to but a little above the sciatic nerve and on the fore part of the pyriformis muscle, led into a bag situated under the glutæus maximus muscle, and this was the hernial sac, in which the portion of intestine had been strangulated. The cellular membrane which connects the sciatic nerve to the surrounding parts of the ischiatic notch had yielded to the pressure of the peritoneum and viscera. The orifice of the hernial sac was placed anterior to the internal iliac artery and vein, below the obturator artery and above the obturator vein. Its neck was situated anterior to the sciatic nerve, and its fundus, which was on the outer part of the pelvis, was covered by the glutæus maximus. Anterior to but a little below the fundus of the sac, was situated the sciatic nerve, behind it the glutæal artery. Above, it was placed near the bone, and below appeared the muscles and ligaments of the pelvis."

We must not conclude this article without a few words on the general form of the glutæal region as affording an important means of diagnosis in disease. In examining this region in a healthy person we observe, 1st, the thick rounded prominence of the nates, formed by the posterior and inferior margin of the glutæus maximus; 2d, the projection of the trochanter major, only covered by the integuments and the thin tendon of the last-named muscle; 3d, the projection of the crista ilii, forming the upper boundary of the region; 4th, a depression, perpendicular in direction, between the nates and the trochanter major; 5th, another depression, slighter than the last and transverse in direction, between the trochanter and crista ilii.

Now almost all these points become altered in character and relation in disease. In dislocation of the femur they of course are changed by the difference in position which the trochanter assumes in common with the head of the bone; and according to the unnatural situation which this occupies, so will the alteration in the general form of the parts be modified. But we now speak particularly of the changes of disease. Even in the inflammatory stage of disease of the hip-joint, it is surprising how great is the effect produced upon the nates. The roundness and fulness gradually go, the nates looks wasted, and the depression between this and the trochanter disappears. This wasting, arising from interstitial absorption of the glutæus and parts adjacent, is the more striking as it occurs too rapidly upon the affection of the joint to be the effect of inaction of the

* See a summary of cases of ischiatic hernia in Cooper's First Lines of Surgery.

* See Sir A. Cooper on Hernia, part ii. p. 67.

muscle, as we have seen it occur in a marked degree in a rather severe attack of inflammation of the joint, which readily yielded to treatment.* Then in the more advanced stages of disease of the joint, the depressions above mentioned are not only lost, but from morbid depositions in the neighbourhood of the hip they become elevated and swollen, and the sharp prominences of the trochanter lost in the general fulness of the part.

(A. T. S. Dodd.)

GROIN, REGION OF THE, (Surgical Anatomy.) (Fr. *l'aine, region inguinale.*) The limits of this region, as understood by most surgical writers, seem to be wholly artificial. The groin constitutes the confines of the abdomen and the thigh; and Poupart's ligament forms a natural line of division between its femoral and its abdominal portions. A line drawn horizontally, the subject being erect, from the anterior superior spinous process of the ilium to the linea alba, forms the superior limit of this region, while below it may be defined by a line parallel to the former one, and extending from the pubis to the outer part of the thigh. For the particulars of this region, see HERNIA, FEMORAL ARTERY, ABDOMEN, and THIGH, REGIONS OF THE.

(R. B. Todd.)

HÆMATOSINE, (αιμα, *blood*, and πιπτω, *to fall.*) The colouring matter of the blood.† This principle separates with the fibrine of the blood when that fluid coagulates, and may be obtained free from adherent albuminous matter by the process recommended by Berzelius, which is as follows. The coagulum is first to be sliced in thin pieces with a sharp knife, and then carefully washed in separate portions of distilled water; by these means we separate the adherent serum, and if the washing is gently performed, but little hæmatosine becomes washed away with it. The slices thus prepared are placed on a filter and allowed to drain: when the draining is complete, the slices are to be thrown into a glass vessel and broken up in distilled water; we thus procure a solution of the colouring matter while any fibrine present gradually subsides. The liquor when poured off is a tolerably pure solution of hæmatosine. If it is wished to procure the principle in the solid form, the solution may be evaporated at a temperature not exceeding 100° Fahrenheit.

Engelhart prefers heating the solution after filtration to about 150° Fahrenheit, which determines the precipitation of the hæmatosine, while any albumen which may possibly exist in solution with it, remains dissolved at that temperature. Engelhart's process yields us hæmatosine in its purest form, but when thus obtained it is no longer soluble in water, whereas, if procured by evaporation at 100° Fahrenheit, it is still soluble, and what is very extraordinary, dry hæmatosine procured at that temperature, though it be afterwards subjected to a heat of 212° Fahrenheit, does not lose its property of dissolving in water. Hæmatosine may be described under two forms, viz. in solution and in the dry state.

The aqueous solution of hæmatosine is precipitated by alcohol and the acids. The alkaline hydro-sulphurets and sulphuretted hydrogen change the colour of the solution to green; nearly all the metallic and earthy salts precipitate it. Infusion of galls produces a pale red precipitate; gallic acid, however, does not show this effect. Chlorine passed through a solution of hæmatosine decolorizes it. Bromine produces a similar result, but it is some time before the effect is observed. Iodine will also decolorize the solution after some hours, and produces a brown precipitate, which is found to contain iodine.

Hæmatosine when dry is of a dark red colour and exceedingly hard, having a vitreous fracture. Its chemical properties in many respects resemble those of fibrine, and albumen in the coagulated state. Berzelius remarks that, like fibrine, it contains a fatty matter peculiar to itself which can be separated by ether; this is one point of resemblance in the opinion of that chemist. The action of acetic acid on hæmatosine is a very striking point of resemblance between that body and fibrine; for when the acid in the concentrated state is allowed to remain in contact with hæmatosine for a few hours, we observe that it is converted into a tremulous brown mass which is more or less soluble in water, and which during solution evolves nitrogen gas. The nitric, hydrochloric, and sulphuric acids, if diluted with an equal bulk of water, and digested on hæmatosine, become coloured yellow and disengage nitrogen; but they do not dissolve the principle even at a boiling heat. The results of such digestions, however, in the hydrochloric and sulphuric acids, are soluble in water; but that which has been digested in nitric acid remains insoluble.

Potash, soda, and ammonia dissolve hæmatosine with facility, and it is precipitated from such solution by the addition of an acid. The acetic acid acts thus, but re-dissolves the precipitate if added in excess, as it would albumen or fibrine.

Tannin precipitates hæmatosine from solution in alkalies.

Tiedemann and Gmelin have observed that boiling alcohol will dissolve hæmatosine; this is also the case to a considerable extent with its combinations with several of the acids which precipitate it. When hæmatosine is incinerated and decarbonized, it yields an ash amounting to 1.3 per cent. of its weight: this, according to Berzelius, is composed of the following substances:—

* There seems to be a law of the animal economy that when a joint is diseased the muscles moving it immediately lose tone and bulk, and there is no more marked symptom of disease of an articulation than this wasting of the muscles which belong to it.

† Lecanu considers that hæmatosine is a compound of albumen with a substance which he believes to be the true colouring matter of the blood, and which he calls *Globuline*.

Carbonate of soda, with traces of phosphate	0.3
Phosphate of lime	0.1
Caustic lime................	0.2
Subphosphate of iron	0.1
Sesqui-oxide of iron	0.5
Carbonic acid and loss........	0.1
	1.3

The ultimate analysis of hæmatosine approaches very nearly to that of fibrine. Michäelis declares to have found a difference of ultimate constitution between the colouring matter of arterial and venous blood: his analyses are as follows:—

	Arterial.	Venous.
Nitrogen........	17.253	17.392
Carbon	51.382	53.231
Hydrogen	8.354	7.711
Oxygen	23.011	21.666

It will be observed, on examining these analyses, that the difference of constitution is so small that we may reasonably conclude it has been produced by a difference in manipulation or some other extraneous cause capable of modifying the result: indeed, ultimate analyses of identical substances have, when in the hands of different chemists, often yielded results far more discrepant than these, and that too when each operator stood high as an analyst. Berzelius, in remarking on these experiments, observes that it is impossible for the chemist to fix the state of blood whether arterial or venous; for it will lose its condition with respect to the colouring matter long before the chemist can procure its hæmatosine for analysis. Thus the venous clot becomes of a bright red colour when exposed to air, and arterial blood soon loses its vermilion hue. A great contrariety of opinion exists as to the cause of the red colour of hæmatosine, some chemists supposing that the iron contained in it takes an active part in its coloration, while others maintain that though iron is present it cannot be considered as the cause of colour. Winterl imagined he had discovered the secret when he formed sulphocyanic acid (blut säure) by carbonizing blood with carbonate of potash and precipitated salt of iron with the lixivium—an experiment quoted by Treviranus; but we are unable to detect the sulphocyanic acid in blood, so this formation of a ferruginous colouring matter must not be considered as in any way assisting in the inquiry, although it simulates the tint of blood most completely. Fourcroy asserted that subphosphate of iron was capable of imparting a red colour to serum, which is not the case, and went so far as to declare that the colourless globules of the chyle contained neutral phosphate of iron, which, when mixed with the blood, was decomposed by the alkali present into a subphosphate, which on reaching the lungs became a per-salt and imparted colour to the fluid. This idea is quite hypothetical, and in discordance with facts as observed by other chemists.

Engelhart's experiments on hæmatosine tend to shew that iron is in some way influential in producing the red colour of the blood. He showed that, though albumen and fibrine yielded no iron on incineration, the metal existed in considerable quantity in hæmatosine. He found that a solution of red particles impregnated with sulphuretted hydrogen became of a violet colour and then passed to a green, it being impossible to restore the original red tint. Chlorine when passed through the solution bleached it, having previously produced a green colour; when decolorization was complete, white flocculi were observed to fall, which on being examined yielded no appreciable ash, while the clear solution gave evidence of iron by the usual reagents. The white flocculi were supposed by Engelhart to be the colouring matter changed to white by the abstraction of its iron. It is evident that even if the colour of the blood were owing to some peculiar animal matter and not to iron, we should still expect decolorization by chlorine; but yet the change of colour from red to green which that re-agent produces previous to decolorizing the solution, renders it probable that its action is on iron in some form of combination as yet unknown. Rose has shown that many organic matters interfere with the action of the tests for iron when present in solution with that metal, and quotes this to account for the failures in procuring the reactions of iron from the blood in a fluid state. Some experiments of Berzelius, however, have proved that the artificial combinations of iron with albumen which Rose formed, can be precipitated by ferrocyanate of potassa if they are previously treated with acetic acid: as this does not happen with blood, it is very properly contended that Rose's experiments are not to be looked upon as an explanation of the difficulty. In a paper published by Mr. Brande in the Philosophical Transactions for 1812, that gentleman proposes to consider hæmatosine as an animal dye, which like cochineal is capable of uniting with metallic oxides; thus the oxides of mercury and tin are active precipitants of this colouring matter, and woollen clothes previously impregnated with a solution of bichloride of mercury have been permanently dyed by steeping them in a solution of hæmatosine. The question as to whether or not iron be really necessary to the existence of the red colour of the blood cannot be considered as determined, and it is difficult to imagine any line of experimenting which could afford results sufficiently satisfactory to settle the point. Mr. Brande's experiments, by which he concluded that hæmatosine contained iron in no greater proportion than fibrine or albumen, would have placed the matter beyond doubt if other chemists had confirmed his observations; but the experiments of Dr. Engelhart published in 1825, and which have received very general confirmation, show that fibrine and albumen when pure contain no iron, and that the metal exists in considerable quantity in hæmatosine.

(G. O. Rees.)

HAIR. See TEGUMENTARY SYSTEM.

HAND, BONES OF THE, (Human Anatomy.) The hand (χειρ, *manus*; Fr. *la main*; Germ. *die Hand,*) is the inferior segment of the upper extremity. Its presence is characteristic of man and the Quadrumana.

Although formed on the same general type, the hand will be found to exhibit many points of difference from the foot—characters strongly indicative of the diversity of use for which it is designed. In examining the skeleton of the hand, we observe subdivisions analogous to those which exist in the foot—the *carpus* corresponding to the tarsus, the *metacarpus* to the metatarsus, and the *phalanges* of the fingers in every way analogous to those of the toes. Independently of the lightness and mobility which are such prominent features in the mechanism of the hand, when contrasted with that of the foot, the divergence of the first or radial finger *(the thumb)* from the line of direction of the other four, is peculiarly characteristic of the hand. Whilst the four fingers, properly so called, are parallel to the middle line of the hand, the thumb, when extended, forms with it an angle of rather more than 45°. To this position of the thumb is due in the greatest part the facility of opposing it to one of the fingers, a movement so necessary in the prehension of minute objects.*

The general form of the hand is oval, the obtuse extremity corresponding to the tips of the fingers, the unequal lengths of which occasion the curvature in this situation. On its posterior surface or *dorsum*, the hand is convex; on its anterior surface or *palm*, it is concave: both these surfaces correspond to, and in the recent state are supported by, the bones of the carpus and metacarpus.

I. *Carpus* (Germ. *die Handwurzel)*. The carpus bears a much less proportion in size to the whole hand than the tarsus does to the foot; it forms scarcely more than one-fourth of the hand. Its outline is oval, the long axis being transverse: if examined in a hand to which the ligaments are attached, the carpus will be found to form the posterior and osseous portion of an osseo-ligamentous ring, which gives passage to the tendons of the fingers. It is consequently hollowed from side to side, and is bounded on each side by a bony ridge, which gives attachment to the ligament *(annular ligament)* which forms the anterior part of the ring; on the radial side the ridge is formed by a process of the os trapezium and of the scaphoid; on the ulnar, where there is a more prominent ridge, by a process of the unciform bone, and by the os pisiforme.

Seven bones, arranged in two rows, form the carpus. The superior row consists of the *os naviculare*, *os lunare*, and *os cuneiforme*, to which last is articulated a bone, constantly reckoned as a carpal bone, but which, I conceive, may be more correctly regarded as a sesamoid bone, the *os pisiforme*. The second or inferior row is formed by the *os trapezium*, *os trapezoides*, os *magnum*, and *os unciforme*.

1. *Os naviculare (os scaphoideum*; Fr. *le scaphoide*; Germ. *das Kahnbein)*. The navicular or scaphoid is the largest of the upper row, and likewise the most external. Its superior surface is convex, oval, with long axis transverse, articular, and is adapted to the outer part of the carpal articular extremity of the radius. The hollowed surface, to which it owes its name *(boat-like)*, is directed downwards and inwards; this is likewise articular and receives the head of the os magnum: continuous with and to the inner side of this hollow surface, there is a plane one of a semilunar form, with which the os lunare is articulated. The scaphoid bone articulates with the trapezium and trapezoides, by a convex surface directed downwards and outwards. Externally this bone terminates in a pointed extremity which receives the external lateral ligament of the wrist-joint and the annular ligament *(tuberculum ossis navicularis*, s. *eminentia carpi radialis superior)*. The anterior and posterior surfaces of the bone are rough, and give attachment to the anterior and posterior radio-carpal ligaments.

2. *Os lunare, (os semilunare* v. *lunatum*; Fr. *le semilunaire*; Germ. *das Mondbein)*, situated between the scaphoid and the cuneiform bones, it presents four articular surfaces; an upper one, convex and somewhat triangular in its outline, articulated with the radius; an inferior one, very much hollowed from before backwards (to the crescentic form of which the bone owes its name), articulated with the os magnum; an external surface, plane and square, adapted to the cuneiform bone; and, lastly, an internal surface, by which it articulates with the scaphoid.

3. *Os cuneiforme (os triquetrum* s. *pyramidale*; Fr. *le pyramidale*; Germ. *das dreiseitige Bein)*. This bone terminates the superior carpal row on the ulnar side; its upper surface is partly smooth, encrusted with cartilage in the recent state, where it is in contact with the triangular ligament of the wrist-joint, and partly rough where it gives attachment to ligaments. Externally it articulates with the cuneiform bone, and inferiorly with the unciform by a large and concave suaface. The inner half of its anterior surface articulates with the pisiform bone, and the radial half of the same surface is rough for ligamentous insertion.

The three bones just described, constituting the superior row of the carpus when united, present on their superior aspect a convex articular surface which forms the carpal portion of the radio-carpal joint, the scaphoid and lunar being articulated with the radius, while the cuneiform glides upon the triangular cartilage of the wrist.

4. *Os pisiforme* (from *pisum*, a pea; Fr. *le pisiforme*; Germ. *das Erbsenbein)*. This little bone projects at the anterior part of the ulnar extremity of the superior carpal row; it forms what some anatomists designate *eminentia carpi ulnaris superior*, being part of the bony ridge already referred to on the ulnar side of the carpus. The prominence produced

* See the prefatory observations to the article FOOT.

by this bone is easily felt during life, more especially during flexion of the wrist-joint. It is round every where, except posteriorly, where it presents a flat circular surface, by which it is articulated with the cuneiform bone. This bone is intimately connected with and as it were inclosed in the terminal portion of the tendon of the flexor carpi ulnaris.

5. *Os trapezium (os multangulum majus;* Fr. *le trapeze;* Germ. *das grosse vielwinkliche Bein).* This bone is situated at the radial extremity of the inferior carpal row, having the scaphoid above it and the metacarpal bone of the thumb below it. We may describe six surfaces upon it, four articular and two non-articular. *a.* A large articular surface, situated on the external and inferior aspect of the bone. This surface is for articulation with the metacarpal bone of the thumb: it is somewhat oval in form, the long axis passing from without inwards and downwards; in this direction it is concave, from before backwards it is convex. The three remaining articular surfaces are on the internal and superior aspects of the bone. *b.* Internally, a very small plane surface, adapted to a corresponding one on the radial side of the carpal extremity of the second metacarpal bone. c. Above the last described surface and separated from it merely by a slight ridge, we find one of a somewhat triangular form and slightly concave, articulated with the radial side of the trapezoid. *d.* Quite on the superior aspect a small semicircular surface, adapted to the scaphoid. Of the non-articular surfaces, one is on the palmar aspect of the bone, and is easily distinguished by the prominent ridge or tubercle at its outer part, which gives attachment to the annular ligament, *(tuberculum, eminentia carpi radialis inferior;)* and on the ulnar side of this ridge a groove in which the tendon of the flexor carpi radialis glides. The second non-articular surface is on the dorsal aspect: it is more extensive than the last, rough and tuberculated, affording insertion to ligaments.

6. *Os trapezoides (os multangulum minus;* Fr. *le trapezoide;* Germ. *das Kleine vielwinkliche Bein).* This is the second bone of the inferior carpal row; it has the os trapezium on its radial and the os magnum on its ulnar side, the scaphoid above and the second metacarpal bone below it. We describe four articular surfaces and two non-articular. *a.* The inferior one the largest, quadrilateral, much narrower in front than behind, convex from side to side, slightly concave from before backwards, is entirely devoted to articulation with the second metacarpal bone. *b.* On the radial side, a slightly convex surface for the trapezium. c. Superiorly a quadrilateral concave surface for articulation with the scaphoid. *d.* On the ulnar side a very small surface, adapted to a corresponding one on the radial side of the os magnum. The palmar surface is non-articular, five-sided, slightly excavated, and rough from the insertion of ligaments. The dorsal surface, also non-articular, is of greater extent, convex, and likewise rough.

7. *Os magnum (os capitatum;* Fr. *le grand os;* Germ. *das Kopfbein).* This bone is, as its name implies, principally characterized by its excess in size over the other carpal bones, and from the number of bones with which it is connected, it may be regarded as the key-bone of the carpus. Superiorly it is in the form of a rounded head *(capitulum)*, flattened on the ulnar side, where it articulates with the unciform bone. The superior prominent portion of this head is received into the excavation of the lunar bone, and by its radial side it articulates with the inferior hollow surface of the scaphoid. The inferior portion of the bone is cuboid, and has been called *the body;* it is rough and convex on its palmar surface, also rough but irregular on its dorsal, both these surfaces affording insertion to numerous ligaments. Inferiorly we notice an extensive articular surface, which is adapted in the centre to the third metacarpal bone, on the radial side to the second, and by a very small portion on the ulnar side to the fourth metacarpal bone. On the ulnar side of its inferior portion it articulates a second time with the os unciforme by a small circular articular surface, the circumference of which nearly equals that of the flat surface of a split pea. Lastly, on its radial side it articulates with the trapezoid bone. Thus the os magnum articulates with seven bones; three metacarpal bones, two carpal bones in the inferior row, and two in the superior row.

8. *Os unciforme* (from *uncus*, a hook, *os hamatum;* Fr. *l'os crochu ou unciforme;* Germ. *das Hakenbein, oder Keilformiger Knochen).* This bone has received its name from that which allows of its being easily distinguished from all the carpal bones,—namely, the hooked process, which projects from the radial edge of its palmar surface. This process constitutes a considerable prominence on the ulnar side of the carpus *(eminentia carpi ulnaris inferior)*, and affords insertion to the annular ligament. Its concavity looks towards the radial side of the carpus; the remainder of the palmar surface is rough for ligamentous insertion. The dorsal surface is likewise rough, convex, and of considerable extent. This bone articulates inferiorly with the fourth and fifth metacarpal bones, on its radial side with the os magnum, and on its superior surface with the cuneiform bone.

Structure of the carpal bones.—These bones are chiefly composed of the reticular osseous tissue, to which their extreme lightness is attributable, the surface being invested by a thin layer of compact texture, in this respect perfectly resembling the bones of the tarsus.

Developement.—The carpal bones are very late in their developement; at birth they are completely cartilaginous. According to Cruveilhier, each bone is developed by a single point of ossification. The os magnum and os unciforme are the first in which the ossific process commences, about the end of the first year; between the third and fourth years it begins in the cuneiform, a year later in the trapezium and lunar, and between the eighth and ninth years in the scaphoid and trapezoid bones. The ossification of the pisiform does not begin till between the twelfth and fifteenth years, and Cruveilhier states that of all the bones of the skeleton it is the last in which the process of ossification is completed.

II. *Metacarpus* (Germ. *die Mittelhand*). Five bones constitute the metacarpus, the four internal ones being parallel to each other, the external one diverging outwards at an acute angle with the middle line of the hand. These bones vary in length from about two inches and a half to one inch six-eighths. They articulate inferiorly with the superior or metacarpal phalanges, and superiorly with the carpus.

Each metacarpal bone presents two extremities, and a shaft or body between them. The *superior* or *carpal* extremity is expanded and wedge-shaped, the broader part being towards the dorsal aspect. Three articular surfaces exist on each; one, the most extensive, on the superior or carpal surface, for articulation with a carpal bone; the other two on the radial and ulnar surfaces, adapted to the adjacent metacarpal bone or to a carpal bone. The palmar and dorsal surfaces are rough and irregular, and afford insertion to the ligaments which strengthen the carpo-metacarpal joints. The *inferior* or *digital* extremity is in the form of a rounded head, flattened on each side, where we notice a depression, and behind it a tubercle which affords insertion to the lateral ligament of the joint. The smooth articular surface of the head extends further upon the palmar surface of the bone than upon its dorsal surface, or, as in the case of the metatarsal bones, more on the side of flexion than on that of extension. The *shaft* or *body* is prismatic and slightly curved, so as to present a concavity towards the palmar surface, and a convexity to the dorsal.

The metacarpal bones are numbered from without inwards. The *first*, or that of the thumb, is the shortest of all and likewise the thickest. Its carpal extremity will likewise serve to distinguish this bone; it wants the cuneiform shape, and is rather wider on its palmar than its dorsal surface. It has no articular facets on its sides, being articulated with the trapezium alone by means of a surface which is concave from before backwards, and convex from side to side; the body of this bone is flatter on its palmar and dorsal surfaces than any of the others.

The *second* metacarpal bone is the longest; it, however, exceeds the third by a very slight difference. It is further distinguished from the third by the diminutive size of the articular facet on the radial side of its carpal extremity.

The *third* metacarpal bone, though shorter than the second, is manifestly thicker and stronger; this excess of developement being attributable to its affording insertion to one of the most powerful muscles of the hand,—namely, the adductor pollicis.

The *fourth* and *fifth* metacarpal bones are shorter and in every way smaller than the preceding ones. The fifth is shorter and somewhat thicker than the fourth: it has no articular facet on the ulnar side of its carpal extremity, but presents a prominent tubercle in that situation for the insertion of the extensor carpi ulnaris.

The *structure* of the metacarpal bones is the same as that of the long bones in general.

Developement.—There are two points of ossification for each metacarpal bone, one for the body and the carpal extremity, the other for the digital extremity. The first metacarpal bone, however, according to Cruveilhier, offers an exception to this, inasmuch as its carpal extremity is developed from a point of ossification distinct from that of the body. In some instances there are three points of ossification for each metacarpal bone. The bodies of the metacarpal bones are completely ossified at birth. Between the second and third years appear the points for the inferior extremity in the four inner bones and the superior extremity in the first, but the complete fusion of the extremities with the shafts does not take place till near the twentieth year.

III. *Fingers (digiti;* Fr. *les doigts;* Germ. *die Finger).* The fingers differ strikingly from the toes as regards their length, to which, indeed, is due their greater mobility. They are numbered in proceeding from the radial to the ulnar side of the hand. All except the thumb are composed of three phalanges, the *superior* or *metacarpal*, the *middle*, and the *inferior* or *ungual:* in the thumb the middle phalanx is absent. The fingers differ considerably in length; the thumb is by far the shortest, and the middle finger is the longest. Next in length is the ring finger, then the index, and last and least the little finger.

The *metacarpal* phalanges have the following general characters:—1st, a body slightly concave from above downwards on the palmar surface, and convex on the dorsal; 2d, a superior or metacarpal extremity more expanded than the inferior, hollowed into an articular surface for the head of the metacarpal bone; and 3d, an inferior extremity, having a pulley-like surface for articulation with the middle phalanx. The metacarpal phalanges are the longest.

The *middle* phalanges present the same characters as the preceding as regards the body. The superior extremity has a pulley-like articular surface, *convex* transversely; that of the inferior extremity being *concave* in the same direction.

The ungual phalanges are readily distinguished by the inferior or ungual extremity, which is rough, non-articular, horseshoe-shaped, with the convexity directed downwards. It is this part of the bone which supports the nail. The superior extremity is articulated with the middle phalanx by a pulley-like surface, concave transversely. The ungual phalanx of the thumb is considerably larger than that of any of the other fingers.

In point of structure and developement the phalanges scarcely differ from the metacarpal bones. There are two points of ossification, one for the body and inferior extremity, the other for the superior extremity. This last is late in making its appearance, not until between the third and seventh year, while the ossification of the body commences at an early period of intra-uterine life.

Although the perfect prehensile hand is peculiar to man and the Quadrumana, the inferior segment of the anterior extremity will be found to possess many interesting analogies throughout the mammiferous series. On this point we refer to the articles OSSEOUS SYSTEM (Comp. Anat.) and SKELETON.

JOINTS OF THE HAND.

Joints of the carpus.—The bones constituting each row of the carpus are firmly connected by strong ligaments, so that their combined surfaces form one extended surface adapted to the radius, or to the metacarpus, or to each other. Thus the union of the superior articular surfaces of the upper carpal row constitutes the convex surface that contributes to the formation of the wrist-joint, whilst the united inferior articular surfaces of the same row are adapted to the united superior surfaces of the inferior carpal row. Again, the inferior articular surfaces of this last row enter into the formation of the carpo-metacarpal joints.

The several articulations of each row are strengthened by two sets of ligaments, one on the palmar, the other on the dorsal surface of the joints, *palmar and dorsal ligaments;* they extend transversely from one bone to the other. The palmar ligaments are considerably stronger than the dorsal. The synovial membranes which exist in these small articulations are merely offsets from the large synovial membrane which is interposed between the two rows of the carpus.

In the articulation between the scaphoid and lunar bones, as well as in that between the lunar and cuneiform, we observe a remarkable fibro-cartilaginous lamina interposed in the whole extent of each articulation from before backwards, although not extending over the entire articular surfaces. These laminæ are readily seen on opening the radio-carpal joint in the interval between the bones above mentioned; they are attached to the palmar and dorsal ligaments by their anterior and posterior extremities. When dissected out they will be found to be wedge-shaped, the thick edge being directed towards the wrist-joint, and adherent to the synovial membrane of that joint. These laminæ are described by most anatomists as ligaments, under the name of *interosseous ligaments.* Of their fibro-cartilaginous nature, however, I have no doubt from repeated and careful examinations; they may therefore be more correctly denominated *interosseous fibro-cartilages.* Feeble interosseous ligaments exist on either side of the os magnum between it and the unciform on one side, and the trapezoid on the other; they are best seen when these bones are torn from each other.

Articulation of the two rows of carpal bones to each other.—The superior articular surfaces of the four bones composing the inferior carpal row are adapted to the inferior articular surfaces of the scaphoid, lunar, and cuneiform bones. The head of the os magnum and the superior articular surface of the unciform bone form a prominent convexity, which is received into a deep concavity formed on the ulnar side by the cuneiform bone, on the radial side by the scaphoid, and in the centre by the lunar bone; whilst external to the projection of the os magnum, a superficial oblong concavity receives the convexity on the inferior and outer surface of the scaphoid. Thus the line of this articulation has somewhat of the course of the roman S placed horizontally, ∽. That part of the articulation which is to the ulnar side, then, partakes more of the nature of enarthrodia or ball and socket joint, while that to the radial side is arthrodia with almost plane surfaces.

This articulation is strengthened in front by an *anterior* or *palmar* ligament which is of considerable strength and thickness. Most of the fibres of this ligament are attached inferiorly to the palmar surface of the os magnum, whence they diverge to be inserted into the scaphoid, lunar, and cuneiform bones; some few fibres extend from the trapezoid and trapezium to the scaphoid, and from the unciform to the cuneiform. Behind we find a *dorsal* ligament, also strong, although much less so than the palmar. This ligament extends obliquely from the bones of the first row to those of the second, but is stronger on the ulnar than on the radial side. The extent and connexions of both these ligaments are best seen when the joint is opened, by cutting through the dorsal ligament to view the palmar, and vice versa. The ligaments called *lateral* by some anatomists are merely the continuation of the lateral ligaments of the wrist-joint; nor do those described by Cruveilhier under the name of *glenoid ligaments* deserve to be separated from the anterior and posterior, of which they constitute that portion most intimately connected with the anterior and posterior notches of the hollow cavity in which the head of the os magnum is lodged.

In opening this joint in the manner already described, it will be seen how extensive is its synovial membrane. It extends some distance on the palmar and dorsal surfaces of the neck of the os magnum, and sends two processes between the bones of the first row (between the scaphoid and lunar, and the lunar and cuneiform), and three processes between those of the second row, (one on each side of the os magnum,) and one between the trapezium and trapezoid.

Motions of the carpal articulations.—An examination of the dissected carpus will at once show how limited are the motions between any two of the carpal bones of each row. The movement of one row upon the other, however, is more extensive, but only in the direction of flexion and extension, the former being considerably greater in consequence of the less resistance of the dorsal ligaments. Solidity and strength, a power of resistance to violence which might easily occasion fracture, were the carpus one solid bone, are gained by the number of small bones of which it is composed, the arthrodial form of its articulations, and the strong ligaments by which the motions of these joints are restricted.

Articulation of the pisiform bone.—The pisiform bone is so little connected with the mechanism of the carpus that its articulation with the cuneiform bone demands a separate consideration. A plane oval surface on the posterior part of the pisiform is articulated with a corresponding one on the palmar aspect of the cuneiform, and several strong ligaments strengthen the joint. Two lateral ligaments pass from the pisiform to the cuneiform bone, the internal, which is also anterior, being of considerable strength. This bone is further connected to the unciform by strong ligamentous fibres; and a strong bundle, which bears the same relation to the tendon of the flexor carpi ulnaris as the ligamentum patellæ does to the tendon of the rectus femoris, extends to the carpal extremity of the fifth metacarpal bone. This joint is provided with a loose synovial membrane; its motions are those of gliding in the directions of the axis of the articular surfaces.

Carpo-metacarpal joints.—These are very strong articulations, and, with the exception of the first and fifth, enjoy a very limited extent of motion. The four internal ones are nearly planiform arthrodiæ, restricted on the palmar and dorsal surfaces by strong and short ligaments *(palmar* and *dorsal ligaments)*, the latter being much better developed. The *second* metacarpal bone is articulated with the trapezoid in an extremely firm manner: its *palmar* ligament extends from the extremity of the metacarpal bone to the trapezium internal to the ridge, and covered by the tendon of the radial flexor of the wrist. There are three *dorsal* ligaments, an external attached to the trapezium, and an internal to the os magnum. These two ligaments are oblique in their direction; the third or middle one is vertical and attached to the trapezoid. The *third* metacarpal bone is articulated with the os magnum: here we find three strong *palmar* ligaments, an external one which extends obliquely outwards to the trapezium, an internal one which passes in front of the carpal extremity of the fourth metacarpal bone, adhering to it, and inserted into the unciform and the fifth metacarpal bone, and a middle one which passes vertically to the os magnum. This joint has two dorsal ligaments, both inserted into the os magnum. The *fourth* metacarpal bone is articulated with the radial portion of the inferior articular surface, and with a very small portion of the os magnum; it has a single palmar and dorsal ligament. The *fifth* metacarpal bone is articulated with the outer part of the inferior surface of the unciform; this surface is convex transversely and concave from before backwards, while that on the metacarpal bone is convex from before backwards and concave transversely. The proper ligaments of this joint are very feeble, being merely a few fibres attached to the anterior and posterior surfaces of the synovial membrane. The joint, however, is protected in front by the prominence of the unciform process, which descends a little below the line of the articulation, and limits the forward motion of the carpal extremity of the bone; and posteriorly it is strengthened by the tendon of the extensor carpi ulnaris, while its motion ulnad is restricted by the strong internal palmar ligament of the third metacarpal bone, which we have already described as passing from that bone to the fifth metacarpal and the unciform bones. The fifth carpo-metacarpal articulation approaches in many particulars to the first; it has a greater latitude of motion than the three immediately preceding it, and its articular surfaces very much resemble those of the first.

Besides the palmar and dorsal ligaments already described, these metarcarpal bones are very firmly connected to each other by short but strong ligaments, extending transversely from one to the other on the palmar and dorsal aspects.

A common synovial membrane extends throughout the four joints above described; this synovial membrane is continuous with that between the two rows of carpal bones.

The digital extremities of the four inner metacarpal bones are connected by their transverse ligaments situated at the palmar surface and extending from one to the other.

Carpo-metacarpal joints of the thumb.—The main feature by which this articulation is distinguished from the other carpo-metacarpal joints is its great mobility. It is an arthrodia, and in many particulars resembles very much the sterno-clavicular joint. The trapezium presents a surface concave from within outwards, and convex from before backwards, that on the metacarpal bone being convex in the transverse, and concave in the antero-posterior direction.

The ligamentous apparatus of this joint has very much the appearance of the capsular ligament of an enarthrosis, and has indeed been described as such by many anatomists; but on a careful examination it will be found to consist of separate bundles of ligament placed at those situations in which the greatest tendency to displacement exists in the various motions of the joint. Four principal bundles may be described: one very thick and strong, situated at the posterior and outer part of the joint, *(lig. dorsale,* Weitbr.) extending from the metacarpal bone to a prominent tubercle on the outer part of the dorsal surface of the trapezium; this ligament limits flexion of the joint. A second ligament is situated directly in front of the joint, *(lig. palmare,* Weitbr.) is inserted into the trapezium immediately internal to its prominence; extension is limited by this ligament. The third and fourth bundles *(lig. laterale ext. et int.* Weitbr.) are situated on the radial and ulnar sides of the joint: they are less distinct as well as less strong than those last described. That on the ulnar side is considerably the stronger; it limits abduction of the thumb, whilst that on the radial side limits adduction.

The synovial membrane of this joint is lax; it is perfectly distinct from the general synovial membrane of the other carpo-metacarpal articulations.

Motions of the carpo-metacarpal joints.—In the second, third, and fourth joints the motions are limited to a very slight, and during life scarcely appreciable gliding forwards or backwards: the strong transverse ligaments, as well as the close manner in which the carpal extremities of the metacarpal bones are impacted together, render lateral motion impossible; in the fifth joint the forward or backward motion is somewhat more extensive, but this joint is equally limited with the others in lateral movement.

The carpo-metacarpal joint of the thumb enjoys motion forwards, backwards, inwards, and outwards, producing the movements of flexion and extension, abduction and adduction. The power of opposing the thumb to any of the fingers is due to the oblique direction of flexion in this joint: the bone moves forwards and inwards, passing through a line which would be concave inwards. This is by far the most extensive motion of the thumb, and it is by an excess of this motion that the dislocation of the metacarpal bone backwards is generally occasioned. Cruveilhier observes that the weakness of the posterior ligament favours the occurrence of this luxation. I cannot, however, admit the weakness of this ligament; on the contrary, it appears to me to be the strongest of all the ligaments of this joint; which opinion, I find, is that of the accurate Weitbrecht.

The motion of adduction is, on the other hand, the most limited, in consequence of the proximity of the second metacarpal bone; that of abduction is very extensive, and when carried too far may occasion luxation inwards.

JOINTS OF THE FINGERS.

1. *Metacarpo-phalangeal joints.*—The first phalanges are articulated by an oval concave surface, with the rounded oblong heads of the inferior extremities of the metacarpal bones: it is remarkable that the long axis of the oval concavity of the phalanx has a transverse direction, while the long axis of the head of the metacarpal bone is directed from before backwards, and consequently at right angles with the former; whence the great extent of lateral motion enjoyed by these joints.

Each of these joints is strengthened by two lateral ligaments, of considerable strength, inserted into the tubercle behind the depression on each side of the head of the metacarpal bone; the point of insertion into the phalanx is anterior to this, and consequently the direction of the lateral ligaments is downwards and forwards; as they descend, these ligaments spread out, and their anterior fibres become identified with the anterior ligament.

A third ligament, the *anterior* ligament, or *glenoid* ligament of Cruveilhier, seems destined more to increase the extent of the phalangeal articular concavity anteriorly, than to maintain the integrity of the joint or limit its motions. This ligament is, as Bichat expresses it, a thick and dense fibrous bundle, in shape half a ring, placed in front of the palmar surface of the head of the metacarpal bone, composed of transverse fibres which adhere inferiorly to the anterior edge of the concavity on the phalanx, and on each side are identified with the lateral ligaments and the transverse ligaments by which the metacarpal bones are connected. If the ligaments and synovial membrane of this joint be cut all round close to their attachment to the head of the metacarpal bone, and that bone be removed, the synovial capsule and ligaments remaining attached to the phalanx, a very clear idea of the relative positions of the ligaments may be formed. The synovial membrane will then appear protected on three sides by ligament; on the radial and ulnar side by the lateral ligaments, and in front the anterior ligaments, whilst posteriorly it is unprotected save by the sheath of the extensor tendon.

In the metacarpo-phalangeal articulation of the thumb two sesamoid bones, developed in the substance of the anterior ligament, protect the joint in front.

2. *Phalangeal joints.*—These joints are all ginglymoid, the articular surfaces being pulley-like; they are provided with lateral ligaments similar to those of the metacarpo-phalangeal joints, and also with anterior ligaments similarly disposed.

Motions of the joints of the fingers.—In the phalangeal joints these motions are only flexion and extension; the former are considerably more extensive, and are favoured by the inferior insertion of the lateral ligaments being on a plane anterior to their superior insertion. In addition to flexion and extension the metacarpo-phalangeal joints enjoy considerable lateral motion, which is due to the glenoid form of the phalangeal articular surface, and to the enarthrodial form which the joint derives from the extension of that articular surface by the anterior ligament.

(R. B. Todd.)

HAND, ABNORMAL CONDITIONS OF THE. Deviations from the normal condition of the different structures which enter into the composition of the hand are very numerous, and may be classed into those which are the result of, first, accident; second, disease; third, congenital malformation.

I. ABNORMAL CONDITIONS, THE RESULT OF ACCIDENT.

Fractures and luxations. — Simple fractures of the bones of the hand are seldom followed by any notable deformity; but luxations of these bones require from us some attention here.

Luxation of the bones of the carpus.—The bones of the carpus are united to each other so solidly, and their movements seem so limited, that, without experience, we should be disposed to pronounce luxation of any of these bones impossible; nevertheless, the head of the os magnum may be dislocated from the cavity formed for it by the scaphoid and semilunar bones. The first range of the bones of the carpus is articulated with the bones of the second range in such a manner that slight gliding movements of flexion and extension of the hand are permitted, which augment a little the movements of flexion and extension of the hand upon the forearm, and add somewhat, as Cruveilhier says, to the grace of the movements of this portion of the upper extremity. In flexion, the head of the os magnum, which is somewhat inclined backwards, raises up the thin capsule which surrounds its articulation, and, if this movement be carried very far, the capsule and accessory fibres which support the bone posteriorly are broken, and the os magnum escapes from the cavity in which it is naturally placed; the dislocation cannot be called complete, yet the os magnum passes somewhat the level of the posterior surface of the other bones of the carpus. The accident is more common in women than in men, no doubt because the ligaments are weaker and the bones enjoy greater motion in the former than in the latter; the luxation backwards of the os magnum, the only one which can occur, is always the result of a forced and violent flexion of the wrist, such, for example, as a fall on the back of the hand would produce.

We recognize the luxation of the os magnum by the history of the accident, and by the deformity produced. We perceive a hard circumscribed tumour which has suddenly appeared on the back of the hand in the situation which corresponds to the head of the bone. This tumour becomes more prominent when the hand is flexed, and diminishes when it is extended; we can make it disappear entirely by a slight compression. This luxation causes but little inconvenience, but the head of the os magnum always remains more salient when the hand is flexed, and forms a tumour more or less marked according to the extent of the displacement.

We can easily reduce this luxation by extending the hand, or by exercising a slight pressure on the head of the os magnum; but, although it is easy to make the bone resume its position in the cavity formed for it by the scaphoid and semilunar bones, it is very difficult to maintain it there, and the inconvenience and deformity resulting from the luxation are so trivial that few persons will submit with patience to the means usually recommended.

Luxation of the bones of the metacarpus.—Luxation of the metacarpal bone of the thumb. The carpal head of the metacarpal bone of the thumb, notwithstanding the range of motion it enjoys, is rarely dislocated. Sir A. Cooper, in his extensive experience, has seen but one species of this accident, viz. luxation of the metacarpal bone of the thumb upon the os trapezium, inwards. "In the cases I have seen of this accident," says Sir Astley, "the metacarpal bone has been thrown inwards between the trapezium and the root of the metacarpal bone of the fore-finger; it forms a protuberance towards the palm of the hand; the thumb is bent backwards, and cannot be brought towards the little finger: considerable pain and swelling are produced by this accident."

Luxation of the carpal head of the metacarpal bone of the thumb *backwards*. Some surgeons seem to doubt that the metacarpal bone of the thumb is capable of being dislocated in any other direction than that inwards; but the following case is given on the highly respectable authority of the experienced Boyer. Madame De la P—— luxated the metacarpal bone of her left thumb backwards on the dorsum of the trapezium by falling on the external or radial border of her hand; the luxation was at first mistaken. When Boyer saw it six months after the accident, the superior extremity of the metacarpal bone of the thumb formed posteriorly a very remarkable prominence on the trapezium, and this bone and the phalanges of the thumb were inclined towards the palm of the hand. On pressing posteriorly on the prominence formed by the superior extremity of the dislocated bone, it could be made to resume its natural place and the prominence disappeared; so long as the pressure was continued, the bone retained its place and the thumb enjoyed its natural powers of flexion and extension; but as soon as the pressure was remitted, the bone became displaced anew, and the movements of the thumb impossible. The lady was unwilling to submit to any treatment, and the condition of the joint remained unaltered. These luxations of the metacarpal bone of the thumb, whether backwards or inwards, must be rare, as the causes which are calculated to produce them must act through the first phalanx of the thumb, which, it is manifest, will be much more disposed to yield than the metacarpal bone.

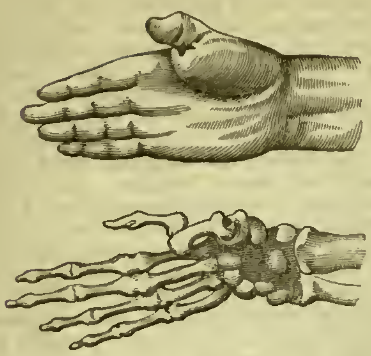
Luxation of the phalanges of the fingers.—The first phalanx of the thumb as well as the first phalanx of any of the fingers may be luxated *backwards;* the luxation *forwards* of the phalanx is very rare and perhaps impossible, except in the index finger and the thumb.

The mutual support which the first phalanges of the fingers afford each other laterally, and the strength of the lateral ligaments render the luxation *outwards* or *inwards* very difficult.

Luxations of the first phalanx of the thumb from the metacarpal bone. The first phalanx of the thumb may be luxated *forwards* to the palmar surface of the metacarpal bone, but this form of luxation is very rare, while the luxation of the same phalanx on the dorsum of the metacarpal bone is the most common and important displacement of any to which the bones of the hand are liable. We shall therefore consider this accident in detail.

In some persons the first phalanx of the thumb can at will be dislocated backwards, solely by the contraction of the muscles. The displacement produced by accident, however, is much more extensive than this, which may be termed the *voluntary luxation*. When the first phalanx of the thumb is in a state of extreme extension, accident may dislocate it on the dorsum of the metacarpal bone. The signs of the injury are so evident that mistake appears impossible; the first phalanx is thrown back as if pulled by its two extensors, and forms nearly a right angle with its metacarpal bone (*fig.* 226); the head of the latter forms a remarkable tumour at the anterior part or palmar aspect of the articulation, while a prominence behind points out the situation of the base of the first phalanx: the last or distal phalanx is (in recent cases) flexed, and it soon becomes difficult or impossible to extend it, or to flex the first phalanx.

Fig. 226.



Luxation of the first phalanx of the thumb on the back of the metacarpal bone.

Anatomical characters of this accident. Opportunities of ascertaining by dissection the actual condition of the parts when luxation backwards of the first phalanx of the thumb has recently happened, of course do not occur, but from the dissection of old unreduced injuries of this kind,* and from experiments on the dead subject, we are led to infer that the immediate effects of the injury are, extensive laceration of the anterior part of the synovial membrane, and of one or both the lateral ligaments, while the posterior portion of the capsule remains entire; the base of the first phalanx is dragged to a considerable extent upon the dorsum of the metacarpal bone, elevating with it the tendons of the extensor primi and secundi internodii pollicis; the tendon of the flexor pollicis longus is carried inwards and under the head of the metacarpal bone. As the extensor ossis metarcarpi and opponens pollicis are not attached to the first phalanx, they are little affected by the luxation, but the condition of the three remaining muscles which are inserted into the base of the first phalanx requires consideration. These short muscles are the abductor pollicis, the flexor pollicis brevis, and the adductor pollicis.

When the dislocation backwards of the first phalanx of the thumb has occurred, the large head of the metacarpal bone is at the same time thrown inwards towards the palm, and having forced its way between the two origins of the flexor pollicis brevis, the shaft of this bone, which is comparatively much narrower than the head, becomes tightly embraced by the two fleshy columns of the muscle. This is a state of things which should be taken into account when the obstacles to the reduction of this dislocation are considered, nor should it be forgotten that the direction and relative position of the points of attachment of all the muscles concerned must be altogether changed when the complete luxation has occurred; their origins and insertions are more than naturally approximated, and the line of direction of their action is thrown much behind the longitudinal axis of the metacarpal bone; the tendons of the extensor primi and secundi internodii, and of the flexor pollicis longus are of course carried by the dislocated bone behind their usual line of action; hence the action of all these muscles, after the luxation has occurred, becomes materially altered, their contraction will no longer be resisted by the lateral and capsular ligaments, and the bone will be drawn upwards and backwards by them, a considerable distance on the dorsum of the metacarpal bone (*fig.* 226). The flexors have their direction so altered and so thrown behind the longitudinal axis of the metacarpal bone of the thumb, that they now no longer act as flexors of the first phalanx to approximate it to the palm; on the contrary, they now have become extensors of the dislocated phalanx, and tend much by their contraction to increase the deformity.*

This dislocation is difficult to reduce, particularly if the nature of the accident have not been speedily recognized. Various causes have been assigned for the opposition to the return of the bone; some think with the late Mr. Hey of Leeds, that a transverse section of the head of the metacarpal bone presents in its outline somewhat of a cuneiform figure; and that, in consequence of the narrowest part of the wedge being thus placed anteriorly, it can easily under the influence of accident glide towards the palm by passing between the lateral ligaments which remain unbroken, and resist all return of the bone backwards to its original situation. Others imagine that the interposition of the anterior ligament and sesamoid bone attached to it between the articular surfaces constitutes the principal obstacles to the reduction of this luxation. Again it has been asserted that the tendon of the flexor longus pollicis has been twisted spirally under the metacarpal bone, while some with more appearance of truth have supposed that the muscles are the principal sources of resistance. The learned author of the First Lines of Surgery has expressed his opinion that the return of the dislocated phalanx to its place is opposed by a combination of causes, viz.—the cuneiform shape of the bone and the resistance of the lateral ligaments, as suggested by Hey, the force of the muscles, and, lastly, he adds, because the surface for the application of the extending means is very limited. To most of these observations we have reason to object, particularly to the last, because we believe that all the force which it is justifiable to use may be easily applied; and we should

* See London Medical Gazette for Oct. 14, 1837, J. A. Lawrie, Glasgow.

* In the experiments made by my colleague Mr. Mayne and myself on the dead subject, when we forcibly dislocated the first phalanx backwards, we found the anterior part of the synovial membrane and the external lateral ligament torn across; the first phalanx was placed as in *fig.* 226. We found the head of the metacarpal bone driven between the two heads of the flexor pollicis brevis in such a way, that the external head of the muscle was placed upon the outside of the shaft of the bone in company with the abductor pollicis, while the internal was situated at the inside of it, along with the adductor and long flexor tendon.

ever keep in mind a case given on the authority of Mr. Hey, who informs us that the celebrated Mr. Bloomfield reported to his class of pupils at St. George's Hospital, London, that he knew a surgeon increase the force of extension to such a degree in attempting reduction of this dislocation, that he tore off the thumb at the second joint.

The idea that a transverse section of the head of the metacarpal bone presents an outline of a cuneiform figure with the narrowest part of the wedge towards the palm, or forwards, was first advanced by Mr. Hey, and has subsequently been adopted with too little reflection by many writers: for our part we do not think that the head of the metacarpal bone does present this form assigned to it by Hey. But even although it be conceded that it has occasionally a form which would answer to the description given by Mr. Hey, and that its cuneiform figure would facilitate its gliding between the lateral ligaments and forbid its return, surely such an obstacle to the return of the bone would suppose a state of integrity of both lateral ligaments. In our experiments on the dead subject, we found one of these lateral ligaments invariably torn whenever a complete luxation was effected; but with the theory of Hey, which seems to us quite unsupported by the normal anatomy of the bone or the anatomy of the accident, how can we reconcile the observation, that when the first phalanx of the thumb is dislocated to the palmar instead of the dorsal aspect of the metacarpal bone, equal difficulty of reducing the luxation has been experienced by very eminent surgeons! For example, Velpeau says, "we have seen but once the first phalanx of the thumb pass in front of the first metacarpal bone. The subject of this accident was a woman aged forty-five years; the bone had been out for three days, there was no inflammation." I thought, says Velpeau, "that it was owing to some want of skill in myself that I could not succeed in reducing the luxation; but M. Professor Bougon also made fruitless efforts to effect it; finally, M. Roux, with his well-known address and ingenuity, was not more successful, and the bone remained ever afterwards unreduced."*

Upon the whole it would appear to us that in the case of the dislocation of the first phalanx of the thumb on the dorsum of the metacarpal bone, the cause of the difficulty we experience in reducing it will not be found either in the mechanical resistance of the lateral ligaments or in the interposition of muscular or fibrous parts between the extremities of the dislocated bones, but that, whether the luxation be the common one backwards or the more unusual one forwards, the *vital contraction* of numerous muscles on a small and yielding bone (whose ligaments have been lacerated) will be the principal opposing force we have to contend with. Most of these muscles will be found to be favourably circumstanced for the opposition, for they are either inserted into or attached very close to the bones of the first phalanx of the thumb: they are six in number; some of them are of considerable length, and the aggregate force of both long and short muscles constitutes a very powerful means of maintaining displaced the first phalanx of the thumb; nor should it be forgotten, in estimating their force, that the very large supply of blood-vessels and nerves which these muscles receive, must add much more to the energy of their contraction than the size and number of their composing fibres would lead us to suppose.

If such a view of the abnormal condition of the different structures which compose this articulation be correct, we should derive from it the important practical precept, that when we have one of those difficult cases to contend with, our first effort should be to reduce, as much as practicable, the irritability and vital force of the muscles which act on the dislocated bone before any of our mechanical appliances be resorted to. When the general system of the patient has been under the depressing influence of the usual means, viz. tartarized antimony, &c., and under these favourable circumstances the surgeon has with patience and perseverance used all the force that he deems expedient or justifiable, and has not succeeded in replacing the bone, our experience would induce us to recommend that in such a case no further measures should be had recourse to. We have, in the museum of the Richmond Hospital, a cast of the hand of a man who had suffered this luxation sixteen years before the cast was taken. The history he gave the writer was briefly that he consulted an eminent surgeon, who used all the means in his power to reduce the dislocation, but could not succeed; that the surgeon then proposed to the man an operation which he explained, and which from the patient's description of it we may conclude consisted in laying bare the head of the metacarpal bone and removing it, as had been about that time recommended by Mr. Evans, of Kettley near Wellington; the man, however, refused to consent to the proposal, and had good reason to be content with his own determination, as he can now oppose the point of the thumb to the other fingers, and can follow his business, which is that of a plasterer, with very little inconvenience, affording us a proof that the advice given by Sir A. Cooper relative to irreducible dislocations of the metacarpal bone, may be well extended to the common dislocation backwards of the first phalanx, viz. "that if the bone cannot be reduced by simple extension, it is best to leave the case to that degree of recovery which nature will in time produce, rather than divide the muscles or run any risk of injuring the nerves or the bloodvessels."

The first phalanges of any of the other fingers may be luxated backwards. The little finger appears to us, after the thumb, the most liable to this accident; it is sometimes difficult to reduce. Mr. Romer, a pupil of the Richmond Hospital, lately brought to the writer a patient who was the subject of luxation of the

* Velpeau, Traité d'Anatomie des Regions, tom. i. p. 475, edit. 1825.

first phalanx of the little finger on the back of its metacarpal bone. This patient was a female about thirty-five years of age; the bone had been only a few hours luxated, and some ineffectual attempts had been previously made to reduce it. The reduction was effected with some little difficulty by at first increasing the extension, and then by forcibly flexing the last phalanx. In this case the long extensor tendon of the little finger was displaced from its sheath and groove, and lay on the ulnar side of the metacarpal bone and luxated phalanx, and never afterwards could be maintained in its proper place. This accident is very easily recognized, yet it has been occasionally left unreduced.

It has been stated already that luxation of the first phalanx of the thumb forwards may occasionally happen, and we have also good authority for supposing that a similar luxation may occur to the phalanx of the index finger. These accidents, however, are very rare; the middle, ring, and little fingers have never been seen thus displaced; indeed, Boyer seems to think such an accident in these last, impossible from the nature of their articulation with their metacarpal bones.

Luxation of the second, and third or distal phalanges.—The articulations of these phalanges being only covered by the skin and the tendons of the flexor and extensor muscles, their luxations are also very easily recognized. In the luxation backwards, the only one which we have had occasion to observe, the luxated phalanx is turned to the side of extension, and forms with the phalanx above it an angle more or less open. When it is the second phalanx which is luxated, the third is flexed by the elongation of the tendon of the deep flexor, and it is impossible to extend it or flex the second. The reduction of these luxations is generally easy if time be not allowed to elapse between the occurrence of the luxation and the period of attempting its reduction.

II. DISEASED CONDITIONS.

Caries and necrosis occasionally affect the bones of the hand, but the complete descriptions of these diseases, which have been elsewhere given in this work,* render superfluous here any special observations on these morbid actions when they manifest themselves in the region of the hand. The bones of the metacarpus and phalanges are very frequently deformed by a disease which (although it cannot be said to be exclusively observed in these bones) produces on the hand and fingers appearances too remarkable to be left unnoticed in this place.

The disease which we wish to describe as we have seen it in the bones of the hand would be by some designated as exostosis,† by others as benign osteo-sarcoma, and others‡ would be disposed to preserve the somewhat objectionable but ancient name of spina ventosa.

The metacarpal bones and the phalanges of the fingers are the usual seat of this disease, and in general many of them are simultaneously engaged in it; the shafts of the affected bones are usually swelled out by the disease into tumours somewhat of a globular form, the articular extremities of the bones remaining perfectly free. It is by no means unusual to see the first and second phalanx of a finger forming two distinct globular swellings, while the last or distal phalanx is perfectly free from enlargement.

It has been already mentioned that these tumours, when viewed externally, seem to have a spheroidal form; but when the integuments of the bony shell which incloses the tumours are removed, we discover on their palmar aspects the flexor tendons buried in deep grooves. This is of course best seen when the disease has existed long, and the tumours have attained a considerable size.

If we have an opportunity of examining anatomically the phalanges while the disease is yet in its early stage, we shall find reason to conclude that the morbid process had commenced deep in the interior of the bone, and that the tumour proceeding outwardly presented itself first on that aspect of the phalanx, or metacarpal bone, where there was the least resistance opposed to it; hence we usually notice these tumours, when small, shewing themselves most on the dorsal aspect of these bones. As the disease increases they swell out laterally, and the whole circumference of the phalanx would be equally expanded were it not for the support given on the side of flexion by the flexor tendons and their strong fibrous sheaths. The integuments of these tumours preserve their natural sensibility, and are at first freely moveable over them; but as the swellings gradually increase and undergo a species of softening in certain points, the integuments become adherent at these points, and circular openings are formed in them which correspond to similar circular apertures in the shell of the bone, and through which the bony cysts discharge their contents; these swellings of the bones of the hand, as far as we know, never degenerate into any disease of a malignant nature; but when they attain a considerable size, and are excavated by these cysts, and have large fistulous orifices, the irritation they produce and the discharge cause some febrile excitement of the constitution, and amputation may become necessary. The following very remarkable case clearly proves the non-malignant nature of this disease; the history of it will serve well to illustrate the natural progress of this form of disease in the hand.

A countryman of rather a delicate appearance, aged twenty-four years, was admitted into Jervis-street Hospital, July 22, 1828, under the care of Dr. O'Beirne. This man had an enormous enlargement of the left hand, which arose from a tumour, the principal seat of which was in the first and second phalanges of the middle finger, but the ring and index finger

* See BONE, *morbid anatomy*.

† See Scarpa, De Anatomia et Pathologia ossium, cum tabulis æneis, tab. vi. *fig*. 1, Exostosis ossium plerorumque manus dexteræ.

‡ Boyer, Maladies Chirurgicales, vol. iii. p. 579.

were also involved in the disease, and the three metacarpal bones supporting the three fingers already mentioned were also much enlarged; in a word, all the bones of the metacarpus and fingers, with the exception of those of the thumb and little finger viewed externally, seemed to enter into the formation of one morbid mass, the size and form of which may be best conceived by a reference to the annexed figure.

Fig. 227.

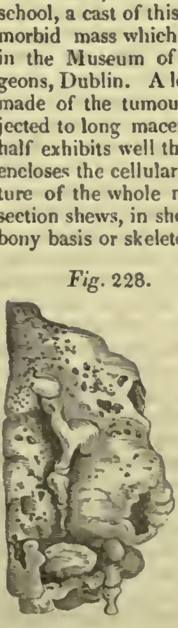
The chief bulk of this large bony tumour existed posteriorly, where it extended as high up as the line of the wrist-joint, and completely concealed the bones of the carpus. The tumour did not extend itself directly forward towards the palm of the hand, but passed downwards; at its remote extremity the last phalanx of the middle finger was to be seen projecting; this phalanx was itself, however, perfectly free from morbid change, and the integuments covering it possessed their natural sensibility. The circumference of the tumour measured accurately twenty-four inches; numerous very large protuberances shewed themselves every where on its surface, which yielded but little to pressure. Three of these tumours had ulcerated at their most prominent points, and by circular depressed openings (nearly an inch in diameter) gave exit to a thin fœtid ichorous matter, which continued to flow from the interior of the morbid mass. These orifices, which presented some loose granulations, readily admitted the introduction of a probe, which could be then freely moved in the interior of these cavities, each of which was large enough to contain an ordinary hen's egg. The integuments every where over the whole of this morbid growth had a perfectly healthy aspect, and were freely moveable on this immense tumour, except at the borders of the circular apertures already mentioned. The disease existed for many years, having begun, as the patient stated, when he was a boy.

The disease was unaccompanied by pain, and the man's health continued good until the period when the tumour had ulcerated; after which he became somewhat debilitated by the exhausting effect of the sanious discharge on his constitution, and his mind was depressed with the idea of his being afflicted with a disease so formidable in appearance, and which hitherto had resisted, nay increased under, all treatment, and deprived him altogether of the means of earning a livelihood. Although there was some difference of opinion as to the name by which this disease of the bone should be designated, it was agreed that there was nothing really malignant in its nature; most of those consulted on the case recommended amputation, but Doctor O'Beirne conceived the happy idea, and speedily put it into execution, of cutting out the morbid mass. Although it was rightly conceived that the index finger was but little diseased, and that the ring-finger was merely enveloped in the tumour, still the thought of preserving either of these fingers could not be for a moment entertained, as the metacarpal bones supporting them were known to be diseased. It was plain that the thumb and little finger only could be saved, and the lines of incision which were followed may be easily imagined. The operation was performed thus: one incision was commenced at the root of the little finger at its radial side, which was extended deeply through the soft parts upwards and backwards as high nearly as the wrist-joint; the termination of this incision here was met by another, which was commenced at the first interosseous space between the index finger and the thumb; the lines of these incisions were followed deeply, and, with the assistance of the knife and metacarpal saw, the whole of the morbid mass was removed; the hæmorrhage was soon arrested, and dressings applied with a bandage to approximate gradually the thumb and little finger. The wound was at first refractory, and cartilaginous granulations sprang up; to repress these, Dr. O'Beirne found nothing so effectual as the actual cautery, and under its influence the wound healed kindly.

It is now nine years since the operation was performed, and the man has, during that period, enjoyed vigorous health; the thumb and little finger have approached each other, and increased much in size, power, and usefulness, and he is fully competent to follow his occupation, which is that of a land-surveyor.

We have, in our collection at the Richmond school, a cast of this remarkable hand; and the morbid mass which was removed is preserved in the Museum of the Royal College of Surgeons, Dublin. A longitudinal section has been made of the tumour: one half has been subjected to long maceration, and dried; and this half exhibits well the thin osseous shell which encloses the cellular and reticulated bony structure of the whole mass;—this portion of the section shews, in short, the true structure of the bony basis or skeleton (if we can so say) of the disease (*fig.* 228). The other half of the section has been preserved in spirits, and in the line of division shews a smooth cartilaginous surface, and several excavations lined by a smooth membrane, which had enclosed an albuminous fluid. Some of these cavities were complete isolated cysts, buried deep in the interior of the cartilaginous mass; but the contents of three of these cysts had made their way ex-

Fig. 228.



ternally through the large circular apertures already mentioned.

We have thought it right to detail this remarkable case at length, as it is the history of an important fact, from which, it is true, different conclusions may be drawn; for our part, we consider the case a well-marked specimen of a disease described by some of the older writers as spina ventosa. Boyer adopts this appellation, and in his work will be found a good account of the disease; and, indeed, he so accurately depicts the appearances we observed in this case, and which were discovered by dissection, that we feel satisfied his description has been drawn from nature. Boyer says, "We understand by spina ventosa an affection of the cylindrical bones, in which the walls of the medullary canal are subjected to a slow, gradual, but sometimes enormous, distension; while, at the same time, they are considerably thinned, and even pierced in many points, in which their tissue undergoes a singular rarefaction,—a disease whose primitive seat would appear to reside in the medullary cavity," &c.

Sanson, from two careful dissections of recent specimens of this disease, considers it to originate in a degeneration of the membrane which lines the interior of the bone. The substance which is found to fill up the cavity of the bone can only proceed from the system of the medullary membrane, the action of which becomes so altered and diseased, as to produce the new growth which is found in the interior of these globular tumours. This product distends by degrees the walls of the medullary canal and reticular structure of the bones. The dilatation, in which the articular surfaces do not participate, is generally sudden, so that the part immediately near the point where the disease is situated preserves its natural dimensions. When the globular tumours thus formed are cut into, in the early stage of the affection, their interior presents a fibro-cartilaginous appearance, surrounded by a thin shell of bone. A section of one of those tumours of the fingers in the early stage appears to us to present a striking resemblance to the common fibrous tumour of the uterus, which is often encased in a similar bony shell. The description Mr. Crampton has given of the structure of the benign osteo-sarcoma may well be applied to this disease. He says, "the interior of the tumour presents a great variety of structure, but I should say, in general, that the cartilaginous character which the tumour exhibits in its origin prevails to the last. In the *early* stages of the disease, the tumour consists of a dense elastic substance, resembling fibro-cartilaginous structure; but the resemblance is more in colour than in consistency, for it is not nearly so hard, and it is granular rather than fibrous, so that it breaks short. On cutting into the tumour, the edge of the knife grates against spiculæ, or small grains of earthy matter with which the substance is beset. If the tumour acquires any considerable size, it is usually found to contain cavities filled with a fluid differing in colour and consistency; but in general the fluid is thickish, inodorous, and of the colour of chocolate. Sometimes the growth of the tumour, and the secretion of the fluid within its substance, is so slow, that the deposition of bony matter keeping pace with the absorption, the bone becomes expanded into a large thick bony case, in which the tumour is completely enclosed."*

Strumous osteitis of the metacarpal bones, and of the phalanges of the fingers.—It is by no means difficult to distinguish the disease last described under the name of spina ventosa, or benign osteo-sarcoma, from that enlargement of the metacarpal bones and of the fingers which we frequently witness in children of the strumous diathesis. The strumous affection of the phalanges we allude to seems little else than an osteitis, which terminates usually either in caries or necrosis. The disease, when fully formed, shows itself in the shape of either a pyriform or globular swelling of the phalanx of one or more of the fingers. There is at first no sensible alteration of the surrounding soft parts; the swelling has usually been preceded by pains of a dull and obtuse character; the movements of the part affected are for a long time preserved, and indeed are not at all restrained, except when the tumefaction of the bone becomes sufficient to turn aside the tendons from their natural direction, or to cause deformity of the articular surfaces, which rarely happens.

As the disease advances, the soft parts are distended, suppuration takes place, and the integuments of the swollen part always ulcerate at a point corresponding to some deficient part of the bony cylinder. Through the ulcerated opening a probe may be passed freely into a cavity which the bone contains; the opening becomes fistulous, and for a long time continues to give exit to a moderate quantity of thin, serous, and ill-conditioned matter; sometimes, however, we notice an improvement in the general health of the patient, and, at the same time, the local disease assumes a new and more favourable aspect, the discharge diminishes, and at length dries up. Such a decided amendment, however, seldom occurs, until a process of necrosis, or exfoliation of a part of the bone, has taken place; after which the wound heals up, the use of the finger is restored, and all that remains of the disease is an unseemly, depressed, and adherent cicatrix.

Malignant tumours of the hand.—Malignant osteo-sarcoma, and even fungus hæmatodes, are diseases which may show themselves in the region of the hand and fingers; but these diseases are readily distinguished from the spina ventosa, or benign osteo-sarcoma, above alluded to. The pains of the malignant disease are lancinating, the progress is more acute, the constitution and health are more quickly and deeply implicated; the prognosis, too, is very different. Although life may perhaps be prolonged by an amputation of the hand of a patient affected by either of these malignant diseases, the terrible disorder will almost uniformly recur. On the contrary, if the disease be spina ventosa, a portion of the hand may be amputated, or a finger removed, and the disease shall not recur

* Vide Dublin Hospital Reports, vol. iv. p. 542.

after these operations. Indeed, we feel persuaded that, in some cases of spina ventosa, (*fig.* 229) the tumour may be cut off from a finger or from a metacarpal bone, and that although the wound may for a while throw up cartilaginous granulations, still, under proper treatment, the ulcer of the bone will be got to heal kindly.

Fig. 229.

Abnormal conditions of the fingers the result of accidents and morbid affections of one or more of their constituent structures.—We occasionally find that the voluntary power of flexing or extending the joints of the fingers is lost. This loss of power may arise from a great variety of causes;—anchylosis of a joint from acute or chronic inflammation; the loss of an extensor or flexor tendon from a similar cause, or from a wound; congenital malformation of the brain; disease or accident affecting this organ, the spinal marrow, or the nerves connected with the movements of the upper extremity; any of these may at times be the source of this loss of the voluntary power over the fingers. Under these circumstances, although there may be but little external deformity, sometimes the fingers cannot be flexed; more frequently they cannot be voluntarily extended. An abnormal condition of the fingers, shewing itself in some distortion of these organs, may be traced to causes affecting—1, the skin; 2, the fascia; 3, the theca of the tendons; 4, the tendon itself; and 5, the bone. If a burn penetrate the skin on the palmar surface of the hand, a dense cicatrix will be formed; and much exertion will be necessary, on the part of the surgeon, to oppose successfully the gradual contraction of the "tissue of the cicatrix." Should contraction take place, notwithstanding these efforts, the functions of the hand will be impaired, and much deformity will remain. A burn on the back of the hand may be followed by analogous effects.

There is a peculiar form of contraction of the fingers, which Boyer seems to ascribe (we believe erroneously) to a shortening of the tendons. Adopting the language of the ancients, he denominates the affection "crispatura tendinum." This contraction of the fingers is never seen in very young persons. Most of those we have known affected by it were adults, who had been for a long time compelled to make laborious use of their hands. The disease will be ordinarily found to commence in a contraction of the little finger; the ring finger is next engaged, and then the middle finger. From day to day the fingers become more contracted, and the power of extending them is lost. When one hand is thus affected, it usually happens that the other soon becomes equally engaged. It is remarkable that neither the indicator nor the thumb have ever been seen affected with this disease.

When we examine the fingers the subjects of this species of contraction (*fig.* 230), we find that the first phalanx is moveable on the metacarpal bone, and is flexed at an angle more or less approaching to a right angle. We can flex it a little more towards the palm; but to extend it so as to efface the angle is impossible; "a weight," says Dupuytren, "of 150lbs. will not bring the finger into a straight line with its metacarpal bone." Boyer says, "our efforts to extend the fingers are resisted to such a degree, that if we continued them they would break before we could force them to yield."

Fig. 230.

Contraction of the fingers from disease of the palmar fascia.

This description, however, applies only to the metacarpal joint of the first phalanx, for the last phalanges of each affected finger, though moveable, habitually remain perfectly straight.

In these cases the integuments of the affected palm and the subjacent fascia seem to be more than naturally thick and consolidated, and we observe the lowest of the natural cutaneous lines of the palm thrown into a very deep crescentic fold, the concavity of which looks towards the fingers, and the convexity towards the wrist joint. We also invariably notice in these cases a rounded projecting chord which passes downwards from the middle of the palm of the hand to the basis of the first phalanx of the contracted finger. This chord feels hard, and is rendered more tense and salient whenever we make an effort to straighten the affected finger.

When in the living subject we examine carefully the palmar fascia, and explore, as far as we can, its connexion above with the tendon of the palmaris longus, and below, follow the prolongations it sends to the lateral aspect of the contracted fingers, we find them all continuous; in a word, when we press upon the tendon of the palmaris longus, we make tense the tendinous digitations above-mentioned. The continuity of all these fibrous structures is thus evident in the living. When we have opportunities of examining, in the dead subject, a hand in which this contraction of the palmar aponeurosis has existed, and have raised the skin in all its extent from the palm of the hand and palmar surface of the fingers, its folds and rugæ all disappear, and it then becomes evident that this defect does not reside in the skin. When the aponeurosis is exposed, it is found contracted, thickened, and diminished in length. From its inferior part, the tense fibrous chords which were already supposed to exist are now exposed, and seen to be inserted into the periosteum on the lateral aspects of the contracted finger.

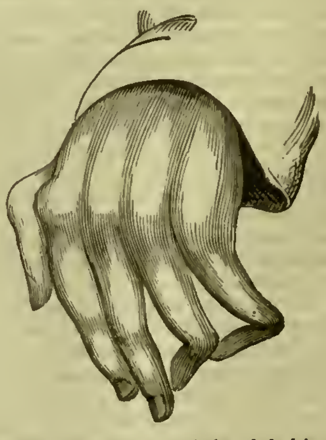
Dupuytren, by various anatomical and pathological investigations of this disease, satisfied himself that this peculiar contraction of the fingers depends essentially on this shortening, thickening, and organic alteration of the palmar aponeurosis and the digitations proceeding from it to the sides of the fingers; for he invariably found when he had opportunities of investigating this disease in the dead subject, that the tendons were of their accustomed volume and mobility. He cut them across, and then made efforts in vain to extend the finger. The bones were found of their natural form, and no alteration was perceptible in either the synovial membranes or lateral ligaments; but as soon as the section of the expansions of the fascia which go to the fingers was effected, the flexion disappeared, and the finger could be brought to its normal position. Finally, he infers, and indeed, as far as a few instances go, he proves, that a similar result will follow the division of the fascia in the living subject, and that the proper use and adjustment of a peculiar splint on the back of the forearm and hand, so as to keep the affected fingers for a time extended, will complete the cure of this disease.

Sir A. Cooper alludes to these deformities when he says, "The fingers are sometimes contracted by a chronic inflammation of the theca and aponeurosis of the palm of the hand, from excessive action of the hand in the use of the hammer, the oar, ploughing, &c.," evidently recognising two species, in one of which the aponeurosis is the cause of the contraction, and the contracted hand is narrow. "And this hand," he adds, "may with advantage be divided by a pointed bistoury, introduced through a small wound in the integuments; the finger may be then extended, and a splint applied to preserve it in the straight position." But he observes that "where the theca is contracted, nothing should be attempted for the patient's relief, as no operation or other means have succeeded."

Anchylosis of some of the joints of the phalanges sometimes succeeds to an attack of acute or chronic inflammation of one or more of these small articulations; this may have arisen from disease; for example, paronychia or accident; but from whatever cause the inflammation has arisen, anchylosis of a finger in the extended position, which cannot be contracted, or of a joint in the flexed position, which cannot be extended, is the too frequent result. The history of the case, and the actual state of the anchylosed joint, which cannot be overlooked, will prevent the surgeon from falling into any error in his diagnosis. A contracted state of the ring finger and little finger is frequently to be noticed in those who have suffered much from gout; but we are acquainted with no disease which more frequently produces deformity of the hand and fingers than *chronic rheumatism* (chronic rheumatic arthritis). This morbid condition of the joints of the hand is too cursorily alluded to by authors under the head of rheumatic gout, nodosity of the joints of the fingers, &c. &c. It is a complaint which is erroneously supposed to be met with only in elderly persons. We have, however, in the pauper department of the House of Industry in Dublin, examples of it in females under the age of 30; but of course it is more frequently observed in the aged and rheumatic patient. When the disease has existed long, the whole hand becomes greatly deformed, and the distortion the fingers have undergone in these cases is of itself calculated to impress us with a correct idea of the sufferings the victims of this disease have endured. The carpus is usually preternaturally convex on its dorsal aspect, owing to the thickening and distension of the synovial bursæ, which become like solid ganglions. All the joints of the hand and fingers become enlarged, particularly those which are formed by the junction of the first phalanges and metacarpal bones; at these joints the fingers are more or less flexed towards the palm, and are, at the same time, adducted or drawn to the ulnar side of the hand.

The head of the metacarpal bone, where it joins with the first phalanx of the index finger, seems particularly swelled and enlarged, and projects much towards the radial side and dorsal aspect of the hand, as is represented in *fig.* 231.

Fig. 231.



Chronic rheumatism, or nodosity of the joints.

The last phalanx of a finger is frequently flexed, while the middle phalanx is extended. Whatever be the faulty position which the fingers happen to have assumed, they are usually found to be remarkably rigid. All movements of them, whether voluntary or communicated to them, are painful; and in either case commonly a crepitus, produced by the contact of rough surfaces, is perceived both by patient and physician when making the examination.

When this disease exists in the hand to this amount, it will almost invariably be found that the distressing complaint has also extensively engaged most of the other articulations.

When we make an anatomical examination of the hand of those who have died with the condition of the joints of the fingers above described, we find that the synovial fluid is somewhat thicker than usual, and deficient in quantity. In some of the anchylosed joints we observe a species of fibro-cellular or ligamentous union of the bones; almost all the joints are deprived of their cartilaginous incrustation, which seems as it were to have been worn away by friction; the porous structure of the root of the phalanges is often exposed, and in some cases hollowed out, to accommodate the enlarged head of the metacarpal bone; a cup is formed in the base of the phalanx which is lined with a porcelainous deposit, while around this little cup an exuberant growth of new bone of a looser texture is thrown out. In the removal of the cartilage without suppuration—in the substitution for it of a porcelain-like deposit, and in the surrounding exuberance of new bone, we find this disease of nodosity of the joints of the fingers resembling accurately the analogous affection of the other joints, which has been supposed to be the slow effects of chronic rheumatism.—See Elbow, Knee, Hip, Abnormal Anatomy of.

III. Congenital malformations of the hand.

Children are occasionally born with one or two fingers more than the natural number. The supernumerary finger almost invariably is found to be an imperfect vegetation, growing from the ulnar side of the hand, and in general the deformity is found to exist on both hands. Examples, however, have been, though rarely, seen of a sixth finger parallel to the other fingers, and properly supported by a sixth metacarpal bone.

It frequently happens that children are brought into the world with their fingers united together. This union may be complete, or the connexion may be loose by means of the skin. It is known that up to the second or third month of intra-uterine life an interdigital membrane exists, and the abnormal condition of the fingers we are now considering is nothing but a persistence of the early condition of the fingers in the fœtal state. It seems pretty well proved that these congenital defects are very frequently hereditary, and that whenever the fingers are the seat of them, the toes are similarly affected.

The whole hand, or one or more of the fingers may suffer in utero what has been denominated spontaneous amputation, and the stump will present peculiarities already noticed.—See Fœtus, *fig.* 155, 159.

(R. Adams.)

HAND, MUSCLES OF THE. (Human Anatomy.)

The varied and beautiful movements of which the hand is capable are effected by muscles belonging to separate and distinct regions,—namely, one set of muscles which are the proper and intrinsic muscles of the hand itself, and a second set, which are continued into the dorsal or palmar region of the hand from the posterior or anterior surface of the fore-arm. In the present article it is proposed to describe the intrinsic muscles of the hand; but in considering the actions of that member or of any of its segments, it will be necessary to notice how far the second set of muscles contribute to or aid in their production.

The proper or intrinsic muscles of the hand may be divided into—1, those on the palmar; 2, those on the dorsal surface.

I. The muscles of the palm are fifteen in all. For convenience of description they may be classified into, *a*, those of the thumb, or *external palmar region*, constituting the *thenar* eminence; *b*, those of the little finger, or *internal palmar region*, forming the *hypothenar* eminence; c, those that occupy the hollow of the hand, or the *middle palmar region.*

a. Muscles of the external palmar region.—The muscles of this region, all of which belong to the thumb, are four.

1. *Abductor pollicis manus** *(scaphoido-phalangien*, Cruveilh.) short, flat, broader above than below; it arises from the anterior surface of the scaphoid and trapezium, the superior, anterior, and external part of the anterior annular ligament, and generally from a prolongation of the tendon of the extensor ossis metacarpi, by aponeurotic and fleshy fibres. It proceeds outwards and downwards to be inserted into the outer edge of the upper extremity of the first phalanx of the thumb. Sometimes the two origins of this muscle are not incorporated for some distance, giving the appearance of two muscles.

Relations.—It is covered by the skin and external palmar aponeurosis. It covers the opponens, a few fibres of which appear to its radial side, running in a transverse direction. It is separated by a thin cellular line from the short flexor, which is on the same plane.

The obvious action of this muscle is to draw the thumb forwards and inwards, thus separating it from the fingers.

2. *Flexor ossis metacarpi*, or *opponens pollicis (trapezo-metacarpien*, Cruveilh.), of a rhomboidal form; it arises from the trapezium, and from the fore part of the anterior annular ligament, anterior to the sheath for the radial flexor of the wrist, by long aponeurotic fibres; and posteriorly from a septum between it and the short flexor. From these attachments the fleshy fibres radiate downwards and outwards, being so much the shorter the higher and the more transverse they are. They terminate by

* Soemmering and Albinus divide this into two distinct muscles, the former giving them the names *abductores breves pollicis manus interior et exterior;* the latter calls the internal portion *abductor brevis alter.*

short aponeuroses along all the outer edge of the first metacarpal bone.

Relations.—With the exception of a small portion of its external border, this muscle is covered anteriorly by the preceding muscle. It covers the anterior surface of the first metacarpal bone, and its articulation with the trapezium.

It draws the thumb inwards, turning it upon its own axis, so that it opposes its palmar aspect to the other fingers.

3. *Flexor brevis pollicis manus (trapezo-phalangien,* Cruveilh.) is a larger muscle than the two preceding ones, triangular, bifid superiorly, having its anterior surface channelled; arises by aponeurotic and fleshy fibres, externally from the fore and under part of the annular ligament, and from the process of the trapezium, internally and posteriorly from all the reflected portion of the annular ligament, forming the sheath for the radial flexor and extending to the os magnum, and from the os magnum often by a distinct portion. From these various origins the fleshy fibres run downwards and outwards, are more oblique as they are more internal, and terminate in a strong fleshy bundle which is attached to the external sesamoid bone and outer side of the first phalanx.

Relations.—This muscle is covered by the external palmar aponeurosis, more internally by the tendon of the long flexor of the thumb, then by the common flexor tendons. It covers the first dorsal interosseous, the tendon of the radial flexor of the wrist, and a small portion of the external margin of the adductor of the thumb. Its outer edge corresponds to the abductor and is often confounded with the opponens, and its inner would be undistinguishable from the abductor near the first metacarpal bone, if it were not separated from it by the arteria magna pollicis,*—a fact that appears to have been overlooked by many anatomists, or the descriptions of the attachments of this muscle would never have been so much at variance: the foregoing description coincides with that of Meckel and Cruveilhier. Its tendon of insertion is covered by that of the abductor, which is external to it.

This muscle is badly named, at least if names be intended to denote action, for its power of flexing the thumb is very slight; but it has considerable power as an opposer of it, its insertion being especially favourable to that action.

4. *Adductor pollicis manus (metacarpo-phalangien du pouce,* Chauss.) is the largest muscle of the thumb as well as the most internal; in shape it is a perfect triangle, arising from all the anterior border of the third metacarpal bone, from its articulation with the magnum, from the anterior and superior portion of the trapezoid, and from the palmar interosseous aponeurosis in its central portion. From this extensive attachment the fibres run transversely outwards, the superior ones being most oblique; they converge to a strong fleshy bundle, which is inserted by means of the internal sesamoid bone into the first phalanx of the thumb.

Relations.—Its two internal thirds are covered by the lumbricales and common flexor tendons, also by a layer of the deep interosseous aponeurosis which constitutes its sheath. It covers the two first interosseous spaces. Its inferior border is subcutaneous, especially posteriorly, where it may be felt in the fold of skin extending from the index finger to the thumb.*

Its name implies its action; it draws the thumb towards the median line of the hand.

b. Muscles of the internal palmar region.—There are four muscles in this region also; one is a cutaneous muscle, the palmaris brevis; the others are proper to the little finger, and are inserted into the inner side of its first phalanx and the fifth metacarpal bone. They consist, as the last described set, of an abductor, short flexor, and an opponens minimi digiti.

1. *Palmaris brevis (peaucier de la main,* Cruveilh.) This muscle when it exists, (for in weakly subjects its fibres are often not to be distinguished, though on the other hand it acquires considerable volume in those that are muscular,) arises by aponeurotic intermingled with fleshy fasciculi which run horizontally inwards, forming a small quadrilateral muscle which terminates in the skin.

Relations.—Covered by the skin and imbedded in the adipose substance, it is spread over the muscles of the little finger and the ulnar artery and nerve, from which it is separated by the internal palmar aponeurosis.

It increases the concavity of the palm by puckering the skin over the part it occupies, thereby drawing the hypothenar eminence forwards and outwards, and rendering it more convex.

2. *Abductor minimi digiti (pisi-phalangien,* Cruveilh.) A long flat muscle, broadest at its centre, arising from the pisiform bone and from an expansion of the flexor carpi ulnaris, by strong aponeurotic fibres, which soon become fleshy, running along the inner edge of the fifth metacarpal bone. It ends in a flattened tendon, which is inserted in common with the short flexor into the inner side of the first phalanx, sending an expansion into the extensor tendon.

Relations.—It is covered by the internal palmar aponeurosis, itself covering the opponens.

Use.—It draws the little finger inwards and forwards, separating it from the others.

* Also deep in the palm, it is generally separated from the adductor by the deep palmar arch.

* Sometimes this muscle is separated into two bellies, the one superior and the other inferior, which are completely separate from each other, and of which the superior is by far the greater. In this case the first arises solely from the os magnum or from this bone and a small portion of the superior extremity of the third metacarpal bone, while the second arises from the inferior portion of the anterior head of the third, fourth, and sometimes even the fifth metacarpal bones; it runs transversely outwards and a little backwards to meet the superior head at the first phalanx of the thumb. This anomaly resembles the normal condition of the transverse and oblique adductors of the great toe. Meckel, Anat. vol. ii. p. 185.

3. *Flexor brevis minimi digiti (unci-phalangien*, Cruveilh.)—This muscle is external to the last; it arises from a small portion of the annular ligament and from the anterior part of the unciform process; it runs downwards and inwards to join the last described muscle, with which it is inserted.

Relations.—At its origin it is separated from the abductor by the ulnar vessels and nerve, but it soon becomes confounded with it. Chaussier described them both as one muscle. It is often wanting. In concert with the last, it abducts and slightly flexes the little finger.

4. *Adductor ossis metacarpi or opponens minimi digiti (unci-metacarpien*, Cruveilh.)—It resembles in disposition and form the opponens pollicis. Having the same origins with the preceding muscle, its fibres proceed downwards and inwards, the superior being nearly horizontal; they are inserted into all the internal border of the fifth metacarpal bone.

Relations.—It is covered by the two last muscles; its posterior surface is applied to the fifth metacarpal bone, the corresponding interosseous, and the tendon of the flexor sublimis going to the little finger.

It carries the fifth metacarpal bone forwards and outwards, thereby augmenting the cavity of the hand, and in a measure opposing the little finger to the thumb, but the articulation of the metacarpal bone with the os unciforme allows of so very little rotatory motion, that it is rather a motion of adduction and flexion than of opposition.

c. Muscles of the middle palmar region.—In the middle palmar region we have seven muscles, four connected to the tendons of the flexor profundus, the lumbricales, so called from their resemblance to earth-worms; and three deeper-seated muscles, the palmar interossei occupying a part of the second, third, and fourth interosseous spaces between the metacarpal bones, the remaining part of those spaces being filled up by muscles; we shall presently examine the dorsal interossei.

1. *Lumbricales (flectentes primum internodium*, Spig.) are four slender, elongated, fusiform, fleshy bundles, attached to the tendons of the flexor profundus, just after it escapes from under the annular ligament, distinguished into first, second, &c. from without inwards. The *first* arises from the fore and outer part of the flexor profundus tendon belonging to the index finger, sometimes also from the accompanying tendon of the flexor sublimis; the *second* lumbricalis arises from the radial side of the tendon of the same muscle destined to the middle finger; the *third* and *fourth* are double penniform arising from the opposed surfaces of the three internal tendons of the same muscle; from these attachments they proceed, the two middle vertically downwards, the outer outwards, the inner inwards, towards the outer side of the metacarpo-phalangeal articulations of the fingers, where they end in flat broad tendons, which are inserted into the outer border of the common extensor tendon, in common with the tendons of the corresponding interossei with which they are confused; they assist in completing the sheath which the extensor tendons form for the back of the fingers.

Relations.—Their anterior surface is covered by the tendons of the flexor sublimis, by the palmar aponeurosis, and collateral vessels and nerves of the fingers. Their posterior surface lies upon the interossei, the inferior transverse metacarpal ligament, and the phalanges.

Use.—They assist in the flexion of the fingers upon the metacarpus, at the same time drawing them outwards, they steady the extensor tendons, keeping them applied to the phalanges.

The *interossei*, of which there are seven in all, are small muscles situated between the metacarpal bones, to which they are attached superiorly, their inferior attachment being to the sides of the first phalanges and the extensor communis tendons; there are three on the palmar aspect, which are simple, and four on the dorsal aspect of the hand, which are bifid muscles; there are two to each interosseous space, excepting the first, which has only one: we shall first examine the palmar interossei.

2. *Interossei interni digitorum manus, (metacarpo-phalangiens lateraux palmaires*, Chauss.) Short, prismatic, and triangular; they arise, the first, or *posterior indicis*, from the root and inner side of the metacarpal bone of the fore-finger; the second, or *prior annularis*, from the root and outer side of the metacarpal bone of the ring finger; the third, or *interosseus auricularis*, from the root and outer side of the metacarpal bone of the little finger. They extend along the metacarpal bones, to which they are attached, and are inserted by short tendons; the second and third in common with those of the lumbricales, into the outer and upper, and the first into the inner and upper part of the corresponding first phalanges and side of the extensor tendons.

Relations.—Anteriorly they are covered by the deep flexor tendons and palmar muscles; posteriorly they correspond to the dorsal interossei, which are also connected with them along their unattached margin.

Use.—The simplest way of regarding their action, which is rather complex, is to refer it towards the axis of the hand or a central line drawn through the third metacarpal bone and the middle finger, in which case it is easily perceived that the palmar interossei are adductors towards the axis of the hand.

II. The only intrinsic muscles on the dorsal aspect of the hand are the dorsal interossei, *interossei externi digitorum manus.* Their common points are, that they appear both on the dorsal and palmar aspects of the hand; they are bicipital; arising from the opposed surfaces of two metacarpal bones, both heads terminating in a common tendon, which is attached to the sides of the first phalanges and extensor tendons that are not supplied by the palmar interossei. They are four in number; the first, or *adductor indicis*, alone merits a particular description. It is the largest; arising from the superior half of the external border of the first metacarpal bone, and externally from all the external surface of the second metacarpal bone;

these origins are separated by a fibrous arch, through which the radial artery passes; they are large and fleshy, and soon unite, forming a triangular flattened muscle, which is inserted into the external side of the first phalanx. The insertion of the other muscles are, the two middle into either side of the first phalanx; they are called the *prior* and *posterior medii;* and the last, or *posterior annularis,* into the internal side of the ring-finger.

Relations.—Posteriorly they correspond to the extensor tendons and skin; anteriorly they appear beside the palmar interossei, from which they are separated by a strong septum derived from the deep palmar aponeurosis. Their other relations are the same as the palmar interossei. The first, the abductor indicis, corresponds anteriorly to the adductor pollicis and part of the flexor brevis, which it crosses at right angles; its inferior and external margin is subcutaneous.

Use.—They are all abductors of the fingers from the axis of the hand, and by reason of their insertion into the extensor tendons, act best when the hand is extended. The same may be said of the palmar.

Before we enter on the general uses of this complex muscular apparatus, it would be well to remark that the proper muscles of the thumb and little finger appear to be nothing more than exaggerated and multiplied lumbricales and interossei. We may, in this light, view the short flexor of the thumb as the first lumbricalis, its abductor and opponens as a dorsal interosseus, while its adductor would represent a palmar interosseous muscle; again, as regards the little finger, its abductor and short flexor together personate a dorsal interosseus, while its adductor would be but an internal or palmar interosseous. Their principal use is, by acting on the carpo-metacarpal articulations of the thumb and little finger, which enjoy freer motion than the intermediate ones, especially that of the thumb, to oppose these extreme points of the hand to each other, more or less increasing its concavity, and thereby giving a firmer grasp, inasmuch as they adapt the cavity of the palm to the volume of the body grasped. The great use of this opposable faculty of the thumb (which action is the peculiar characteristic of the hand as distinguishing it from the foot) may be shewn by firmly clenching the fist, when the thumb, by its combined powers of opposition and flexion, is made to overlap the fore and middle, and in some the third fingers, pressing them firmly against the palm, while, at the same time, the thenar eminence is thrown forwards and inwards, meeting them in the palm, and by abutting against counteracts their tendency to fly open when a blow is struck, acting at the same time as a cushion to deaden the violence of the shock. We here see, also, the flexion of the fingers modified by the radial interossei and lumbricales, which, by their action, throw the fingers radiad, so as to bring the three outer ones to abut against the thenar eminence; the little finger is protected, in like manner, by the hypothenar, which is thrown forwards and outwards. The converse modification of the flexion of the fingers by means of the ulnar interossei may be seen in the action of the left hand of a fiddler, where the fingers are flexed and pointed ulnad to run up the scale.

It only remains for us to give a summary view of the muscles, extrinsic and intrinsic, concerned in the motions of the hand. These motions are flexion, extension, adduction or motion ulnad, abduction or motion radiad. First, the flexors of the wrist are six. 1. Flexor longus pollicis; 2 and 3, flexor sublimis et profundus; 4, palmaris longus; 5, flexor carpi radialis; 6, flexor carpi ulnaris. The extensors are six. 1, Extensor communis; 2, indicator; 3, extensor secundi internodii pollicis; 4 and 5, extensores carpi radiales longior et brevior; 6, extensor carpi ulnaris. The last three of the extensors as well as the last three of the flexors act directly on the wrist; the others act first on the phalanges. These also are the muscles that, in extreme flexion and extension, call into play the motion that exists between the two rows of the carpus, the two former extending, the three latter flexing the second row upon the first.

The adductors are five. 1, Extensor carpi ulnaris; 2, extensor communis; 3, flexor carpi ulnaris; 4, sublimis; 5, profundus.

The abductors are also five. 1 and 2, Extensores ossis metacarpi et primi internodii pollicis; 3 and 4, extensores carpi radiales longior et brevior; 5, flexor carpi radialis.

The following table is intended to exhibit at one view the motions of which the fingers are capable, and the muscles which effect them.

The movements of the fingers are—

1. *Flexion* performed by nine.
   - Flexor longus pollicis.
   - Flexor sublimis.
   - Flexor profundus.
   - Three internal lumbricales.
   - Three interossei interni.
2. *Extension* by eight.
   - Three extensores pollicis.
   - Extensor communis.
   - Indicator.
   - Three internal dorsal interossei.
3. *Adduction* by seven.
   - Three adductor, flexor brevis, and opponens pollicis.
   - Abductor minimi digiti.
   - Three interossei, viz. posterior indicis, posterior medii, posterior annularis.
4. *Abduction* by eleven.
   - Abductor pollicis.
   - Adductor et opponens minimi digiti.
   - Four lumbricales.
   - Four interossei, viz. abductor indicis, prior medii, prior annularis, interosseus auricularis.

We thus see that the hand is furnished with no less than thirty-three muscles, each capable of acting either singly or in conjunction with others. The most powerful of these are the flexors and opposers, both performing actions, as we have seen, peculiarly adapted for the prehension and retention of bodies.

But there is yet another function in which they are the chief agents, and of which the hand is the principal organ, that of touch, which may be regarded as a kind of sentinel by which we ascertain the nature of bodies; which without seeing warns the hand from too closely embracing what may prove hurtful to itself, or admonishes it to handle gently those delicate objects that would be destroyed by too rude a grasp. In the blind this sense, by constant exercise, becomes so perfect as in a great measure to compensate for the loss of sight. But by the combination of these two functions the hand is indeed rendered an organ worthy of, and admirably suited to the mind of man. With the one he plans, while through the other he performs and executes all that administers to the pleasures, the comforts, and the conveniences of life, and that establishes his superiority in the creation.

(F. T. M'Dougall.)

HAND, REGIONS OF THE. (Surgical Anatomy.) In the consideration of the surgical anatomy of the hand, we shall commence our description from an imaginary line encircling the fore-arm, at a point immediately below the insertion of the pronator quadratus, or about half an inch above the radio-carpal articulation. From this point downwards for about a finger's-breadth, the wrist is narrow and flattened like the fore-arm; from thence the hand, gradually expanding, acquires that remarkable breadth and flatness so necessary to it both as a tactile and prehensile organ; it is broadest inferiorly where it terminates in the fingers. In front, this region is concave and hairless; posteriorly, it is convex and slightly hairy.

In woman, the hand is smaller and more delicately shaped; it is also rounder and smoother, on account of the greater quantity of subcutaneous adipose tissue, softening down the harsher outline of bone and tendon displayed in the brawny hand of man.

In order to avoid needless prolixity, we shall not subdivide this inferior segment of the upper extremity into the three distinct regions of wrist, hand, and fingers; which, indeed, if we were considering its bony frame-work, would naturally present themselves. But as the soft parts, with which we have principally to do in the present article, exhibit no such natural distinctions in these separate parts, and are, for the most part, common to them all, we shall consider them as constituting one entire region, which is naturally subdivided into *palmar* and *dorsal regions.*

I. *Of the palmar region of the hand.*—The remarkable points on the exterior of this region are as follows:—Commencing from the presupposed imaginary line, and proceeding downwards, we perceive most externally a projection formed by the united tendons of the short extensors of the thumb; next in order, proceeding from without inwards, we notice a hollow, most visible when the hand is flexed, corresponding to the radio-carpal articulation, and in which the radial artery may be felt pulsating immediately before it passes under the tendons we have just noticed; bounding this hollow, on its inside, is a second eminence, formed by the tendons of the flexor carpi radialis and palmaris longus, and the projecting crests of the scaphoid and trapezium; more internally a second depression, corresponding to the ulnar nerve and artery, bounded internally by a third eminence, that of the flexor carpi ulnaris tendon and the pisiform bone, posterior to which may be felt the inferior extremity of the ulna and the interval between it and the bones of the carpus.

Lastly, in front of the wrist, owing to the thinness of the skin in this part of the palmar region, we perceive a blue network of veins, from which the median is formed.

More inferiorly, in the palm proper, we notice externally the thenar eminence, extending from the crest of the scaphoid to the base of the first phalanx of the thumb. On the inner side of the palm is the hypothenar eminence, longer and thinner, but less prominent than the last; it extends from the pisiform bone to the base of the first phalanx of the little finger. Separating these prominent parts, and extending from the inner furrow of the wrist towards the root of the index finger, is a deep excavation,—the hollow of the palm; next may be seen or felt four elevations, corresponding to the heads of the four metacarpal bones, about an inch in front of which the fingers free themselves from the skin of the palm, which is prolonged over them for that distance in a manner somewhat analogous to the web in the foot of a Newfoundland dog, or other swimming animals. Of the fingers themselves, the middle is the longest, the first and third are on a level, the little finger reaches the level of the last articulation of the annular, and the thumb terminates about three lines behind the second articulation of the index; the phalangeal articulation of the thumb being exactly on a level with the metacarpo-phalangeal union of the same finger.

There are likewise certain lines or furrows caused by the folding of the skin in flexion of the hand and fingers, some of which constantly occur, and are worthy of notice, inasmuch as they sometimes serve as guides or landmarks to the surgeon in operating on this region. They are as follows: two on the wrist; the superior one, extending between the styloid processes of the radius and ulna, corresponds to the radio-carpal articulation. Another, more remarkable, slightly convex downwards, projecting between the palmar eminences, separates the wrist from the hand, and corresponds to the articulation between the two rows of the carpus. In the palm, one commences from the metacarpo-phalangeal articulation of the index finger, which soon bifurcates, one of its divisions bounding the thenar on its inner side; the other runs obliquely across the palm, and terminates on the upper part of the hypothenar: this in a measure corresponds to the superficial palmar arch, having the same obliquity across the palm, but being three or four lines inferior to it; these lines are caused by the opposition of the thumb. There is yet another line running from the interval between the index and middle fingers to the base of the little finger; this traverses the hand about two lines above the metacarpo-phalangeal articulations. Opposite the joints of the fingers there are also transverse lines; the two first have double, the last joint but a single line;—an incision made perpendicular to it would fall about a line above the articulation. Of the middle joint, the superior transverse line is the most constant, and is placed about half a line above its articulation.

Of the lines corresponding to the first joint of the fingers, the superior is on a level with the termination of the interdigital web, and from ten lines to an inch below the articulation, excepting that of the thumb, which resembles the middle joint of the fingers, its line nearly corresponding to the articulation. There are many other inconstant folds, or markings of the skin, in this region, which, to the surgeon, are of little import, but which present a book of mystic lore to the gipsy and the cheiromancer, wherein (when opened by the necessary charms) they discern the future destinies of all that seek to be enlightened by them.

We shall now proceed to examine the various structures found in this region, and, for convenience of description, shall consider them as constituting the following layers:—1, skin; 2, subcutaneous cellular tissue, vessels, and nerves; 3, aponeurosis; 4, deep vessels and nerves; 5, muscles and tendons.

1. *The skin.*—The integument on the front of the wrist resembles that on the anterior surface of the fore-arm; but, on reaching the palm, it suddenly changes its character, and instead of the fine, smooth, yielding skin, we find it dense, resisting, exceedingly vascular, and covered with a very strong and thick cuticle; on the thenar, however, it preserves some degree of suppleness and elasticity. In those accustomed to hard manual labour, and in the aged, the cuticle becomes so thick and callous as to enable them to handle even hot coals without inconvenience; but in them, from this increased resistance, and from the difficulty of getting at matter, or freeing the parts by incisions, inflammations of the palm are the more dangerous. Corns are sometimes developed at the roots of the fingers, on the prominences formed by the heads of the metacarpal bones. There are no sebaceous follicles to be discovered in this region; but M. Velpeau thinks, from the fact of the occasional appearance of variolous pustules on the front of the fingers, that follicles there exist. The physical conditions of the skin of the hand, as to coolness or warmth, as to moisture or dryness, often furnish valuable signs in disease.

2. *Subcutaneous cellular tissue* is dense and serrated, more fibrous than cellular, enclosing in its meshes small rounded pellets of fat. On the wrist it binds the skin so closely to the subjacent parts, that, in cases of serous or other infiltration above this point, the effused fluids are arrested, and prevented from passing into the palm of the hand; also, in very fat and flabby people, and in young children, a kind of strangulation is observable at the wrist from the same cause. On the thenar this layer is laxer and less compact, permitting the skin to play freely. On the centre of the palm and hypothenar it is very dense and fibrous, enclosing larger pellets of fat, binding the skin very firmly to the palmar aponeurosis and sheaths of the fingers, towards the extremities of which it becomes more fatty, increases in thickness, forming a soft elastic cushion called the pulp of the fingers. This tissue is the seat of that painful phlegmonous inflammation, the true whitlow. The unyielding nature of the thick consistent skin on the one hand, and of the bones and sheaths on the other, whereby the swollen and inflamed pulp, together with its great number of vessels and the nervous expansion it encloses, are violently compressed, easily account for the violent symptoms, and call loudly for the prompt relief of the strangulation by means of the knife, and also indicate the great advantage of emollients.

The *subcutaneous nerves* are few, and derived from the palmar cutaneous branch of the median and some terminal branches of the internal and musculo-cutaneous nerves. The *veins* are also very few, and give rise to the median, and are accompanied by the superficial lymphatics.

3. *The aponeurosis.*—At the wrist the aponeurosis, derived from that of the front of the forearm, is interwoven with and inseparable from the anterior annular ligament, from the lower border of which, and from the tendon of the palmaris longus, the palmar fascia proceeds. Above the annular ligament the aponeurosis is attached to the extremity of the ulna, and the pisiform and the styloid process of the radius; it furnishes sheaths to the tendons that do not pass under the annular ligament, one to the ulnar and its nerve, and another to the radial trunk and its volar branch. The *anterior annular ligament* is exceedingly strong, attached internally to the pisiform and unciform, and externally to the scaphoid and trapezium. It consists of two layers, the one superficial, of divergent fibres, derived from the tendon of the palmaris longus when it exists, or belonging to the origin of the palmar fascia when it does not; the other deep, of transverse fibres, continuous with the fascia of the forearm. It forms, together with the concavity of the palmar aspect of the carpal bones, a sort of elliptical ring about two inches in its transverse, and one inch in its antero-posterior diameter, and gives passage to the common flexor tendons and median nerve, which are enveloped by a common synovial bursa which binds them together, and terminates in a common cul-de-sac above and below the ligament; also to the long flexor tendon of the thumb, which has a distinct bursa. This ligament, from its great strength, presents an insurmountable obstacle to the progress of tumours developed beneath it, forcing them to protrude on the forearm above the ligament in the hand below it. Thus, when the common synovial bursa of the tendons is distended, it forms two tumours, the one above, the other below the ligament; and upon compressing the fluid from one the other will be found to enlarge. Ganglia rarely occur here.

The annular ligament gives attachment inferiorly on either side to the muscles of the thumb and little finger, and in the centre to *the palmar fascia*, a dense fibrous layer binding down the flexor tendons in their passage along the hand.

The palmar fascia is chiefly derived from the expansion of the palmaris longus, which, when present, is its tightening muscle. It is strongest in the palmar hollow, where it is triangular in shape, its apex at the annular ligament, and is composed of divergent and longitudinal, interwoven with a few transverse fibres; the latter, becoming gradually fewer and more scattered, are lost on the tendons running to the fingers, and some few are at times continuous with the tendinous sheaths of the fingers. Near the roots of the fingers this portion of the palmar fascia divides into four bands, which subdivide each into two tongue-like processes, that embrace the heads of the metacarpal bones, and are attached to the sides of the first phalanges and the inferior transverse metacarpal ligament. At this point of division the transverse fibres are stengthened, and convert these slits into four distinct fibrous arches, through whicb pass the flexor tendons. Between these arches we find three lesser ones resulting from the primary division of the fascia. They transmit the collateral vessels and nerves, and the lumbricales. This fascia is intimately connected with the preceding layer anteriorly, its deep surface covering the superficial palmar arch, flexor tendons, ulnar and median nerves, from which it is separated by loose and very extensible cellular tissue, which permits the tendons to play freely. This portion of the fascia presents numerous apertures through which the deep fat and cellular tissue communicate with the subcutaneous, and when the parts beneath are swollen they protrude, forming small herniæ, which, getting strangulated in these apertures, give rise to great pain. It detaches from either side two processes, a superficial and a deep one. The two deep processes dive deep into the palm, to form the interosseous aponeurosis; of the superficial ones, the external, assisted by the tendinous expansion of the extensor ossis metacarpi, envelopes the thenar muscles; the internal stronger, and assisted by the flexor carpi ulnaris expansion, encloses the hypothenar muscles, and to it is attached the palmaris brevis. We next meet with the strong sheaths binding down the flexor tendons in their passage along the fingers. They are continuous above with the palmar fascia, by means of strong detached transverse fibres, which are prolonged over the tendons as they pass through the arches of the fascia; laterally they are firmly attached to the ridges on the sides of the phalanges. On the bodies of the two first phalanges these sheaths are very strong and resisting; but opposite the articulations they become very thin, and are often wanting; so that the synovial sacs of the tendons are in contact with the subcutaneous layer; and it is through these spaces that the inflammation in whitlow is propagated to the synovial membrane and joints. At the last joint of the fingers they become weak and thin, and are confounded with the pulp and periosteum. They each enclose a distinct elongated synovial sac, which reaches as far upwards as the fibrous arch of the fascia, but does not communicate with the synovial membranes of the joints, entirely enveloping the flexor tendons, lubricating them, and facilitating these motions in the sheaths. At the point where the tendon of the profundus passes through the divisions of the sublimis, there is a falciform process of the synovial sheath of considerable strength, attaching the tendon of the latter to the first phalanx, so that if the fingers be amputated at the second joint, the power of moving the first phalanx will still be retained, though the contrary has been stated. We may here likewise notice that the gradual contraction of the three last fingers occurring in adults, (*crispatura tendinum,*) formerly thought incurable, as it was supposed to be the result of a drying or contraction of the tendons, is stated by Baron Dupuytren to be nothing more than a band or strip of the palmar fascia, adhering to the sheath of the tendon, upon the division of which a complete cure may be effected; or it may be caused by a fibrous transformation of the subcutaneous cellular layer, depriving it of its elasticity, and causing it to contract, so that the finger cannot be extended. What favours this opinion is, that this malady generally occurs in labourers, boatmen, and those whose avocations necessitate constant flexion of the fingers, at the same time that firm pressure is kept up, especially against the roots of the three inner fingers, as in handling a spade, or grasping an oar.

4. *The vessels and nerves* are exposed on removing the fascia, being immediately underneath it. The palmar aspect of the hand being that of flexion, according to the general rule of arterial distribution, the principal trunks are there found; they are the ulnar and radial arteries, and a branch of the interosseous accompanying the median nerve.

The ulnar artery at the wrist lies on the annular ligament, to the radial side of the pisiform bone, where it is covered by the expansions of the flexor carpi ulnaris; it then curves towards the mesial line, and crossing the annular ligament, traverses the palm between the fascia and the flexor tendons, in a curved direction towards the centre of the metacarpal bone of the index finger. In this course it forms an arch, the convexity of which looks downwards and inwards, towards the ring and little fingers, its concavity being turned to the ball of the thumb. It then inosculates with two branches from the radial, the superficialis volæ, and the radialis indicis, forming thus the superficial palmar arch, from the convexity of which proceed four digital arteries which subdivide into the collateral branches at about two lines below the metacarpo-phalangean articulations; they supply the palmar and lateral surfaces of all the fingers except the thumb and the radial side of the index finger. They all run along the sides of the fingers external to the sheaths, to the last phalanx, where those of either side coalesce, forming an arch, from which arise numerous branches to supply the pulp of the fingers. When the artery arrives at the wrist, it sends off two regular branches, the arteriæ carpi ulnares anterior et posterior, to the fore and back parts of the joint. After crossing the annular ligament, it detaches also a deep communicating branch, which dips down between the flexor brevis and abductor minimi digiti, to join the deep arch from the radial.

The radial artery, just below the styloid process of the radius, passes round to the back of the wrist under the two external extensors of the thumb, to the cleft between the two first metacarpal bones, where it again passes into the palm between the heads of the first dorsal interosseous, and then between the short flexor and adductor of the thumb, to form with the communicating branch from the ulnar the deep palmar arch. In this course it lies upon the capsular and external lateral ligaments, and close upon the head of the first metacarpal bone; it is therefore generally divided in the amputation of that bone; but it would often be avoided, were the edge of the knife kept close to the inner side of the bone, as it is carried down to the joint. Before it curves round the wrist, this artery gives off the superficialis volæ, a branch which runs over the annular ligament to unite with the superficial palmar arch; also the anterior carpal branch, which anastomoses with the anterior interosseous and corresponding ulnar branch. At the back of the carpus it detaches the dorsalis carpi radialis, which inosculates with the corresponding branch from the ulnar; it runs beneath the extensor tendons, supplying the synovial membrane and the bones of the carpus; it also anastomoses with the posterior interosseous. This branch generally sends off the metacarpal artery, which forms a kind of posterior arch across the heads of the metacarpal bones, that supplies the integuments and interossei muscles;—this metacarpal branch sometimes arises from the trunk of the radial. The only remaining dorsal branches are, the arteriæ dorsales pollicis, in general two distinct branches, but sometimes arising by a common trunk. They run along the dorsum of the thumb, the one on the radial, the other on its ulnar side; this last sends a branch to the index finger, the dorsalis indicis. The radial artery then dips deep into the palm, as before described, and divides into its three terminal branches: the first is the magna pollicis, which runs along the ulnar side of the metacarpal bone of the thumb, and at its inferior extremity divides into two collateral branches, which are distributed similarly to those of the fingers. The next branch is the radialis indicis, which forms the external collateral artery of that finger; it receives a branch of communication from the superficial palmar arch. Lastly, the arteria palmaris profunda; this runs deeply into the palm, generally separating the flexor brevis and adductor pollicis muscles. It crosses the interossei and anterior part of the superior extremities of the metacarpal bones; it is covered by the deep flexor tendons and lumbricales; and opposite the fifth metacarpal bone inosculates with the communicating ulnar,—completing thus the deep palmar arch, the convexity of which is towards the fingers; and it gives four or five regular branches, which supply the interossei, and at the clefts of the fingers anastomose with the digital branches. This arch is less oblique, and farther from the fingers, than the superficial one.

Thus we see that the disposition of the arteries of the hand is peculiar, and is somewhat analogous to that of the venous system generally,—viz. that they are divided into a superficial and deep set. The question naturally occurs, whether it may not be for the same cause, viz. that when pressure obstructs the superficial vessels, the deep may still carry on the interrupted circulation? In the hand, as we have seen, the communications between the deep and superficial arches are frequent and free, while we daily experience with what violent and continued pressure the circulation through the superficial arch is liable to be interrupted.

The varieties of the arteries of the hand are numerous: sometimes the radial predominates, at other times the ulnar, in the share they respectively take in supplying the hand; they are always in an inverse ratio; and if both are small, then the artery of the median nerve derived from the interosseous is proportionably large.

From the constant call for vigorous and rapid, as well as sustained and powerful action, the hand, with the exception of the tongue, is the most vascular of the voluntary locomotive members of the human body. The communications between its arteries are so numerous and free, as, in cases of simple wounds of this region, frequently to prove a source of great embarrassment to the surgeon, and, in unskilful hands, of danger to the patient. Wounds of the integuments of the palm often bleed profusely, and are liable to secondary hæmorrhage. This may in some measure be accounted for by the peculiar density of the cellular tissue and skin, and its intimate connection with the subjacent fascia, which, as well as the numerous branches given off from the divided vessels, prevent their retraction, nor can a coagulum easily form around them; they are not generally vessels that require a ligature, (excepting in cases similar to one related by M. Velpeau, where the arteries of the hand were in a varicose state, and of an enormous size,) but where ordinary means fail, plugging the wound, the continued application of cold, and a tightish bandage up to the shoulder, in order to moderate the circulation in the whole limb, will usually stop even very severe bleedings. If these means should not succeed, and no large divided vessels can be seen in the wound, the surgeon must tie one or even both arteries above the wrist. The inosculations with the interosseous will sometimes even then allow the bleeding to continue, especially in cases where the median branch is large, or helps to form the arch; but pressure and cold will then soon stop the remaining hæmorrhage.

Veins.—The deep ones accompany their arteries; the superficial veins are very few on the palm.

The lymphatics accompany the veins.

The nerves of this region are superficial and deep: the former have been already noticed; the latter are the median and ulnar. The first passes under the annular ligament with the flexor tendons; it then divides into five branches, behind the superficial palmar arch. The first, or most external of these branches, supplies the short muscles of the thumb; the second sends one or two deep branches down to the interossei, to communicate with the deep palmar branch of the ulnar nerve; it then finishes on the outer side of the thumb; the remaining three branches soon bifurcate, and are distributed to the ulnar side of the thumb, to both sides of the index and middle, also to the radial side of the ring finger; giving likewise a branch to each corresponding lumbrical muscle.

The ulnar nerve passes over the annular ligament to the internal and posterior side of its artery; while passing over the ligament, it sends the cutaneous branch to the skin on the hypothenar, and then it divides into three branches: first, the deep palmar branch, which accompanies the communicating branch of the artery, and behind the deep palmar arch unites with the branch sent from the median to supply the deep muscles; the next branch supplies the ulnar side of the little finger and its muscles; while the remaining branches supply the collateral nerves not furnished by the median, to the radial side of the little, and the ulnar side of the ring fingers. All these collateral nerves accompany the corresponding arteries along the sides of the fingers, giving numerous branches in their course that terminate in the skin; and on the last phalanx they divide into two branches, a dorsal and palmar: the dorsal, or ungual branch, is lost in the skin, under the nail; and the palmar is expanded in the pulp of the fingers. It is remarkable that the nerves of the opposite sides of the fingers never anastomose.

The *muscles and tendons* with which the hand is pre-eminently endowed, lastly present themselves for our consideration. In the upper part of this region, or in front of the wrist, there are scarcely any muscular fibres, excepting a small portion of the origins of the thenar and hypothenar muscles; and sometimes the lower border of the pronator quadratus reaches as far, or a little below the imaginary line we have marked out as the superior boundary of this region. But we have no lack of tendons in this part; for we here find an assemblage of them more numerous, and more tightly packed, than in any other part of the body; they are also invested by synovial sacs, and pass through the carpal ring, which was described in speaking of the annular ligament in which they are closely bound down. There are, however, some that do not pass through this ring, and they are the following:—Most externally is the tendon of the supinator longus, which terminates by being inserted into the radius at the upper boundary of this region; then the tendons of the extensores ossis metacarpi, and primi internodii pollicis, running in the most external groove in the radius, which is converted into a sheath for them by a process of the posterior annular ligament. The radial artery passes under these, separating them from the joint in its passage to the back of the wrist.

More internally we have the tendon of the flexor carpi radialis passing into the palm, behind the external reflected portion of the annular ligament, in a canal destined for it in the scaphoid and trapezium; the next tendon is that of the palmaris longus, which here begins to expand on the anterior surface of the annular ligament, to which it is also attached; and lastly, we find the flexor carpi ulnaris tendon implanting itself into the pisiform bone. This tendon, and those of the short extensors of the thumb, form the lateral boundaries of this region, dividing it from the dorsal.

All the other tendons from the front of the fore-arm pass through the carpal ring; they are nine in number:—Four of the flexor sublimis; four of the flexor profundus,—these are all bound up in a common synovial sheath, along with the median nerve; the remaining tendon, that of the flexor pollicis, is situated more externally, and has a distinct synovial sac. All these tendons, after emerging from under the annular ligament, diverge towards the different fingers to which they are destined. In the palm they are placed beneath the aponeurosis, and lie upon the palmar interossei and the adductor pollicis.

As the muscles of the palm have already been described, (see HAND, MUSCLES OF,) we shall not notice them further than merely to observe, that the intrinsic muscles of the thumb and little finger constitute the external and internal regions of the palm, which they almost solely occupy; while the middle region, or hollow of the palm, is occupied not only by the remaining intrinsic muscles, (the interossei and lumbricales,) but also contains the tendons just described, with their synovial sheaths, as well as the principal vascular and nervous trunks of the hand. Wounds are therefore more dangerous in the middle of the palm than on either the external or internal regions, which are constituted principally of muscle, having but a thin aponeurosis and no important vessels or nerves. It is also worthy of remark, that the short muscles of the thumb, especially the abductor, flexor brevis, and adductor, though they act but indirectly on the first metacarpal bone, present a serious obstacle to its dislocation forwards; their action tending to throw its base backwards, whilst, by their bulk and tension, they repel its attempts to slip forwards.

Having now examined all the soft parts on the palmar region, as nearly as possible in the order in which they would have been exposed by the dissector, we proceed to the second division of our subject, and shall consider the various layers of the dorsal region in similar order.

II. *The dorsal region of the hand* is convex and irregular; the veins are large and prominent. When the hand is extended the extensor tendons stand out in strong relief, converging at the wrist; and when flexed the heads of the metacarpal bones and phalanges protrude. The other prominent external characters of this region are, at the superior and external part, when the thumb is extended and abducted, an elongated depression, bounded externally by the two short extensor tendons of the thumb, and internally by its long extensor and the tendon of the extensor carpi radialis longior. In this depression the pulsation of the radial artery may be felt, also the heads of the two first metacarpal bones: internally and about the same level there is a hollow corresponding to the union of the wrist and hand; and at this point we can feel the tendon of the extensor carpi ulnaris and the styloid process of the ulna. When the thumb is adducted the first dorsal interosseous projects considerably. The fingers appear longer on their dorsal aspect, the interdigital web that was noticed on their palmar surface being here wanting.

1. *The skin* is very loose and thrown into transverse folds; opposite the two last joints of the fingers may generally be seen three or more transverse furrows; the middle one is the deepest and most constant, and an incision made about a line and a half below it will hit upon the articulation. It resembles that on the back of the fore-arm, but it gradually thickens at the sides as it approaches the palmar surface. Hairs and sebaceous follicles are most abundant on the ulnar side of the back of the hand and on the first phalanges. On the ungual phalanx, the skin, as it approaches the nail, becomes tighter and glabrous, extends for about two lines over the root of the nail, and is then reflected back, so as to be continued over its anterior surface to its free border, where it becomes continuous with the skin of the pulp of the fingers. It is in this portion of the skin about the roots of the nails that the false whitlow, called by the French *tourniole*, takes place. It is an inflammation more of an erysipelatous than a phlegmonous nature, sometimes attacking several fingers successively or at once, therein differing from the true whitlow, which is generally confined to one finger. Warts also frequently occupy the skin of the dorsum of the fingers, especially in those that have to perform hard manual labour.

2. *The subcutaneous layer* is very lax, serous infiltration easily taking place; it contains no pellets of fat like that of the palmar surface.

The *veins* are subcutaneous, large and numerous; all the large veins of the hand being on its dorsal surface, the venous circulation is not interrupted by the effort of prehension. On the back of the fingers they form a complete net-work, which gives rise to the dorsal collateral veins of the fingers. At the interosseous spaces these unite as the arteries divide, and then proceed towards a kind of dorsal venous arch, the concavity of which is upwards, and from which arise larger branches; these, in conjunction with one from the little finger called the *vena salvatella*, and another from the thumb called the *cephalic*, form the basilic and cephalic veins described in the fore-arm. (See Fore-arm.) Some people prefer being bled on the back of the hand, but, owing to the laxity of the skin and subcutaneous layer, considerable extravasation of blood is apt to take place. The subcutaneous nerves, derived from the dorsal branch of the ulnar, and the terminal branches of the musculo-spiral accompany the veins, as also do the lymphatics.

3. The *aponeurosis* is continued from that of the back of the fore-arm; it is strengthened across the back of the wrist by strong parallel oblique fibres, forming a band of nearly an inch in breadth; which extends obliquely downwards over the extensor tendons from the styloid process of the radius to the internal lateral ligament of the wrist.* It sends down strong processes between the tendons that convert the grooves in the back of the radius and ulna into sheaths, which are as follows:—1st, that noticed on the palmar region for the short extensors of the thumb; 2d, for the radial extensors; 3d, for the long extensor of the thumb; 4th, for the extensor communis and indicator tendons; 5th, for the extensor minimi digiti; 6th and last, for the extensor carpi ulnaris. The metacarpal aponeurosis is very thin and split into two layers; the one separates the subcutaneous layer, vessels, and nerves from the tendons; the other covers the dorsal interossei, isolating them from the tendons.

4. The *nerves* are, externally, the radial, which sends one branch, that, bifurcating, supplies the thumb and radial side of the index finger; and another, which in like manner furnishes the inside of the index and the middle finger. Internally the posterior branch of the ulnar supplies the two remaining fingers. These branches receive frequent communicating ramuli from the anterior collateral nerves.

5. *Tendons and muscles.*—The former are less numerous on this region than on the palmar; the order in which they cross the wrist was mentioned in describing the aponeurosis. If the divisions of the extensor communis be enumerated, they are twelve in number; four of these are inserted at the base of the metacarpal bones of the thumb, index, middle, and little fingers; they are the extensor ossis metacarpi pollicis, extensores carpi radiales, and extensor carpi ulnaris. The other tendons proceed onwards to the phalanges. Those of the common extensor are flattened and riband-like; the three inner ones communicate with each other, while that going to the index is free. Opposite the metacarpo-phalangean articulation these tendons narrow and thicken, sending an expansion to either side of the articulation: they again flatten on the first phalanges, where they receive the tendons of the lumbricales and interossei. At the articulation of the first and second phalanges they divide into three portions: a middle one, that is inserted into the superior extremity of the second phalanx; and two lateral ones, that run along its sides, reunite at its inferior end, and are implanted into the upper part of the ungual

* Generally called the posterior annular ligament.

phalanx.* The remaining tendons of the index and little fingers are implanted into the phalanges of those fingers with those of the common extensor: those of the thumb are inserted separately. Having no sheaths, these tendons are firmly attached by means of a membranous expansion to the bones to prevent them slipping aside, nor have they here any synovial membranes, and are therefore in contact with those of the joints; but as they pass through the sheaths in the posterior annular ligament, they are all provided with synovial sacs. The largest is that of the extensor communis and indicator; they are less complex than those of the palmar region, and their inflammation less formidable and not so painful. The occurrence of ganglia is here very frequent. They sometimes attain a large size and produce considerable inconvenience. The puncture of them is not so dangerous here as in the palmar region.

6. *Arteries.*—The course of the radial over the back of the hand has been already noticed; its metacarpal and carpal branches run across the wrist beneath the extensor tendons, unite with the posterior carpal branch of the ulnar, forming a kind of dorsal arch, from which proceed the interosseous and perforating branches, to communicate with the deep arch; also the dorso-digital branches, one to either side of the fingers.

The *bones* and *ligaments* forming the firm, light, and compact skeleton of the hand have been elsewhere described. See article HAND, BONES AND JOINTS.

In the amputation of the metacarpal bone of the thumb, which is easily performed at its articulation with the trapezium, the edge of the knife should be kept close to the ulnar edge of the bone, in order, if possible, to avoid wounding the radial artery as it traverses the interosseous space. The metacarpal bone of the little finger may also easily be removed by an operation similar to that practised for the thumb; the articulating surfaces are nearly plane and inclined obliquely upwards and inwards. Disarticulations may also be performed of the other metacarpo-carpal joints; but the operations are very difficult and embarrassing, owing to the irregularity of the articular surfaces and their close connexions with each other, and in removing them singly a much neater and easier plan is, if their upper extremities are sufficiently sound, to saw through them in an oblique direction.

In amputating at the phalangeo-metacarpal articulations the flap is, if possible, made on the palmar surface. At the first joint of the fingers two flaps are preserved by making two semilunar incisions, which extend from the head of the metacarpal bones to the termination of the commissure of the fingers, meeting behind and before at the joint, which is an inch above. They may all be amputated together when a single flap is made on the palmar surface terminating at the line in the skin that bounds the commissure. In amputating at the other joints of the fingers it is necessary to recollect the marks, before alluded to when speaking of the skin, and to divide the lateral ligaments before entering the joints.

(F. T. M'Dougall.)

* It is not uncommon for these tendons to send a slip to the superior extremity of the first phalanx.

HEARING, ORGAN OF. The ear (in the wide acceptation of the term). *Organon auditûs s. auris.*—Fr. *L'organe de l'ouie au l'oreille.* Germ. *Das Gehörorgan oder das Ohr.*—As the apparatus of vision naturally admits of being divided into two parts, viz. the eye-ball and its appendages, so we can distinguish in the apparatus of hearing a fundamental organ, and parts accessory to the perfect performance of its function. The fundamental organ of hearing is what is commonly called the internal ear, or from the complexity of its structure, the *labyrinth.* The accessory organs consist of the middle ear or tympanum and external ear.*

If we extend our observations to the animal series, and trace the apparatus of hearing along the descending scale, we shall find that the accessory parts gradually disappear, and that the sense of hearing comes at last to have for its organ merely a representative of the labyrinth in the higher animals. This part even, having laid aside much of its complicated structure, presents itself under the form simply of a membraneous pouch containing a fluid, with a calcareous concretion suspended in it, on which the auditory nervous filaments are expanded.

The labyrinth being in the apparatus of hearing exactly what the eye-ball is in that of vision, may be distinguished by the name of *ear-bulb.* The ear-bulb, like the eye-ball, consists of a hard external case, in the interior of which are contained membraneous and nervous parts and humours. The accessory parts of the apparatus of hearing have also their prototypes in the accessory organs of the apparatus of vision.

The different parts of the apparatus of hearing are situated in the interior and on the surface of the temporal bone. See the description of the temporal bone in the article CRANIUM.

I.—THE EAR-BULB, *or fundamental organ of hearing.* (*Bulbe auditif,* Breschet.)

In man and the higher animals, the hard external case of the ear-bulb is of bone, and is called the *osseous labyrinth.* The soft textures contained in its interior bear the name of *membraneous labyrinth.* The interior of the osseous labyrinth, which we may with Breschet† call the *labyrinthic cavity,* is not completely filled by the membraneous labyrinth; the remaining space is occupied by a limpid watery fluid.

1. *The osseous labyrinth (labyrinthus osseus;* Fr. *Labyrinthe osseux;* Germ. *Das knöcherne Labyrinth.)*—The osseous labyrinth presents three compartments, distinguished by the names

* Haighton, in Memoirs of the Medical Society of London, vol. iii. p. 7. London, 1792.

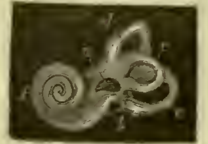
† Recherches anatomiques et physiologiques sur l'organe de l'ouie et sur l'audition, &c. chap. i. s. x. Paris, 1836.

of *vestibule, semicircular canals*, and *cochlea*. The semicircular canals and cochlea do not communicate immediately with each other, but only *mediately* through the vestibule. The latter may be considered the principal compartment.

The osseous labyrinth is imbedded in the substance of the petrous portion of the temporal bone, from the compact texture of which it is, in the adult, scarcely to be distinguished. In the early periods of life, however, its walls consist of a hard but brittle osseous substance, around which is the then less compact tissue of the petrous bone. Hence it is in a young bone only, and that by means of some little preparation, that the external form of the osseous labyrinth can be well demonstrated.

Of the compartments of the osseous labyrinth, the vestibule lies in the middle, the semicircular canals behind it, and the cochlea in front.

Fig. 232.



The exterior of the osseous labyrinth of the left side. Natural size.

a. Oval or vestibular fenestra; *b*. round or cochlear fenestra; *c*. external or horizontal semicircular canal; *d*. superior or anterior vertical semicircular canal; *e*. posterior or inferior vertical semicircular canal; *f*. the turns of the cochlea.

The vestibule, (vestibulum; Fr. *le vestibule;* Germ. *der Vorhof.)*—The vestibule is an irregularly shaped cavity, the diameter of which from above downwards, as also from behind forwards, may be stated to be about one-fifth of an inch. The distance between its inner and outer wall is somewhat more than one-tenth of an inch. In an anatomical sense we can distinguish in it three horns, one of which is towards the anterior and lower part, another towards the posterior and lower part, whilst the third composes the upper part of the vestibular cavity.

The anterior and lower horn leads by an oval opening directed forwards and downwards into the vestibular scala of the cochlea. This opening is called the vestibular orifice of the cochlea, *osteum s. opertura scalæ vestibuli cochleæ*. The posterior and lower horn of the vestibule corresponds to three of the orifices of the semicircular canals; the upper horn to the other two orifices.

At the under part of the inner wall of the vestibule, within the limits of its anterior horn and to the inside of the vestibular orifice of the cochlea, is a hemispherical depression, *fovea hemispherica s. sub-rotunda*. Its bottom, which corresponds to the posterior part of the lower depression at the bottom of the internal auditory meatus, presents a sieve-like spot, *macula cribrosa*, that is, it is perforated by minute apertures for the passage of filaments of the auditory nerve. On the upper wall of the vestibule, bordering the upper margin of the hemispherical fossa and within the limits of the upper horn, is another depression, of an oval shape, which is known by the name of *fovea hemi-elliptica*. The hemispherical and hemi-elliptical depressions are separated by a ridge or pyramidal eminence, *eminentia pyramidalis*, pervaded by small canals for the passage also of nervous filaments. On the inner wall of the vestibule, a little in front of the orifice common to the two vertical semicircular canals and within the limits of the posterior horn, there is, bordering on the hemi-elliptical and hemispherical depressions, below the former and behind the latter, another very small depression or sulcus, *fossa s. cavitas sulciformis*, which leads upwards and backwards to a small oblique orifice, that of the aqueduct of the vestibule, *osteum internum aqueductus vestibuli*. At the middle of the inner wall of the vestibule, where the boundary lines of these three depressions meet, there is a slight eminence.

The inner wall of the vestibule corresponds to the bottom of the internal auditory meatus, and is pervaded by small canals, some of which have been already mentioned, for the passage of fibrils of the auditory nerve and of blood-vessels.

In the outer wall of the vestibule there is an oval, or rather a kidney or bean-shaped hole, called *foramen ovale, s. fenestra ovalis, s. fenestra vestibuli*. The long diameter of this aperture, which is about one-tenth of an inch or perhaps a little more, is directed from behind forwards. Its vertical diameter is about half that of its long diameter. The upper part of the circumference of the hole is arched upwards, the lower part is slightly inclined in the same direction. The margin of the vestibular fenestra is turned in towards the vestibule. Viewed from the tympanum, into which it opens in the macerated bone, the vestibular fenestra appears situated at the bottom of a fossa, which was called by Cotugno *pelvis ovalis*. In the recent state the vestibular fenestra is closed in by the base of the stapes.

The semicircular canals, (canales semicirculares; Fr. *les canaux semicirculaires;* Germ. *die Bogengänge oder halbcirkelförmigen Canäle.)* These are three canals, which, describing more than the half of an irregular circle, open at each of their extremities into the vestibule; hence, if it was not for the circumstance that two unite by one of their extremities to form a common short canal, there would be in the vestibule six orifices of semicircular canals, instead of the five only which exist. The calibre of these canals is about one-twentieth of an inch in the direction from the concavity to the convexity of their curve; in the opposite direction they are somewhat compressed, so that a transverse section, instead of presenting a round orifice, presents an elliptical one. The semicircular canals are wider where they open into the vestibule, but especially so at one of their extremities, which presents a dilatation in the form of a bulb, called ampulla or ampullary sinus, *sinus ampullaceus*.

Two of the semicircular canals occupy a vertical position and one of them a horizontal.

Of the *vertical*, one is *anterior* and *superior*, the other *posterior* and *inferior*. The *horizontal* is *external*.

Superior vertical semicircular canal, canalis semicircularis verticalis superior. The superior vertical semicircular canal has its arch directed upwards, and its extremities, which are more widely divergent than those of either of the other two semicircular canals, downwards. Followed from its outer extremity, it describes its curve from without and upwards, then downwards and inwards, with an inclination from before backwards,—in a word, across the petrous bone. The convexity of the curve of this semicircular canal can always be recognized on the upper surface of the petrous bone. The concavity of it is free in the fœtus and in the adult of some of the lower animals, as the dog, hare, &c.

The inner extremity of the superior vertical semicircular canal and the upper extremity of the posterior vertical unite to form a common canal, *canalis communis*, which is about one-eighth of an inch long, and somewhat wider than either of the two which unite to form it.

Posterior vertical semicircular canal, canalis semicircularis verticalis posterior. Leaving the common canal, the posterior vertical semicircular canal describes its curve parallel to the inner and posterior surface of the petrous bone, perpendicularly from above backwards, then downwards and forwards. The convexity of the curve is thus directed backwards and slightly outwards, its extremities forwards and inwards.

Horizontal semicircular canal, canalis semicircularis horizontalis. This is the shortest of the three canals; traced from its anterior extremity, which is close to that of the superior vertical, it curves outwards and backwards, then inwards and forwards. Its convexity is outwards, its extremities directed inwards.

We described in the vestibule three horns, into the posterior and into the superior of which the semicircular canals opened. In the superior horn is observed the orifice of the external extremity of the superior vertical semicircular canal, and immediately below that and above the fenestra vestibuli, the orifice of the anterior extremity of the horizontal semicircular canal. Both of these orifices are dilated into ampullæ. In the posterior horn is the orifice of the canal common to the two vertical semicircular canals. Below and in front of this orifice is the opening of the inferior extremity of the posterior vertical semicircular canal. Above the latter and immediately outside the former is the opening of the posterior extremity of the horizontal. Of all these orifices in the posterior horn, that of the lower extremity of the posterior vertical semicircular canal is the only one which is dilated into an ampulla.

There are thus three ampullary dilatations, one at the outer extremity of the superior vertical semicircular canal, a second at the anterior extremity of the horizontal, and the third at the lower extremity of the posterior vertical. In the lower and anterior wall of the ampullary sinus of the posterior vertical semicircular canal is a small sieve-like spot indicating the entrance of nervous filaments.

The cochlea, (cochlea; Fr. *le limaçon*; Germ. *die Schnecke.)*—The cochlea does not exist in all its perfection except in the Mammifera. In birds it is in a very rudimentary state, but it is easy to trace parts analogous to what we find in the Mammifera. In regard to frequency of occurrence in the animal series, the cochlea does not stand next to the semicircular canals; the tympanum is found in a greater number of animals.

The cochlea forms the anterior part of the labyrinth, and is, perhaps of all the parts of the ear, that of which it is the most difficult to give, either by descriptions or delineations, a correct idea. If we can figure to ourselves a tube tapering towards one extremity where it ends in a cul-de-sac, and coiled, like the shell of a snail, round an axis or central pillar; and if we suppose this tube subdivided into two passages by a thin partition running throughout its length, and of course spirally round the axis, we shall have some conception of the disposition of the cochlea.

The tube of which the cochlea is composed, *canalis spiralis cochleæ*, is about an inch and a half long, about one-tenth of an inch in diameter at its commencement, and about one-twentieth of an inch at its termination. It describes two turns and a half, and that in a direction from below upwards—from left to right in the right ear, and from right to left in the left ear. The apex of the coil, which is also the apex of the tube itself, is directed forwards and outwards. The commencement of the first turn of the cochlea forms an eminence towards the cavity of the tympanum, called the *promontory*. The second turn lies at its commencement within the first, and only towards its termination rises decidedly above the level of it. By the base of the tube the cochlea is connected with the vestibule. The cul-de-sac at the apex forms a sort of vaulted roof called *cupola*.

The axis, or central pillar, modiolus s. columella cochleæ. The first turn of the cochlea takes a wider circular sweep than the rest, a sweep having an average diameter of a quarter of an inch, and is separated from the second turn by the interposition of a soft bony substance, which extends also a little way between the second and third. The axis, or central pillar, as has been pointed out by Ilg,* is nothing more than the internal walls of the tube of the cochlea and the central space circumscribed by their turns, in which space the filaments of the cochlear nerve, running in small bony canals, are contained. Now in consequence of the wide sweep the first turn of the cochlea takes in comparison with the rest, the axis is very thick, about one-seventh of an inch, where it is surrounded by the first turn, and rapidly becomes thinner from the second onwards to its termination. The last part of it is in fact formed merely by the fold which

* Einige anatomische Beobachtungen, etc. Prag. 1821, p. 7.

the internal wall of the tube of the cochlea necessarily forms where it bends abruptly at the last turn. This last part of the axis, viewed from the cavity of the second turn of the tube, has a funnel-like appearance, the wide mouth corresponding to the cupola; hence it is called *infundibulum* or *scyphus*. But viewed from the last turn, the so-called infundibulum is a mere free edge which proceeds directly to be confounded with the walls of the cochlea. But all this, if the disposition of a snail's shell, or a tube coiled round be rightly conceived, is understood of itself.

Exposed by the removal of the outer walls of the cochlea, the axis is somewhat like the common pictorial representations of the tower of Babel. It has a spongy porous appearance. It is pervaded by numerous small canals which run from its base onwards to orifices on its sides, corresponding to the spiral lamina, and transmit into the cochlea the ramifications of the cochlear branch of the auditory nerve and bloodvessels. The outermost of the canals are the shortest; towards the interior they gradually become longer, and there is one canal in particular wider than the rest, which runs throughout its whole length; it is called *tubulus centralis modioli*, and opens at the so-called infundibulum.

The base of the axis corresponds to the anterior part of the inferior depression at the bottom of the internal auditory meatus, and presents the commencing orifices of the small canals just mentioned, arranged in a spiral manner corresponding to the turns of the cochlea, *tractus spiralis foraminulentus* of Cotugno.*

Spiral lamina and scalæ of the cochlea.— The passages into which the tube of the cochlea is subdivided are called *scalæ*, and the partition *lamina spiralis*.

The spiral lamina is partly bony, partly membraneous; but as we are describing the osseous shell of the labyrinth only, it is with the bony part alone we have at present to do. The bony part of the spiral lamina, *zonula ossea laminæ spiralis*, is coiled round the axis or central pillar of the cochlea like the stairs in a spiral staircase. The internal or central margin of the bony spiral lamina is inserted on the axis. Its peripheral margin is free in the dry bone, so that the two scalæ are not found completely separated from each other, as in the recent state, when the membraneous extension of the spiral lamina exists. At the place where the spiral lamina is inserted on the axis, there is a sort of canal all round, which has been specially described by Rosenthal† under the name of *canalis spiralis modioli*.

The spiral lamina commences with a bend or sweep upwards and forwards at the base of the cochlea, below the hemispherical depression of the vestibule and opposite the bridge of bone which separates the vestibular fenestra from the cochlear fenestra. Its broadest part, which is about the middle of the first turn of the cochlea, is about one-twentieth of an inch. Towards the summit of the cochlea it insensibly contracts, and ceasing to be connected to the axis, where the latter presents the free margin already mentioned, terminates at the commencement of the third turn in a curved hook-like point. This hook, *hamulus laminæ spiralis*, has a free concave margin towards the axis, and a convex margin, which latter, however, like the rest of the peripheral margin of the bony spiral lamina, is not free in the recent state, but is continuous with the membrane which completes the partition.

In consequence of the above mode of termination of the bony spiral lamina by means of a free margin towards the axis of the cochlea, an opening of communication is left, even in the recent state, between the two scalæ of the cochlea. For this opening, which was called by Cassebohm* *canalis scalarum communis*, we adopt from Breschet† the name *helicotrema*.‡

The bony spiral lamina consists of two thin plates of bone, between which run numerous small canals from the central margin of the lamina to its peripheral—the continuation of those already described in the axis, and which therefore bend at a right angle in passing from the axis into the spiral lamina. At the free edge of the osseous part of the spiral lamina, the two plates of bone are intimately incorporated. This part of the bony spiral lamina, which is more delicate, denser, whiter, more transparent, and, in the recent state, more elastic than the rest, is what Breschet calls the middle zone. The surface of the spiral lamina corresponding to the tympanic scala is much marked with striæ running from the inner margin to the outer. The surface corresponding to the vestibular scala is less striated.

Of the two scalæ of the cochlea, one, *scala tympani*, communicates with the cavity of the tympanum through the fenestra rotunda or cochlear fenestra, which however, in the recent state, is closed by a membrane; the other, *scala vestibuli*, opens by an oval orifice freely into the vestibule, and it is only by means of the communication which the tympanic scala has with the vestibular scala through the helicotrema that the former communicates with the rest of the labyrinthic cavity. The tympanic scala is wider at the commencement than the vestibular, which on its part again is larger toward the termination. Near the fenestra rotunda there is in the tympanic scala a very minute orifice, that of the aqueduct of the cochlea. We shall return to the spiral lamina, the scalæ of the cochlea, and the mechanism of the helicotrema, when speaking of the membrane lining the labyrinthic cavity.

The aqueducts.—What are called the aqueducts are two canals of very minute calibre, opening by one extremity in the labyrinthic

* De aqueductibus auris humanæ internæ anatomica dissertatio, s. xxiv. pp. 36—38. Viennæ, 1774.

† Ueber den Bau der Spindel im menschlichen Ohr. In Meckel's Archiv. Bd. viii. p. 75.

* Tractatus quintus anat. de aure humana, etc. Halæ Magd. 1735, s. 194, p. 12.

† Op. cit. s. xiv.

‡ Ελιξ, ελισσω, *volvere*, and τρημα, *foramen*.

cavity, and by the other on the surface of the petrous portion of the temporal bone. They are generally associated with the name of Cotugno,* who, though not their discoverer, was the first to give a complete description of them. One, called *aqueductus vestibuli*, communicates with the vestibule; the other, *aqueductus cochleæ*, with the tympanic scala of the cochlea.

The internal orifice of the aqueduct of the vestibule is observed to commence by a groove or sulcus, the *sulciform depression* already described in the vestibule, immediately below and in front of the opening common to the two vertical semicircular canals. From this the aqueduct turns itself round the inner wall of the common canal, and then follows a course downwards and backwards. Gradually widening, it opens under that sort of osseous scale observed a little behind the middle of the posterior and inner surface of the petrous bone, just above the jugular fossa; towards the latter there is usually a groove running on the surface of the bone from the orifice of the aqueduct. The length of the course of the aqueduct of the vestibule is about one-third of an inch.

The aqueduct of the cochlea commences by a very small orifice in the lower wall of the scala tympani immediately before the fenestra rotunda. It proceeds downwards, inwards, and forwards, in the inner wall of the jugular fossa of the temporal bone, and widening in its course it opens at the bottom of that triangular pyramidal depression, situated towards the middle of the edge which limits the inner and inferior surfaces of the petrous bone, and below the internal auditory meatus. The length of its course is about a quarter of an inch. The aqueduct of the cochlea is very wide in the pig. Of the aqueducts we shall observe farther in speaking of the membrane lining the labyrinthic cavity.

Fig. 233.

The labyrinthic cavity of the right side, magnified two diameters.

a. superior horn of the vestibule; *b.* posterior and inferior horn; *c.* anterior and inferior horn leading into the cochlea; *d.* hemispherical depression; *e.* hemi-elliptical depression; *f.* pyramidal elevation between the two having a porous sieve-like appearance from being pervaded by canals for the passage of nervous filaments; *g.* superior vertical semicircular canal; *h.* its ampullary dilatation; *i.* posterior vertical semicircular canal; *k.* its ampullary dilatation; *l.* canal common to the superior and posterior vertical semicircular canals; *m.* orifice by which the common canal opens into the vestibule; *n.* horizontal semicircular canal; *o.* its ampullary dilatation; *p.* vestibular orifice of the aqueduct of the vestibule; *q.* osseous part of the spiral lamina, seen from the surface which corresponds to the vestibular scala; *r r.* space which is occupied by the membraneous part of the spiral lamina; *s.* hamulus or hook in which the bony spiral lamina ends; *t.* helicotrema; *u.* substance of the petrous bone, between the first turns of the cochlea; *v.* orifice of the aqueductus cochleæ.

Membrane lining the labyrinthic cavity.—The cavities of the osseous labyrinth which we have just described are lined by a serous or fibro-serous membrane, extremely delicate and closely adherent to the surfaces. *The membraneous labyrinth must not be confounded with it.* This membrane, which may be compared to that serous pellicle on the inner surface of the sclerotica, known by the name of membrana fusca or arachnoidea oculi, is more manifest at an early age than in adults, and is nowhere so distinct as at the places where the nerves enter, and at the bottom of the tympanic scala of the cochlea. It is it which completes the spiral septum of the cochlea, by an arrangement immediately to be described.

The fenestra rotunda or cochlear fenestra is, in the recent state, closed by a membrane which shuts out the cavity of the tympanum from any direct communication with the cochlea. This membrane, called by Scarpa* the secondary membrane of the tympanum, *membrana tympani secundaria*, is concave towards the cavity of the tympanum, convex towards the tympanic scala of the cochlea, and is received at its circumference into a groove within the orifice of the fenestra rotunda. It is composed theoretically of three layers, the inner of which is nothing but the fibro-serous membrane under consideration. The outer layer is a continuation of that which lines the cavity of the tympanum. The third and proper layer is situated between the two mentioned. The same may be said in regard to that membrane, which, together with the base of the stapes, closes the vestibular fenestra.

The membrane lining the tympanic scala of the cochlea is continued into that lining the vestibular scala at the opening called helicotrema. The membrane of the vestibular scala is continuous with that lining the vestibule, which on its part is continuous with that of the semicircular canals. Lastly, the same membrane lines the aqueducts.

Such is a general description of the membrane lining the labyrinthic cavity; but to understand the disposition of the cochlea and aqueducts in the recent state, we must take a nearer view of this membrane such as it exists in those cavities, which, indeed, is the most important and difficult part of it.

Of the cochlea in the recent state.—The cochlea is the last addition made to the labyrinth in the ascending scale of the animal series. As was said, it is in birds in a very ru-

* Op. cit.

* De auditu et olfactu, cap. ii. s. 19. p. 35.

dimentary state. It is in fact a mere pouch or diverticulum not at all coiled up, in which, however, can be distinguished a part corresponding to a lamina spiralis, which is represented by a cartilage, and a vestibular and a tympanic scala, together with a cochlear fenestra. This analogy, much insisted on by Breschet,* I gave a brief notice of some years ago.†

The cochlea is richly supplied with nerves. The spiral lamina is that part of it on which its nerves expand; this must therefore be considered as forming a very essential element of the cochlea, and may be viewed as being in the economy of that part of the internal ear what the apparatus of the membraneous labyrinth is to the vestibule and semicircular canals.

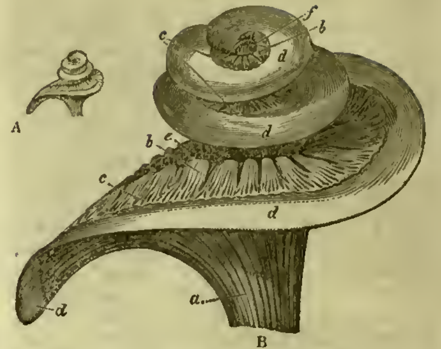
The bony spiral lamina is rendered a complete partition between the scalæ of the cochlea by a membraneous continuation, *zonula membranacea laminæ spiralis s. zona Valsalvæ*, formed by the application against each other of the membranes, which line the interior of the two scalæ, at the moment they are reflected from the free edge of the bony spiral lamina to the outer walls of the cochlea. Hence the spiral partition of the cochlea, when complete, is osseous at its inner or central part, and membraneous at its outer or peripheral.

The outer part of the osseous zone of the spiral lamina is thinner than the rest; it is semi-osseous, semi-membraneous, and the membraneous spiral lamina at its junction with it presents a fine cartilaginous stripe; hence Comparetti and Sömmerring described the spiral lamina as composed of concentric bands or zones. They admitted four, viz. 1, the inner thick part of the bony spiral lamina; 2, the outer thin part; 3, the cartilaginous stripe commencing the membraneous spiral lamina; and 4, the rest of the membraneous spiral lamina, or the membraneous spiral lamina properly so called. The first zone is continued into the hamulus cochleæ, the second ceases towards the second turn of the cochlea, and the third and fourth are continued beyond the hamulus cochleæ, forming of themselves the spiral partition in the last turn.

It is sufficient to admit, with Breschet,‡ only three zones; an osseous zone, a middle zone, and a membraneous zone; the third and fourth zones of Comparetti being comprehended under the latter.

The osseous zone of the spiral lamina we have already described, and alluded to the middle zone. The latter, when it still exists in the dry bone, appears merely as the outer margin of the former. It is the narrowest of the three zones, and is most distinct in the first

Fig. 234.



The axis of the cochlea and spiral lamina isolated, in order to show the disposition of the three zones. The vestibular lamina of the osseous zone is removed. (From Breschet.)

A, natural size. B, magnified.

a. trunk of the cochlear nerve; *b.* distribution of the filaments of this nerve in the osseous zone; c. nervous anastomoses in the middle zone; *d.* membraneous zone; *e.* osseous substance of the axis; *f.* helicotrema or hole of communication betwixt the two scalæ.

turn of the cochlea. Breschet describes it as composed of the membranes lining the interior of the two scalæ, where they first meet each other in passing from the bony spiral lamina, together with osseous particles deposited between them. In this interstice between the membranes also are contained the last ramifications of the filaments of the cochlear nerve, still enveloped by their neurilemma, and sprinkled over by the small bony particles just mentioned.

Different from the middle zone, the membraneous zone goes on increasing in breadth, though not regularly, from the base to the summit of the cochlea. It is the longest and most extensive of the three zones. It is it alone which extends into the last turn of the cochlea. According to Breschet the membraneous zone should be composed of three layers, the two exterior of which should be, as already said, formed by the membranes lining the interior of the scalæ, and the middle one by the expansion and interlacing of the neurilemmatic sheaths from the middle zone; but these layers are so thin and so closely united that they are inseparable, and constitute a membrane of great thinness and transparency, on which, however, bloodvessels can be easily seen.

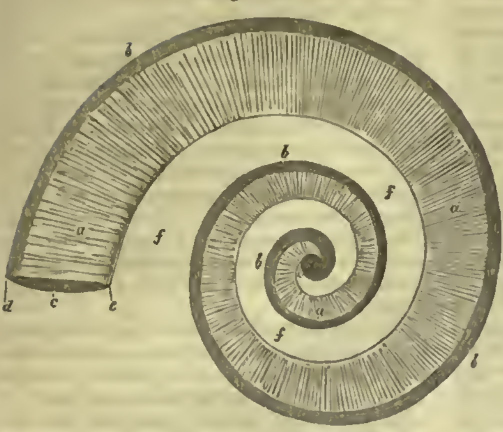
The membraneous zone presents a central margin continuous with the rest of the spiral lamina, except in the third turn of the cochlea, where this margin forms nearly the third of the circumference of the helicotrema, and where it runs into the peripheral margin at an acute angle. The peripheral margin, which is much thicker than the rest of the membraneous zone, is pervaded by a vascular sinus, like that which in the eye runs round the circumference of the cornea at the insertion of the iris.

* Op. cit. and also Recherches Anatomiques et Physiologiques sur l'organe de l'audition chez les Oiseaux. Paris, 1836.

† "Note on the ear of Birds," in the first and only volume of the second series of the Edinburgh Journal of Natural and Geographical Science. Edinburgh, 1831.

‡ Op. cit. chap. ix. s. cxcix.

Fig. 235.



A diagram from Breschet, intended, according to him, to give an exact idea of the disposition of the helicotrema. The walls of the vestibular scala are supposed to be removed.

a a a. represent the osseous and middle zone of the spiral lamina; its termination in the hamulus or hook is seen; *b b b b.* this darker and narrower stripe represents the membraneous zone of the spiral septum; towards the summit of the cochlea it becomes a little broader, and at its termination constitutes by itself alone the septum between the two scalæ at their termination; *c.* the commencement of the tympanic scala; *d.* the external or great margin; *e.* the internal margin of the turns of the cochlea; the two margins *d* and *e* meet at *o*; *f f f.* the vacant space corresponding to the axis; it terminates at o, which corresponds to the summit of the axis; *x.* helicotrema or hole which establishes a communication between the two scalæ.

The section of the peripheral margin of the membraneous zone presents a triangular surface, the base of which is inserted on the osseous wall of the cochlea. This swollen margin of the membraneous zone is, according to Breschet, evidently continuous, at the origin of the spiral lamina in the base of the cochlea, with the osseous zone, a circumstance which is particularly to be remarked in very young fœtuses, where all these parts are still cartilaginous. This thickened margin of the membraneous zone Breschet therefore considers as analogous to the tympanic cartilage of the bird's cochlea, having exactly the same relations and uses.

Fig. 236.

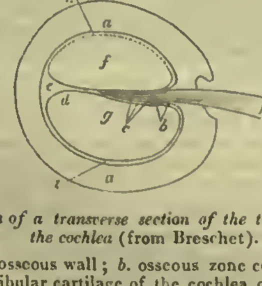


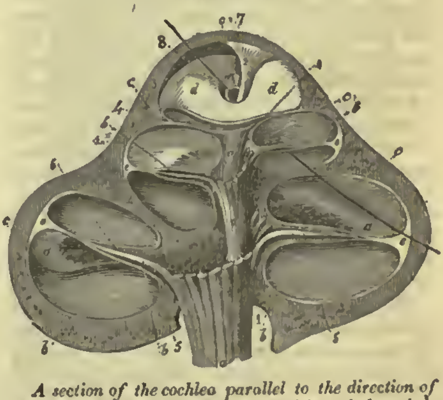
Diagram of a transverse section of the two scalæ of the cochlea (from Breschet).

a. a. osseous wall; *b.* osseous zone compared to the vestibular cartilage of the cochlea of birds; *c.* middle zone compared to the auditive lamellæ; *d.* membraneous zone; *e.* cartilaginiform swelling of the external margin of the membraneous zone, compared to the tympanic cartilage of birds; *f.* scala vestibuli; *g.* scala tympani; *h.* periosteum lining the vestibular scala, more vascular than fibrous; *i.* periosteum of the tympanic scala; *j.* nerve.

In vascularity and richness in nerves, the spiral lamina bears a great resemblance to the iris. Like it, also, it is the partition between two chambers, containing an aqueous humour, and communicating, like the aqueous chambers of the eye, by a single orifice.

The two scalæ of the cochlea have not the same length nor the same diameter. Toward the base of the cochlea the tympanic scala exceeds somewhat the vestibular; its diameter is, at the same time, also a little more considerable, as far as towards the middle of the first turn of the spire. The two scalæ have then the same diameter, and preserve the equality to the commencement of the last turn. There the tympanic scala contracts, and in particular flattens considerably, and is at last confounded, through the helicotrema, with the vestibular scala, which still continues for two-thirds of a turn, and then ends in a cul-de-sac. This is also to be noted in regard to the vestibular scala of the bird's cochlea, which indeed is very large, and proceeds considerably beyond the tympanic scala. It ends in a large cul-de-sac called *lagena*.

Fig. 237.



A section of the cochlea parallel to the direction of its axis, in order to show the disposition of the whole of its parts. Magnified. (From Breschet.)

a. a. a. trunk of the cochlear nerve; *b. b.* filaments of this nerve in the osseous zone; *c. c. c. c.* nervous anastomoses in the middle zone; *d. d. d. d.* membraneous zone; *e. e. e. e.* swelling of the external margin of the membraneous zone; 1, 1, axis of the cochlea; 2, infundibulum; 3, 3, 3, 3, external osseous wall of the cochlea; 4, 4, 4, 4, osseous lamina separating the turns of the spire of the cavity of the cochlea; 5, 5, 5, 5, tympanic lamella of the osseous zone of the spiral lamina; 6. vestibular lamella; 7, hamulus or hook, which terminates the osseous zone; 8, helicotrema, with a bristle introduced into it.

Further observations on the aqueducts.—The aqueducts, the one leading from the vestibule, and the other from the tympanic scala of the cochlea, are lined by a continuation of the thin and delicate pellicle which invests the interior of those cavities.

Under the osseous scale, on the surface of the petrous bone, where the aqueduct of the vestibule ends, there is a small triangular pouch produced by a separation of the dura mater into two layers. Into this pouch the lining membrane of the aqueduct enters, and ends in a cul-de-sac. The pouch is called by Cotugno the *membraneous cavity of the aqueduct.* I found the structure just described of unusual size, in consequence of irregular development, in the ear of a man deaf and dumb from birth, which I examined some years ago. The triangular pouch in the dura mater was about one-third of an inch long at its sides, and was distended by a clear liquid. Every time pressure was made on the distended pouch, a fine jet of liquid issued through a small opening which had been made in the superior vertical semicircular canal. Similar cases have been described by Mondini* and others.

The lining membrane of the aqueduct of the cochlea ends, in like manner, in a cul-de-sac, which, however, is not so large as that of the aqueduct of the vestibule.

The liquid contained in the labyrinthic cavity, or liquid of Cotagna, or perilymph. (Aquula Cotunnii.)—The cavities of the osseous labyrinth contain a liquid, the secretion, probably, of their thin and delicate lining membrane. *They contain no air, as has been asserted.* The liquid called the liquid of Cotugno, or by De Blainville *perilymph*, must not be confounded with another which is contained in the interior of the *membraneous labyrinth.* Dominico Cotugno,† though not actually the discoverer of this liquid, yet took a more correct view of it than his predecessors in this branch of anatomical research, Valsalva,‡ Vieussens,§ Cassebohm,|| and Morgagni.¶ He in fact recognised in it a substance fulfilling some office in the exercise of hearing, a view of the matter which was admitted by Haller, and put beyond doubt by Ph. Fr. Meckel,** and since their time recognised by all physiologists.

The perilymph occupies, in the vestibule and semicircular canals, all the space not taken up by the membraneous labyrinth. The cochlea contains nothing but it; and as all the cavities of the osseous labyrinth communicate, it is the same humour in each.

In all fishes, except the cartilaginous with fixed gills, the labyrinthic cavity is very imperfect, being in many of them open towards the cranial cavity, or at the most separated from it only by a membraneous partition, as in the cod; hence the encephalic liquid in some of them is not distinct from the perilymph whose function it must perform. In the cartilaginous fishes with fixed gills, on the contrary, the labyrinthic cavity is completely separated from the cranial; therefore in them we meet with perilymph distinct from the encephalic liquid, and that, too, in pretty large quantity.

In birds the perilymph is in much less quantity than in the mammifera, in proportion to the size of the membraneous labyrinth. In reptiles the quantity of perilymph is still less.

Cotugno and Meckel supposed that the aqueducts were a sort of diverticula, or cavities which served to let off the superabundant perilymph, when necessary, during the act of hearing. This opinion is, however, now-a-days very much questioned, and several anatomists, Brugnone, Ribes, Breschet, &c., refuse to those aqueducts the uses which Cotugno assigned them, and consider them merely as canals destined for the passage of bloodvessels. Although they may be insignificant in a physiological point of view, still, if the description I have given of them be correct, they must be considered as something more than mere canals for the transmission of vessels. The constancy of the aqueducts, moreover, is another argument against their being mere vascular canals.

Breschet,* and in Hildebrandt's *Anatomie* by Weber† the same idea is concisely expressed, explains the mode of formation of the aqueducts by supposing that at first the labyrinthic cavity is nothing but a sac formed by a prolongation of the dura mater in the same way as the tunica vaginalis is of the peritoneum; that as development proceeds, the tube of communication between the labyrinthic sac of the dura mater and general cavity of the dura mater is gradually contracted and elongated; and that as ossification extends, the tube becomes surrounded by osseous substance, and presents itself under the appearance of an aqueduct. "This view," says Breschet, "is rendered probable, for in many fishes the labyrinthic cavity forms one with that of the cranium, and if, in these animals, a prolongation of the walls of the cranium tended to separate the brain from the ear, there would result a small canal establishing a communication between the two cavities, and this canal would be nothing but an aqueduct."

According to this view, the lining membrane of the labyrinthic cavity may be considered as a continuation of the arachnoideal layer of the dura mater, perhaps of the dura mater also.

2. *The membraneous labyrinth, (labyrinthus membranaceus.* Fr. *Labyrinthe membraneux.* Germ. *Das häutige Labyrinth.)*—Within the

* Comment. Bonon. tom. vii. Anatomia Surdi Nati. p. 422.

† De Aqueductibus Auris Humanæ Anatomica Dissertatio, s. xxix.-xxxi. Neapoli, 1760.

‡ De Aure Humana Tractatus, &c., cap. iii. s. 17, p. 79. Trajecti ad Rhenum, 1707.

§ Traité Nouveau de la Structure de l'oreille, p. 75. Toulouse, 1714.

|| Tractatus Quintus Anatomicus de Aure Humana, &c., pp. 20-21. De Labyrintho. Halæ Magd. 1735.

¶ Epist. Anatom. xii. s. 64, p. 469. Venetiis 1740.

** Dissertatio Anatomico-Physiologica de Labyrinthi Auris Contentis, &c. Argentorati, 1777, s. 8.

* Op. cit.

† Band iv. p. 32.

osseous labyrinth is contained an extremely delicate and complicated membrano-nervous apparatus, called *membraneous labyrinth*, first properly described by Scarpa.* It does not extend into all the compartments of the osseous labyrinth, but only occupies the vestibule and semicircular canals. The cochlea, as has been said, contains in its cavity nothing but perilymph.

The vestibular part of the membraneous labyrinth, and of that perhaps one of the pouches only, is all that is really fundamental in the structure of an organ of hearing. In the Crustacea and Cephalopodous Mollusca in which the organ of hearing exists in its simplest form, and even in the Cyclostomatous fishes there is nothing but a small pouch containing a little liquid and a lapilliform body.

Much smaller than the cavities which contain it, the membraneous labyrinth is suspended as it were in the perilymph. It does not appear to adhere to the walls of the labyrinthic cavity except at the points where it receives nervous filaments.

The component parts of the membraneous labyrinth are:—

1. The common sinus. 2. The membraneous ampullæ and semicircular tubes. 3. The saccule.

Fig. 238.

A magnified representation of the left osseous labyrinth laid open to show the membraneous labyrinth in its situation. (From Breschet.)

a. membraneous ampulla of the ampullary sinus of the anterior semicircular canal; *b*. membraneous ampulla of the ampullary sinus of the external semicircular canal; *c*. membraneous ampulla of the ampullary sinus of the posterior semicircular canal; *d*. anterior membraneous semicircular tube; *e*. external membraneous semicircular tube; *f*. posterior membraneous semicircular tube; *g*. common membraneous tube resulting from the junction of the tubes *d* and *f*; *h*. the place where the external membraneous semicircular tube opens into the common sinus; *i i*. common sinus filling a great part of the vestibule; *k*. a small mass of calcareous powder shining through its walls; *l l*. saccule, also containing, *m*. another mass of calcareous powder; *n* a nervous fasciculus, furnishing, *o*. an expansion to the anterior membraneous ampulla; *p*. another to the ampulla of the external tube, and *q*. a third to the common sinus; *r*. nervous fasciculus to the saccule; another fasciculus of nervous filaments, not lettered, is seen going to the ampulla of the posterior membraneous semicircular tube; *s s*. spiral lamina; *s'*. the termination of the spiral lamina in the hamulus; *t*. commencement of the scala tympani near the fenestra rotunda, which is here no longer seen; *u*. commencement of the scala vestibuli; *x*. extremity of the axis around which the termination of the spiral lamina turns; *y y*. a bristle engaged in the helicotrema; *z*. place where the summit of the axis is continued into the wall of the osseous labyrinth; *w w w*, membraneous portion of the spiral lamina, particularly broad in the last turn, (lettered *u u u* in the figure instead of *w w w*); * * * * * * spaces between the walls of the labyrinthic cavity and membraneous labyrinth occupied by the perilymph.

Fig. 239.

The left membraneous labyrinth isolated together with the nerves. Magnified. (From Breschet.)

a. ampulla of the anterior semicircular tube; *b*. ampulla of the horizontal semicircular tube; *c*. ampulla of the posterior semicircular tube; *d*. common tube; *e*. mass of calcareous particles lying in the common sinus; *f*. the saccule containing also a mass of calcareous particles; *k*. portio dura of the seventh pair; *m*. nervous filaments to the ampulla of the anterior semicircular tube; *n*. filaments to the ampulla of the horizontal semicircular tube; filaments are also seen going to the ampulla of the posterior semicircular tube, not lettered; o. filaments to the common sinus; *q*. filaments to the saccule; *r*. cochlear nerve.

The common sinus, membraneous ampullæ, and membraneous semicircular tubes.— These constitute but one apparatus which is just the counterpart of the vestibule, ampullary sinuses, and semicircular canals of the osseous labyrinth; the semicircular tubes opening into the ampullæ and common sinus in the same way

* De auditu et olfactu.

that the semicircular canals open into the ampullary dilatations and the vestibule.

The common sinus is an elongated, laterally compressed pouch, and lies in the posterior part of the vestibule. It extends into the upper horn to join the ampullæ of the superior vertical, and of the horizontal semicircular tubes; and into the posterior and lower horn, to join the ampulla of the posterior semicircular tube, and to receive the tubulus communis and cylindrical extremity of the horizontal tube, as they emerge from their respective canals. Its upper end, which is larger than its lower, lies in the hemi-elliptical cavity, to the bottom of which it is fixed by nervous filaments.

The membraneous tubes are only about a third part of the calibre of the semicircular canals in which they are contained. Like the latter they are distinguished by the epithets, superior vertical, posterior vertical, and horizontal. Each membraneous semicircular tube opens at one of its extremities, like its corresponding osseous canal, into an oval dilatation called *ampulla*, which on its part communicates with the common sinus. As the vertical semicircular canals unite at one of their extremities to form the common canal, so their corresponding membraneous tubes also unite to form a common tube, *tubulus communis*, which occupies the common canal.

At the place where the nervous filaments enter the common sinus, its wall presents a much more considerable thickness and consistence than elsewhere.

According to Steifensand,* who has examined the structure of the ampullæ very carefully, each ampulla presents a very much arched surface, *superficies convexa*, and opposite to this a concave or indented surface, *superficies concava s. inflexa*, which receives the nervous filaments. Where the nerve enters there is a transverse depression, *sulcus transversus*, by which this surface is divided into two parts. This transverse depression on the outside produces in the interior a fold of the membrane composing the wall of the ampulla, and through which the nerve enters. This fold forms a transverse septum, *septum transversum*, which divides the interior of the ampulla into two parts; one of which, the sinus part, communicates by the *osteum sinus* with the common sinus, and the other, the tube part, by the *osteum tubuli* with the membraneous tube.

Saccule, sacculus rotundus. This is a round membraneous bag, smaller than the common sinus in front of which it lies in the hemispherical depression of the vestibule. It is firmly fixed in its place by nervous filaments which proceed to it through the apertures observed in the bottom of the hemispherical depression. As has been mentioned in regard to the common sinus, the wall of the saccule presents an increase of thickness and consistence at the place where the nervous filaments enter it.

* Müller's Archiv. für Anat. Physiol. und wissenschaftl. Medecin. 1835. Heft. II. pp. 173, 174.

Small in the Mammifera, the saccule is very distinct and large in fishes.

The common sinus and saccule adhere to each other, but whether their cavities communicate has not been determined. They are fixed, as has been said, to the inner wall of the vestibule, by the nervous filaments which they receive through the apertures with which that part is perforated. Towards the outer wall they are nowhere in contact with the base of the stapes, the perilymph intervening. This circumstance, first distinctly pointed out by Scarpa,* and particularly insisted on by Breschet, shows that it is only by the intermedium of the perilymph that the movements of the stapes can have any impression on the nervous expansions of the membraneous labyrinth.

The common sinus, ampullæ, semicircular tubes, and saccule are composed of a firm transparent membraneous coat, within which is a nervous expansion, and outside which is a cellulo-vascular layer, in some places tinged black or brown. Of the nervous expansion we shall speak under the head of the auditory nerves. In the sheep, hare, rabbit, &c. the walls of the membraneous labyrinth present patches of black pigment, a circumstance noticed by Scarpa,† Comparetti,‡ and Breschet.§ Before I knew of the observations of these anatomists I had myself observed the fact. I was not, however, led to the discovery of it by accident; but, being engaged in researches on the pigment of the eye, and considering the analogy which the organs of sense bear to each other in their general anatomical structure, I was curious to know whether pigment did not exist also in the ear. Examination proved to me that it did; for I found, as Scarpa and Comparetti had previously noticed, pigment deposited in the form of small black spots in the membraneous parts of the labyrinth in different Mammifera. In some I have found a distinct cellulo-vascular layer of a black or brown colour forming the outer surface of the membraneous labyrinth. And, contrary to what Breschet asserts, I have found pigment in the membraneous labyrinth of the human ear also. It appears, especially on the ampullæ, under the form of a slight but perfectly distinct brown tinge, similar to what is seen around the ciliary processes in the eyes of Albinos.

Semicircular tubes are found in all the Vertebrate animals, with the single exception of the Cyclostomata. When they do exist there are never more nor less than three.

The common sinus, ampullæ, semicircular tubes, and saccule contain a limpid humour. Suspended in this humour there is found in the common sinus and also in the saccule a small mass of calcareous powder.

The liquid of the membraneous labyrinth,

* Anatomicæ disquisitiones de Auditu et Olfactu, s. xvi. p. 55.

† Op. cit. s. iv. p. 49.

‡ Observat. Anatom. de aure internâ comparat. p. xxxii. Præfat.

§ Op. cit.

or endolymph or vitreous humour of the ear. (*Aquula labyrinthi membranacei. Humor vitreus auris.* Fr. *Vitrine auditive.* Germ. *Wasser des häutigen Labyrinths. Die Glasfeuchtigkeit des Ohres.*—This humour, first distinctly pointed out by Scarpa, fills exactly all the cavities of the membraneous labyrinth,—that is to say, in the human ear, the common sinus, ampullæ, the semicircular tubes, and saccule. Like the perilymph, it is almost as limpid as water. In the endolymph there are, as has been said, always found suspended calcareous concretions. The endolymph is in birds as limpid as in the Mammifera; but in reptiles it is in general more dense than water and a little viscid. It is viscid in all fishes, but especially so in the Chondropterygenous, in which it often presents itself in the form of jelly. It is also very decidedly viscid in the Cephalopodous Mollusca.

The masses of calcareous matter contained within the membraneous labyrinth.—In the ear-bulb of all animals which possess one, there are found small masses of a chalky nature; in some solid, in others pulverulent. Solid concretions are found in the osseous fishes, and in the Chondropterygenous fishes with free gills, such as the sturgeon. The chalky matter is in a pulverulent state in Mammifera, birds, reptiles, and in Chondropterygenous fishes with fixed gills. In the Batrachian reptiles and Cephalopodous Mollusca, the calcareous matter appears rather under a concrete form.

These calcareous masses are best known in osseous fishes, in which they are hard but brittle bodies of a determinate shape. In those animals, indeed, they have been erroneously considered as analogous to the tympanic ossicles of the higher Vertebrata. MM. Breschet* and Huschke† have lately called particular attention to the subject, and have described masses of calcareous matter in the ear of reptiles, birds, and Mammifera. Scarpa and Comparetti had observed them in the human ear, without, however, detecting their nature. But they had been unequivocally noticed before by De Blainville;‡ and previously to the first publication of Breschet's papers on the ear in the Annales des Sciences Naturelles, I had also studied them throughout the animal series.

Breschet has proposed for the solid masses the name of *otolithi*, from ους, auris, and λιθος, lapis; and for the pulverulent ones that of *otoconia*, from ους, and κονις, pulvis. Otoconia has been translated into German by Lincke § *Ohrsand.* Huschke calls the pulverulent matter ear-crystals, *Ohrkrystalle.* Krause, ear-chalk, *Ohrkalk.*

In the ear of man and the Mammifera in general there are two masses of calcareous matter; one in the common sinus and the other in the saccule. According to Huschke and Barruel they are composed of mucus, carbonate and phosphate of lime, and some animal matter. They are said to be more distinct in the fœtus than in the adult. From my own observations I should say that they exist in the human adult as distinctly as in the fœtus. Concretions are never found in the ampullæ or semicircular canals, either in man or any of the lower animals.

Examined in man and the Mammifera the concretions are suspended in the endolymph, and correspond to the points of the common sinus and saccule where the nervous filaments are implanted.

The grains composing the calcareous mass are held together by a soft mucous tissue.

Huschke describes the grains as crystalline, small six-sided columns, pointed at the ends with three surfaces. They appear to me, under the microscope, to have an oval form, more or less elongated, in man and the mammifera, passing into a spindle shape in birds and reptiles, and, though transparent, they do not present any very decided crystalline form. The particles of chalk examined through the microscope have a somewhat similar appearance, but much smaller. The grains of the ear are of different sizes. Of a mass which I removed from the ear of a middle-aged man, the greatest number had their longest diameter equal to that of the globules of the human blood, that is, about the three-thousandth part of an inch.

There is found in the cochlea of birds a mass of calcareous matter. Breschet says he has found, in cochleæ of the human fœtus, which had been dried but not macerated, small masses of cretaceous matter deposited near the summit of the cochlea; and Huschke* once found, in the fluid of the cochlea of a child, a collection of microscopical crystals.

Cruveilhier* asks, do the small masses of cretaceous matter, found in the ear of man and the mammifera, fulfil the same function as the stones in the ear of fishes? or must they be considered as a remains only of a part important in other animals? Breschet says, "the otolithes and otoconies have, for their use, to communicate to the nervous extremities a more vivid and energetic impression than a simple liquid like the endolymph could do; for the vibrations of a solid body are much more sensible for their force and degree of intensity than those of a liquid body." However this may be, it appears that the development of these concretions coincides, in some degree, with the medium inhabited by the animal; thus, they are stony in most animals living in water, and pulverulent in such as exist in air.

The auditory or acoustic nerve.—Nervus au-

* Lib. cit.

† Isis, 1834. Heft. 1. p. 107. 1833. Heft. vii. p. 676.

‡ De l'Organization des Animaux ou Principes d'Anatomie comparée, tom. i. p. 451-458. Paris, 1822. Also, Cours de Physiologie générale et comparée, &c. Paris, 1829. xii Leçon. p. 399.

§ Das Gehörorgan, &c. s. 176. p. 203. Leipzig. 1837.

* Loc. cit.

† Anatomie descriptive, tome iii. p. 524.

ditorius s. acusticus.—Fr. *Nerf auditif ou acoustique.*—Germ. *Der Gehörnerv.*—The internal auditory meatus of the temporal bone appears to end in a cul-de-sac; but, examined more closely, the bottom is found divided into two unequal-sized depressions, an upper and a lower, by a crest, which extends backwards from the anterior and outer wall of the meatus. The upper depression, which is the smaller, is subdivided into two, an anterior and a posterior, by a small vertical pillar. The anterior leads into the aqueduct of Fallopius, and gives passage to the facial nerve. The posterior is almost funnel-shaped, and presents two or three pretty large apertures, and several smaller and less distinct ones. These are the mouths of small canals which lead into the vestibule, and their terminating orifices produce that sieve-like appearance in the pyramidal elevation between the hemi-elliptical and hemispherical depressions, and which extends towards the ampullary dilatations in the superior horn of the vestibule.

The lower and larger depression presents two subdivisions. The anterior and larger corresponds to the base of the axis of the cochlea; it presents a spiral groove or tract—*tractus spiralis foraminulentus*, answering to the turns of the cochlea, and perforated like a sieve by numerous apertures, which diminish in size towards the centre, where there is one opening larger than the rest. The posterior subdivision of the lower depression is a small superficial fossa, perforated by two or three larger, and a great number of smaller apertures, which open into the hemispherical depression of the vestibule, producing the sieve-like spot already mentioned as existing there. Below this superficial fossa there is a pretty large hole, leading into a canal in the posterior wall of the vestibule, which opens by several small orifices, forming the sieve-like spot within the mouth of the ampullary dilatation of the lower extremity of the posterior vertical semicircular canal.

The different minute apertures we have described give passage to the fibrils of the auditory nerve.

The internal auditory meatus is lined by dura mater.

The facial nerve enters the internal auditory meatus along with the auditory nerve. At the bottom of the meatus there is a communication between the two nerves, which was first pointed out by Mr. Swan. Separating from the auditory nerve, the facial leaves the internal meatus, by entering the aqueduct of Fallopius.

From its origin to about where it enters the internal auditory meatus, the auditory nerve presents most distinctly the delicate-walled tubular structure of brain. Within the meatus it assumes the ordinary thick-walled cylindrical tubular structure of nerves; a circumstance overlooked by Ehrenberg, when he adduced, as a peculiarity of the special nerves of sense, that they presented throughout their course the so-called varicose tubular structure.

The auditory nerve divides into two branches —an anterior, or cochlear; and a posterior, or vestibular branch,—which externally remain united together as far as the bottom of the meatus. The former is whiter, and has its filaments more compactly bound together than the latter. Examined under the microscope, the cylindrical tubules of the cochlear nerve appeared to me to be larger than those of the vestibular, and to contain, or at least to give out, a greater quantity of nervous medulla.

The anterior branch, or cochlear nerve, *nervus cochleæ*, is something like a flat tape rolled on itself longways. It proceeds forwards to that depression at the bottom of the internal auditory meatus, already described as corresponding to the base of the axis. Here it resolves itself into a number of fine filaments, which enter the apertures in the spiral tract of holes. Traversing the small bony canals leading from those apertures into the substance of the axis, they enter the bony spiral lamina according as their turn comes, by bending nearly at a right angle, and spread out upon it. The first filaments given off are the largest, the rest gradually diminish in size.

The first turn of the spiral lamina is supplied by those which enter the first turn of the spiral tract of holes; the second turn receives the filaments which traverse the bony canals, into which the fine apertures of the second turn of the spiral tract lead; and the last half turn is supplied by that large bundle of filaments terminating the nerve, and which, entering the axis by the large opening in the centre of the spiral tract, emerges at its summit.

The vestibular nerve, *nervus vestibuli*, which presents a small gangliform enlargement, divides into three branches. The uppermost, which is the largest, lies in the depression behind the entrance to the aqueduct of Fallopius. Its filaments having penetrated the vestibule by the small apertures of the canals already mentioned in the pyramidal elevation, arrange themselves into three fasciculi; of which one is distributed to the common sinus, and the other two to the ampullæ belonging to the superior vertical and to the horizontal semicircular tube.

The fibrils of the next branch enter the vestibule by the apertures at the bottom of the hemispherical depression, and terminate in the saccule.

The third, or lowest branch, which is the smallest, enters that canal described in the posterior wall of the vestibule, and which opens by a sieve-like spot within the ampullary dilatation of the posterior semicircular canal. Its fibrils are distributed to the ampulla of the posterior semicircular tube.

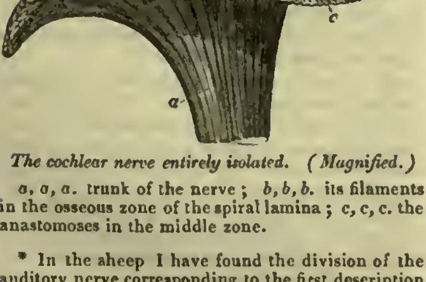
Such is the description of the divisions of the auditory nerve as given by most authors, and as it has appeared to me in the examinations I have made. Krause and Breschet, however, describe the mode of division differently. The former says the nerve of the saccule comes off from the cochlear nerve; the latter, that the cochlear nerve (which he calls the posterior fasciculus of the auditory nerve) gives off both the saccular nerve and the filaments to the posterior ampulla. I have not at present an opportunity to repeat my examination of the parts, to enable me to say positively which description is the most correct.*

The nervous fibrils of the cochlea, according to Breschet, traverse the osseous zone of the spiral lamina under the form of cylindrical bundles, which, in the *middle zone*, become flat, and anastomose by loops. These loops are intermingled with small osseous particles. Near the outer margin of the middle zone, the neurilemma leaves the nervous filaments, and goes to form the framework of the membraneous zone, whilst small globules are seen irregularly disseminated around the convexity of the loops which the filaments form by their anastomoses. All this, however, is not so unequivocally distinct as Breschet pretends. What I have been able to see in regard to the termination of the nerves on the spiral lamina, is simply this:— The tubular structure of the nervous filaments ceases, among grains of nervous matter arranged into a sort of expansion. There is nothing that can be called a termination in loops. Mueller thinks the nervous fibrils do not form loops in the bird's cochlea. "But," says Mueller, "it is of no consequence, in the present state of the physiology of the nerves, whether the nerves of sensation form at their terminations loops or not."

Treviranus† found a papillary termination of the nervous filaments, not only in the retina, but also in the nervous expansions of the ear and nose. The papillæ of the auditory nerve he saw on the spiral lamina of the cochlea in young mice. The osseous part is entirely covered with filamentous papillæ, lying close together. Gottsche also found the ends of the nerves of the cochlea in hares and rabbits club-shaped. In the hare, the nervous cylinders terminate in an oval knob.

The following figures from Breschet illustrate his views of the mode of termination of the nervous filaments of the cochlea.

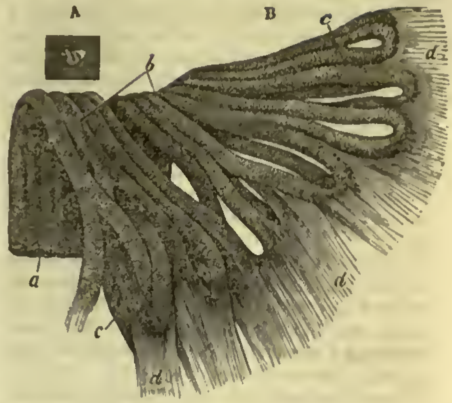
Fig. 240.



The cochlear nerve entirely isolated. (Magnified.)

a, a, a. trunk of the nerve; *b, b, b.* its filaments in the osseous zone of the spiral lamina; c, c, c. the anastomoses in the middle zone.

Fig. 241.



A, *a small piece of the spiral lamina, natural size, as seen from the surface corresponding to the scala vestibuli.*

B, *the same part considerably magnified to show the globular structure (?) of the nerves and the mode in which the neurilemma leaves them at the place where they form their anastomoses.*

a. Portion of the trunk of the cochlear nerve; *b.* fasciculi lodged in the osseous zone of the cochlea; c, *c.* anastomoses in the middle zone; *d, d, d.* the neurilemma leaving the nervous loops, interlacing and forming the basis of the membraneous zone.

As to the mode in which the nervous filaments enter and terminate in the membraneous labyrinth. The nervous filaments, according to Scarpa, before penetrating the vestibule of the small bony canals, lay aside their thicker sheath, and become softer and whiter. The filaments expand on the parts for which they are destined, appear to form a network, and, having penetrated into the interior, are resolved into a nervous pulp which lines the inner surface. Scarpa compares this nervous expansion in the saccule to the retina.

According to Breschet's account, the nervous filaments, in penetrating into the interior of the different membraneous pouches, are accompanied by a sheath furnished by the pouch itself, which is folded inwards, and accompanies them until these filaments spread themselves out. Hence it is that, at the entrance of the nerves, the walls of the pouch are always thicker, and form a more or less considerable projection in the interior. This prominence is slight in the saccule and common sinus, but very well marked in the interior of the ampullæ, where it forms a sort of incomplete septum across; a structure which is small in man and the mammifera, but very much developed in birds and the higher reptiles.

At those prominences the nervous filaments, says Breschet, present anastomosing loops, and the neurilemma leaving them to be incorporated with vessels, and thus to form the framework of the membraneous labyrinth, the nervous globules come into immediate contact with the mass of calcareous matter.

What I have said of Breschet's account of

* In the sheep I have found the division of the auditory nerve corresponding to the first description given above.

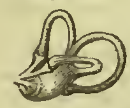
† Beiträge, &c. 1sten Bandes 2tes Heft. Neue Untersuchungen ueber die organischen Elemente der thierischen Koerper, p. 55. Bremen, 1835.

the terminations of the cochlear nerve is also applicable here. The filaments of the nerves of the common sinus and saccule expand in a fan-like manner on their walls, and having penetrated them, are resolved into a nervous layer like the retina, situated on the inner surface of the walls of those cavities. This nervous layer is, in the human ear, pervaded by extremely minute transparent fibres. In the rabbit I have distinctly seen, with a doublet magnifying 150 diameters, a fibrous or tubular structure similar to that of the retina first discovered by Ehrenberg.

As regards the entrance of the nerves of the ampullæ, Steifensand* gives a similar but more detailed account than Breschet. He says, the nerve, after having embraced in a forked manner about a third of the circumference of the ampulla, enters the wall of it.

Resolving itself now into infinitely fine filaments, the nerve penetrates the septum which lies quite close to the opening in the common sinus, and which resembles a semilunar eminence projecting into the interior. It now covers the surface of the septum and a circumscribed portion of the adjacent inner surface of the wall of the ampulla with an extremely delicate nervous pulp. The two ends of the semilunar septum, gradually flattening and spreading out, lose themselves in the wall of the ampulla.

Fig. 242.



Common sinus, together with the ampullæ and semicircular tubes, and the entrance of the nerves into them. (From Steifensand.)

Fig. 243.

The ampullæ of the superior and horizontal semicircular tubes, with a part of the common sinus. The fan-like expansion of the nervous fibrils on the latter is seen, and also the fork-like expansion of the nerves on the outer surface of the ampullæ. Magnified. (From Steifensand.)

* Müller's Archiv. für Anatomie, Physiologie, und wissenschaftliehe Medecin, 1835. Heft. ii. s. 174 and 184.

Fig. 244.

Fig. 245.

Fig. 246.

Fig. 244, *(from Steifensand.) The ampulla opened in order to exhibit the septum.*

Fig. 245, *(from Steifensand.) The fork-like termination of the nerve of the ampulla and the semilunar septum, having the appearance of pure nervous substance.*

Fig. 246, *(also from Steifensand.) The expansion of the nervous pulp over the septum.*

Bloodvessels of the labyrinth.—The principal artery of the labyrinth is the *arteria auditiva interior.* It is a branch of the basilar. It enters the internal auditory meatus along with the nerve of the seventh pair, and at the bottom of it divides into two branches, the cochlear and vestibular arteries, which enter the labyrinth with the corresponding nervous filaments.

The cochlear artery, *arteria cochleæ,* divides into a number of branches which enter the cochlea by the spiral tract of holes; one in particular, *arteria centralis modioli,* passes through the central canal of the axis as far as the apex of the cochlea.

The vessels of the walls of the cochlea are more numerous in the scala vestibuli than in the scala tympani. The arterial branches on the spiral lamina anastomose with each other at the outer margin of the osseous zone. From the convexity of the anastomotic arches numerous small arteries arise and run parallel as far as the outer margin of the middle zone, where they again anastomose, forming loops infinitely smaller, from the convexity of which capillary vessels run. These capillary vessels terminate in a sinus of a venous nature, lodged in the substance of the outer margin of the spiral lamina.

The vestibular artery, *arteria vestibuli,* supplies the vestibule and semicircular canals together with their contents, the saccule, common sinus, ampullæ, and semicircular tubes, and sends a branch along the surface of the spiral lamina corresponding to the vestibular scala. The *stylo-mastoid artery,* a branch of the *posterior auricular,* sends a twig to the external semicircular canal. The *occipital artery* also frequently sends twigs to the labyrinth.

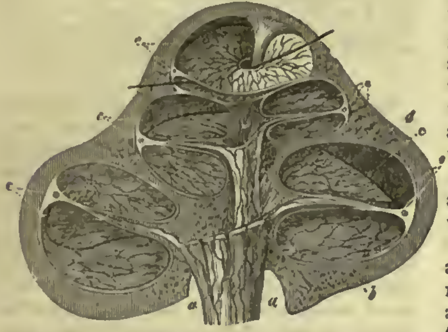
The bloodvessels form a beautiful plexus on the ampullæ, and considerable trunks run along the whole length of the semicircular tubes, supported on their surface by a delicate cellular tissue, which forms the vehicle for the passage of the small lateral branches given off to the walls of the tubes.

Not much is known of the veins of the labyrinth. The internal auditory artery is accompanied by a corresponding vein which carries away the blood from the labyrinth, and empties it into the superior petrosal sinus. Another vein, says Weber,* goes perhaps from the labyrinth through a small opening in the cleft of the aqueduct, and empties itself into the transverse sinus.

Of the veins of the cochlea, some, according to Breschet, accompany their arteries; others enter the sinus, lodged in the substance of the outer margin of the spiral lamina. Near the base of the cochlea, this sinus communicates with the veins of the vestibule.

Nothing is known of the absorbents of the labyrinth.

Fig. 247.



A section of the cochlea parallel to its axis, showing the distribution of the vessels in its interior. It is the veins that are delineated, but their distribution is almost the same as that of the arteries. Magnified. (From Breschet.)

a, a. Veins accompanying the trunk of the cochlear nerve, and penetrating the nervous branches across the spiral lamina; *b.* first anastomoses at the periphery of the osseous zone; *c, c.* second anastomoses at the periphery of the middle zone; *d.* last ramuscules, which are almost parallel, occupying the membraneous zone; *e, e, e.* venous sinus in the peripheral margin of the membraneous zone.

II. Accessory parts of the apparatus of hearing.

Of these parts, the auricle collects the sonorous undulations, and the auditory passage conducts them to the middle ear or tympanum, where they are modified and transmitted to the sensitive part of the apparatus, the ear-bulb.

A tympanum is found in reptiles, birds, and Mammifera, a perfect external ear only in the Mammifera. The lip-like folds of skin before the membrana tympani, in some birds and reptiles, may, however, be considered rudiments of an external ear. Among the Mammifera, the Cetacea have no auricle, and only a very contracted auditory passage.

It was said that the tympanum exists in a greater number of animals than the cochlea. This refers to a discovery made by Weber,† that a prolongation of the swimming-bladder in the herring, in the cyprinoid fishes, in silurus glanis, and in several species of cobitis, has a connexion with the membraneous labyrinth in the same manner that the prolongation of the mucous membrane of the throat, forming essentially the tympanum and Eustachian tube, is extended to the surface of the labyrinth; and moreover, that in all those fishes, with the exception of the herring, there exist bones analogous to the tympanic ossicles in the higher animals.

1. *The middle ear, or tympanum, and its appendages.*

The cavity of the typanum, cavitas tympani; Fr. *caisse du tympan ou du tambour;* Germ. *die Trommelhöhle oder Paukenhöhle.*—The cavity of the tympanum is a space lying at the peripheral surface of the ear-bulb, and measuring from above downwards as well as from before backwards about four-tenths of an inch, and from without inwards about three-twentieths of an inch. It is bounded internally by the outer wall of the osseous labyrinth; externally by a vibratile membrane, the membrana tympani, and that portion of the temporal bone into which it is framed. Anteriorly a canal, the Eustachian tube, leads from it into the throat; and posteriorly and superiorly it communicates with the mastoid cells.

The cavity of the tympanum is traversed by a chain of small bones, extending from the membrana tympani to the vestibular fenestra, and is lined by a very delicate membrane of a fibro-mucous character, which is prolonged into all its sinuosities and dependent cavities. This membrane is moreover reflected on the parts which traverse the cavity, and envelopes them. The lining membrane of the tympanum is continuous through the medium of that of the Eustachian tube, with the mucous membrane of the throat.

A condition essential to the due performance of the function of the tympanum is that the external air have free access to its cavity.

Examined on the dry bone, the *inner wall* of the tympanum presents a considerable eminence; behind and below which is an opening somewhat of a triangular form, and in a fossa above it another opening, about twice the size of the preceding, and of an ovoid shape. From the description which has been already given of the osseous labyrinth, it will be immediately perceived that the eminence in question, called the *promontory*, is that which the commencement of the cochlea forms; that the opening below and behind it is the *fenestra rotunda* or *cochlear fenestra*, and the opening above it the *fenestra ovalis* or *vestibular fenestra.*

The surface of the promontory is marked by a groove; sometimes instead of a groove there is a canal. This groove is continuous below with a canal, several lines in length, which opens in that depression in the partition betwixt the lower orifice of the carotid canal and the foramen lacerum posterius. Above, in front of the vestibular fenestra, the groove again runs into a canal which proceeds forwards and upwards between the canal for the internal muscle of the malleus and the commencement of the

* In Hildebrandt's Anatomie.

† De Aure et auditu Hominis et animalium, Lipsiæ, 1820.

aqueduct of Fallopius, and opens on the upper surface of the petrous portion of the temporal bone outside and in front of the hiatus of Fallopius. This canal, first accurately described by Arnold,* and called by him the tympanic canal, *canalis tympanicus*, is traversed by the nerve of Jacobson, which establishes a communication betwixt the glosso-pharyngeal and the otic ganglion. Besides this groove there are several others corresponding to the branches of the tympanic plexus of nerves.

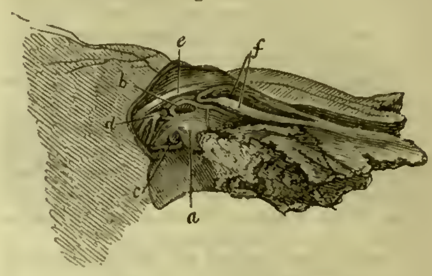
The opening below and behind the promontory, the *fenestra rotunda* or *cochlear fenestra*, leads, by a short infundibuliform canal directed obliquely inwards, into the lower or tympanic scala of the cochlea. Looking into this very short canal sideways, a groove is remarked encircling the margin of its inner orifice. This groove receives the circumference of the secondary membrane of the tympanum.

The opening above the promontory, the *fenestra ovalis* or *vestibular fenestra*, has already been described in speaking of the vestibule. All that we have to add here is that it is surrounded externally close to its edge by a small channel or groove.

Above the vestibular fenestra and running in much the same direction as its long diameter is a round elongated ridge, within which is the aqueduct of Fallopius. Below this ridge and behind the vestibular fenestra is a small mammillary or pyramidal eminence, called the pyramid, *eminentia papillaris s. protuberantia pyramidalis*. The apex of the pyramid, directed forwards and a little outwards, presents an opening leading into a canal, which extends backwards and downwards, then becoming vertical lies in front of the lower part of the aqueduct of Fallopius. In the thin lamina of bone which separates the two canals there is an aperture. The muscle of the stapes is lodged in the canal, and its tendon issues by the aperture in the apex, of the pyramid. About one-sixth of an inch behind the pyramid and close to the groove for the insertion of the circumference of the membrana tympani is the opening by which the chorda tympani, accompanied by an artery, enters the tympanum.

In front and a little above the vestibular fenestra, and on the anterior extremity of the prominence of the aqueduct of Fallopius, is a tubular projection with a wide open mouth directed outwards. This tubular projection, which is generally found incomplete in the dry bone, in consequence of being composed of a very thin brittle substance, is what has been called the *cochleariform process*. It is the continuation, bent at nearly a right angle outwards, of the canal or half canal, about half an inch in length, and destined for the reception of the internal muscle of the malleus, which lies above the osseous part of the Eustachian tube, and is separated from it merely by a thin lamina of bone, the continuation of that forming the tubular projection.

Fig. 248.



The inner wall of the tympanum.

a. Promontory; *b*. vestibular fenestra; *c*. cochlear fenestra; *d*. pyramid; *e*. eminence of the aqueduct of Fallopius; *f*. cochleariform process and half canal for the internal muscle of the malleus.

The outer wall of the tympanum is formed by the membrana tympani and the inner extremity of the osseous part of the external auditory passage, in which the membrana tympani is framed.

Osseous portion of the auditory passage.— This leads from the outside of the temporal bone. In front of it lies the glenoid cavity, and behind it is the mastoid process. It is about three-quarters of an inch long. Its course is from without inwards and from behind forwards, at first a little upwards and then downwards. It is wider at either extremity than in its middle. A cross section of the passage presents an elliptical orifice, the long diameter of which is directed from behind forwards and from below upwards. Its extremities are cut obliquely in such a way that internally the anterior wall exceeds the posterior, whereas at the outer orifice the posterior wall exceeds the anterior in length.

The margin of the *outer orifice* is rough and irregular to give attachment to the cartilaginous portion of the passage and to the auricle. Just within the *inner orifice* the osseous auditory passage is grooved all round except at its upper part. This groove is for the reception of the circumference of the membrana tympani.

In the fœtus the osseous portion of the auditory passage is a mere ring of bone, the *tympanic ring*, incomplete at the upper part where the groove in the adult is wanting. The tympanic ring serves as a frame for the membrana tympani. On the inner surface of the superior extremity of the anterior crus of this incomplete ring of bone there is a broad superficial groove, into which the processus gracilis of the malleus is received.

By-and-bye the tympanic ring is united to the temporal bone, and in process of time the part outside the groove grows outwards so as to form that plate of bone, thick behind, thin in front, rolled together in the form of an incomplete tube, which in the adult composes the lower, the anterior, and the posterior walls of the osseous auditory passage.

* Ueber den Canalis tympanicus und mastoideus, in Tiedemann's, Treviranus, und Gmelin's Zeitschrift für die Physiologie, B. iv. Heft 2, No. xxi. p. 284.

The tympanic ring lies immediately behind the glenoid cavity of the temporal bone, from which its anterior part is separated by a fissure. The middle part of this fissure, together with a line indicating the whole, remains permanent in the adult, and is known by the name of fissure of Glasser. Its internal orifice is, in the adult as it is in the young bone, in the outer wall of the tympanum, anteriorly of, and close to the groove for the reception of the membrana tympani. The fissure of Glasser gives passage to the ligament, or so-called great external muscle of the malleus, which is inserted into the processus gracilis of the malleus. The chorda tympani does not actually pass through the fissure of Glasser as commonly described, but as M. Huguier* has shown, through a particular canal, extremely narrow and about half an inch long, which runs in the line of the fissure, and opens at the re-entering angle between the squamous and petrous portions of the temporal bone.

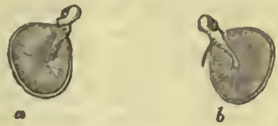
Membrane of the tympanum, (membrana tympani, Fr. *la membrane du tympan ou du tambour,)* Germ. *das Trommelfell oder Paukenfell.*—A proper membrana tympani exists only in birds and mammifera. In reptiles there is a very imperfect representation of one. In birds the membrana tympani is convex externally, in the mammifera, on the contrary, it is concave. The convexity externally in birds forms a very important distinguishing character of the class. In the cetaceous mammifera the membrana tympani is thick, and presents a prolongation like the tube of a funnel into the cavity of the tympanum.

The membrana tympani is situated at the bottom of the external auditory passage, between which and the cavity of the tympanum it is interposed like a partition. It is a thin, semi-transparent, glistening, dry-looking membrane. Its shape is an oval, truncated at one extremity, the upper. Rather more than the upper half of its vertical diameter is traversed by the handle of the malleus, which, when the membrane is examined on the living subject by means of the speculum auris, appears directed from above downwards and backwards.

The longest diameter of the membrana tympani, which is directed from above downwards, and from behind forwards, is about eight-twentieths of an inch, and its shortest, that from behind forwards, somewhat less than seven twentieths of an inch. It is fixed by its circumference in the circular groove already mentioned, at the inner orifice of the osseous part of the external auditory passage, or in the fœtus, the tympanic ring; and as in the adult the orifice is cut obliquely from behind forwards, from above downwards, and from without inwards, so is the direction of the membrane. Hence it forms, with the upper and posterior wall of the auditory passage, an obtuse angle, and with the lower and anterior wall, an acute angle.

Figure 249 represents the adult membrana tympani of the right side; *a.* as seen from the auditory passage; *b.* as seen from the tympanum. Its shape, size, the mode in which the malleus is connected with it, and the cartilaginous ring which forms its circumference, are sufficiently well shown.

Fig. 249.



The membrana tympani does not present plane surfaces. On the contrary its centre is drawn inwards, so that it is concave externally, and convex internally. This disposition of the membrana tympani depends on its connexion with the handle of the malleus. The latter being fixed in its whole length to considerably more than the upper half of the vertical diameter of the former, and having an inward direction inferiorly, the membrana tympani is, as it were, drawn inwards to it, hence the concavity externally.

As regards the composition of the membrana tympani, it consists of a proper membrane and two borrowed layers, one of which, covering the external surface of the proper membrane, is a delicate continuation, in the form of a blind end, of the lining of the auditory passage, and the other, situated on the inner surface, is a continuation of the delicate membrane which gives a lining generally to the cavity of the tympanum. The latter adheres very closely to the proper membrane, the other not so intimately, as it readily separates from it by putrefaction, and can be drawn out along with the rest of the epidermis of the external auditory passage in a cul-de-sac.

Structure of the proper membrane.—The proper membrane can be divided into two layers, an outer thin one, consisting of radiating fibres, and an inner thicker layer, which is less distinctly fibrous, though when torn it does indicate a fibrous disposition, and that in a direction opposite to the former. The radiating fibres run from its circumference towards the centre, to be fixed to the handle of the malleus along its whole extent. Towards the centre they become stronger, and being, of course, more aggregated, the layer which they compose is thicker and more compact in the centre than towards its circumference. The fibres which cross the radiating ones are also more aggregated at the centre. They run parallel with the handle of the malleus, and turn round its extremity. At the circumference of the proper membrane, there is a thick firm ligamentous or cartilaginous ring, (*fig.* 249,) which is fixed in the groove of the bone. This ligamentous ring appears to be formed by an aggregation of the circular fibres interwoven with the peripheral extremities of the radiating ones. The part of the membrana tympani midway between its centre and circumference is the thinnest.

The radiating fibres have been supposed to

* Cruveilhier, Anatomie Descriptive, tome iii. p. 508.

be muscular by Sir Everard Home and others, but this has not been confirmed by microscopical examination.

Mr. Shrapnell* describes at the anterior and superior part of the membrana tympani, above the short process of the malleus and its suspensory ligament, and where the groove in the bone is deficient, a flaccid tissue, composed of irregularly arranged fibres, to which he gives the name of *membrana flaccida*, in opposition to the rest of the membrana tympani, which he calls *membrana tensa*. This flaccid tissue is more developed in some of the lower animals, the sheep and hare for instance, than in man, and can be readily made to bulge out towards the auditory passage by blowing air into the Eustachian tube. But we cannot look upon it, with Mr. Shrapnell, as properly forming any part of the membrana tympani. It is merely a mass of dense, reddish, vascular cellular tissue, surrounding the neck of the malleus, and continuous with a similar tissue found under the lining integument of the upper wall of the osseous auditory passage. It is this same tissue which has been described as a muscle, and sometimes as a ligament.

The membrana tympani has been said to present in the natural state a perforation closed by a valve. Rivinus,† though not the first to mention it, dwelt on it, however, in a particular manner, hence the perforation has been called *hiatus Rivinianus*. The subject has been more recently taken up by Wittmann and Vest.‡

The membrana tympani receives a nerve from the third division of the fifth, which has communications with filaments of the chorda tympani.

To resume our description of the cavity of the tympanum:—In the upper wall of the tympanum there is an excavation for receiving the upper part of the incus, and leading from that, at the upper and back part of the tympanum, is a short, wide, triangular canal, with a rough cellular surface. This is the passage to the mastoid cells, through the medium of a large cell, *sinuositas mastoidea s. sinus mammillaris, s. antrum mammillare*, which already exists in the young bone between the squamous and petrous portions.

The mastoid cells are cavities in the mastoid process, all communicating with each other. They are quite irregular in regard to size, number, and relative situation. In early life, as the mastoid process is not fully formed, they do not exist, they are only found completely developed in the adult.

Inferiorly, the cavity of the tympanum forms a sort of furrow, which presents nothing particular. It is bounded by the plate of bone which forms the outer wall of the jugular fossa.

* On the form and structure of the membrana tympani, in London Medical Gazette, vol. x. p. 120. London, 1832.

† De auditus vitiis, Lipsiæ, 1717, 4, p. 32. Tab. adj. Fig. 1, *b*. et fig. 2, *b*.

‡ Ueber die Wittmannsche Trommelfellklappe, in den medizinisch. Jahrbüchern des oestr. Staates. Bd. v. Wien, 1819, p. 123, 133.

Anteriorly, the cavity of the tympanum opens into the osseous portion of the Eustachian tube.

The ossicles or small bones of the ear (ossicula auditus s. aurium, Fr. *osselets de l' ouie; Germ. die Gehörknöchelchen, or Gehörbeinchen).* In the upper part of the cavity of the tympanum, there are three small bones articulated with each other, and forming a chain which reaches from the membrana tympani to the vestibular fenestra. The bones are named *malleus, incus*, and *stapes*, from their resembling more or less respectively a hammer, an anvil, and a stirrup iron.

The innermost and most essential is the stapes; it is it alone which in birds and reptiles remains, when the others have disappeared, or been reduced to merely cartilaginous pieces. The stapes is engaged in the vestibular fenestra.

The outermost of the chain, the malleus, is in connexion with the membrana tympani.

The hammer bone, (malleus,) Fr. *le marteau*, Germ. *das Hammer*, presents a head, a neck, a handle, and two processes, one longer, and one shorter.

The head, *caput s. capitulum*, is round and smooth on one surface, and on the other presents a saddle-shaped depression, surrounded by a small elevated border. The depression articulates with the incus, and the border is for the attachment of the synovial capsule of this minute joint.

The neck, *collum s. cervix*, is flattened in one diameter, and joins the handle at an obtuse angle.

The handle, *manubrium mallei*, compressed from the side corresponding to the articular depression to the opposite side, and diminishing in thickness towards its extremity, forms, together with the short process, a double curve, like an Italic *f*. The extremity is also compressed, as if beaten flat, but in an opposite direction, so that the broad surfaces of the extremity correspond to the edges of the rest of the handle.

Short or blunt process, *processus brevis s. obtusus*. From the projecting side of the angle formed by the junction of the neck and manubrium, this process, which is short, thick and conical, rises.

The long or slender process, *processus longus, s. gracilis, s. spinosus, s. Folii*, springs from the neck, and from that side of it which corresponds with the non-articular surface of the head. The long process is of considerable length, and terminates in a broad, flat, spatula-like extremity, first described by Rau,* although the commencement or root of the process itself had been previously delineated and described by Folius. The long process is generally found broken off, either from its being so slender, or from its having been, especially in old subjects, united to the groove in which it is lodged.

The anvil bone, incus, Fr. *l'enclume*, Germ.

* Boerhaave Prælect. in Instit., Prop. iv. p. 358.

der Amboss.—This has been compared, also, to a bicuspid molar tooth. It is divided into a body, and two processes, or crura.

The body, *corpus*, presents a concave articular surface, by which it is joined to the malleus: around this surface is a groove, (particularly deep and broad on the side towards the labyrinth, that is, the side on which the lenticular process projects,) for the insertion of the articular capsule.

The shorter of the two processes, *crus s. processus superior s. brevis*, is blunt at its apex, and compressed from one side to another.

The longer process, *crus s. processus inferior s. longus*, is more slender, and becomes gradually thinner towards its extremity, where it is slightly curved, and where it presents, supported on a short bony pedicle, given off at a right angle from its side, the lenticular process, *processus lenticularis incudis*;*—a small oval plate so situated, that a line drawn through the long diameter of it would intersect obliquely a line corresponding to the long crus of the incus. The free surface of the lenticular process is convex, and is destined to articulate with the corresponding concave surface on the head of the stapes. The lenticular process has been, and is still, often described as a separate bone, under the name of *os lenticulare*.

The stirrup bone, (stapes). Fr. *L'etrier.* Germ. *Der Steigbügel.*—Exactly like a stirrup, this bone presents a base, two crura, and a head, where the crura unite.

The base, *basis*, the essential part of the bone, has precisely the same shape as the vestibular fenestra to which it is applied, only a little smaller. The arched margin of the base corresponds to the upper edge of the fenestra, and the indented margin to the lower edge.

The surface of the base corresponding to the vestibular fenestra is slightly convex. The other surface is grooved; but the groove is subdivided by a ridge, which extends obliquely along it lengthways, and which is continuous at its extremities with the upper margin of the groove on the inner surface of one crus, and the lower margin of the groove of the opposite crus. The margin of the base projects like a ledge beyond the insertion of the crura.

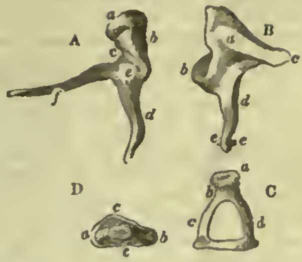
Of the two *crura*, one is shorter and straighter than the other; both are grooved on the surfaces regarding each other, and the grooves are continued into that just described in the base, in such a way that the groove of one crus is continued into one of the divisions, and the groove of the other crus into the other.

The head, *capitulum*, somewhat oblong and flat, presents a superficial depression on its top, oblique from above downwards, and from without inwards, for receiving the convex articular surface of the lenticular process of the incus. There is sometimes an appearance of a *neck* supporting the head.

Position, connexions, and articulations of the small bones of the tympanum.—The handle of

* Blumenbach, Geschichte, und Beschreibung der menschl. Knochen, s. 50, p. 145.

Fig. 250.



Small bones of the tympanum of the left side, magnified considerably more than twice. (From Soemmerring.)

A is the malleus seen from the side corresponding to the membrana tympani: *a.* head; *b.* articular surface; c. neck; *d.* handle; *e.* short process; *f.* long process.

B. The incus seen from its outer surface also: *a.* body; *b.* articular surface; c. short crus; *d.* long crus; *e e.* lenticular process.

C. The stapes: *a.* head; *b.* neck; *c.* anterior and less bent crus; *d.* posterior and more bent crus; *e.* base.

D. A fore-shortened view of the stapes: *a.* anterior and less curved crus; *b.* posterior crus, the two are seen uniting at the head, the articular surface of which is seen; c. base.

the malleus is fixed to the membrana tympani. The articular surface on the head of the malleus, to the corresponding surface on the body of the incus, and the long process of the incus, is through the medium of its lenticular process articulated with the stapes. These two joints are furnished with small articular capsules.

The head of the malleus lies in the upper space of the tympanum, above the upper margin of the membrana tympani. Its articular surface is directed obliquely backwards and inwards. The surface of the neck, corresponding to the prominence of the angle which it forms with the manubrium, is hitched like a shoulder under the upper part of the circumference of the inner extremity of the auditory passage. The handle of the malleus, it has been said, is compressed from one side to another, so that it presents two flat surfaces and two edges or ridges. That edge or ridge which is continued down from the short process is turned outwards, and corresponds to the membrana tympani; into it, indeed, along its whole extent, the central extremities of the radiating fibres of that membrane are inserted. The extremity of the handle of the malleus, which is curved forwards and outwards, is compressed, but in a direction contrary to the rest of the handle; so that one of the flat surfaces, that corresponding to the outer ridge of the rest of the handle, is connected with the membrana tympani at a point below its centre, and nearer its anterior edge. It is at this point that the bottom of the concavity is which the membrana tympani presents externally. At its upper part the membrana tympani is pushed outwards by the short process of the malleus, which projects towards the auditory passage.

The long process of the malleus is directed forwards, and lies in a groove within the anterior part of that for the reception of the membrana tympani, and close to the fissure of Glasser.

To the top of the head of the malleus, a ligament extends downwards from the upper wall of the cavity of the tympanum. Another ligament, known also under the name of the *great external muscle of the malleus,* proceeds from the spinous process of the sphenoid bone backwards and inwards, through the fissure of Glasser, and is inserted into the long process of the malleus. A third ligament has been described, as arising from within the upper and posterior margin of the inner orifice of the auditory passage above the margin of the membrana tympani, and proceeding downwards and inwards to be inserted into the handle of the malleus below the short process, close to the place where the connexion between the handle of the malleus and the membrana tympani ceases. Of this ligament, which has also been described as a muscle, *small external muscle of the malleus,* there is not much trace, except in the reddish cellular tissue already mentioned.

The body of the incus lies in the upper and posterior part of the tympanic cavity. Its articular surface, corresponding to that of the malleus, is directed forwards, and a little upwards and outwards. The articulating surfaces of the two bones are incrusted with cartilage, and the joint is provided with a synovial membrane, which is strengthened by ligamentous fibres. The short branch is directed horizontally backwards towards the entrance into the mastoid cells, and is there fixed by means of a short and broad ligament, which arises from a small pit in the outer wall, and embracing its extremity, is inserted on it. The long branch extends perpendicularly downwards, almost parallel with the handle of the malleus, but nearer the inner wall of the tympanum, towards which its extremity, bearing the lenticular process, is curved.

The *stapes,* situated lower down in the cavity of the tympanum than the other bones, lies with its base applied to the vestibular fenestra, to the circumference of which it is closely fixed by a circular ligament, *ligamentum annulare baseos stapidis.* This ligament springs from the margin of the vestibular fenestra, and is inserted into the jutting margin of the base of the stapes all round. Besides this ligament, there are reflections of the membrane lining the tympanum, and of that lining the vestibule. The connexions of the base of the stapes with the vestibular fenestra are such as to admit of some degree of movement, but not to any very great extent,—so little, that it would seem one object of the mechanism of the fenestra ovalis, and its closure by the base of the stapes, was merely to interrupt the continuity of the osseous walls of the vestibule.

The short branch of the stapes is in front; the long branch behind, and its head outwards, where it meets and articulates with the lenticular process of the long branch of the incus. This articulation presents also cartilages of incrustation, and a minute synovial capsule, together with strengthening ligamentous fibres.

Fig. 251.

The small bones connected together, and their relation to the osseous labyrinth. Left side. Magnified. (From Soemmerring.)

Muscles of the small bones.—Some anatomists admit four muscles: three attached to the malleus and one to the stapes. Of the three attached to the malleus, two are described as having for their action the relaxation of the membrana tympani; but these so called *laxatores tympani* are merely ligaments, and have been described above as such. I agree with Hagenbach,* Breschet,† and Lincke,‡ that two muscles only can be distinctly demonstrated, and these two are both tensors of the tympanum. A relaxation, or state of rest of the membrana tympani, takes place of itself, as Treviranus§ remarks, when the tensors cease to act; hence a relaxator muscle of the membrana tympani was not required.

Muscle of the malleus, *musculus internus mallei s. tensor tympani.*—This muscle occupies the canal, or half canal, which was described as lying above the osseous part of the Eustachian tube. It arises from the posterior and under part of the sphenoid bone, from the superior part of the cartilaginous portion of the Eustachian tube, and also from an aponeurotic sheath which lines the canal, or completes the groove in which it is lodged. Its fibres proceed from before backwards, and terminate in a slender tendon, which bending at a right angle, as a rope over a pulley, enters the cavity of the tympanum, through the tubular projection already described as a continuation of the canal in which it lies. Having entered the tympanum, it proceeds outwards, and is inserted into a slight elevation, sometimes remarked on the inner and anterior surface of the handle of the malleus below the long process, and also a little below and opposite the root of the short

* Disquisitiones anatomicæ circa musculos auris internæ hominis et Mammalium, &c. Basileæ, 1833, p. 20.

† Op. cit. s. xxxiii.

‡ Das Gehörorgan, &c. Leipzig, 1837, p. 140, s. 114.

§ Biologie, Band. vi. p. 376.

process. The muscle of the malleus receives a nervous branch from the otic ganglion.

By the action of this muscle, the handle of the malleus is drawn inwards and forwards, whilst the head is moved in the opposite direction, in consequence of the bone moving on its long process as on an axis. The result of this movement of the bone is, that the membrana tympani, which is attached to the handle of the malleus in its whole length, is also drawn inwards and stretched. Besides the tension to which the membrana tympani is thus subjected, the base of the stapes is forced against the vestibular fenestra, in consequence of the movement communicated by the head of the malleus to the incus, which tends to press inwards the long extremity of the latter.

Muscle of the stapes, M. stapedius.—This is lodged, and takes origin in the cavity of the pyramid already described. Much paler and smaller than the preceding muscle, it is inserted into the posterior and upper part of the head of the stapes by a slender tendon, which issues by the aperture in the summit of the pyramid, and proceeds downwards and forwards to its termination.

The stapedius muscle receives a nervous filament from the facial nerve.

The first effect of the action of this muscle will be to press the posterior part of the base of the stapes against the vestibular fenestra. At the same time the long branch of the incus will be drawn backwards and inwards, and the head of the malleus being, by this movement of the incus, pressed forwards and outwards, its handle will be carried inwards, and the membrana tympani thus put on the stretch. Breschet calls the muscle of the stapes a *laxator*, but I do not know on what grounds.

Magendie* mentions the circumstance that in the stapedius muscle of the ox and horse, there is imbedded a small lenticular bone. Professor Berthold of Göttingen† has more lately called attention to the same circumstance. Berthold has not found this bone in man, nor sheep, nor deer, nor goats, nor swine. In the ox and calf it is about one-half to three-fourths of a line in its longest diameter, and one-third in the shortest, and lies surrounded by the muscular and tendinous substance where the former passes into the latter. In the horse it is a little nearer the lower margin of the muscle and tendon, and is much smaller than in the ox; moreover, it is not round, but is a longish plate, somewhat thicker in the middle.

At the place where the stapedius muscle is inserted into the stapes, Hyrtl‡ has sometimes found in the human ear a small process of bone which in some cases was so long as to extend into the belly of the muscle itself. Teichmeyer* has described this free bone of the stapedius muscle as constant in man.

* Sur les organes qui tendent ou relachent la membrane du tympan et la chaine des osselets de l'ouie dans l'homme et les animaux mammifères. In Journal de Physiologie experimentale, t. 1., p. 346. Paris, 1821.

† Ueber ein linsenförmiges Knöchelchen im Musculus Stapedius mehrerer Säugethiere. In Mueller's Archiv. Jahrg. 1838.

‡ Beiträge zur pathologischen Anatomie des Gehörorgans, in the Medicin. Jahrbücher des k. k. oestr. Staates. Wien 1836. Bd. xx. p. 439.

Having described the walls and contents of the cavity of the tympanum, we come now to speak of the membrane which lines it.

The lining membrane of the cavity of the tympanum is in continuity with the mucous membrane of the throat, through the Eustachian tube. Extremely delicate, and in some parts very vascular, it is not merely a mucous membrane, but is theoretically a combination of periosteum and mucous membrane, being what Bichat called fibro-mucous. It invests all the elevations and depressions observed on the walls of the tympanum, and extends into the mastoid cells. The outer layer of the membrane of the fenestra rotunda, *membrana tympani secundaria*, is a continuation of it.

The base of the stapes is fixed by its circumference to the outer edge of the groove, which encircles the vestibular fenestra, by a membrane or ligament. The lining membrane of the vestibule, continued over the base of the stapes from within, also invests the inner surface of this annular ligament, whilst the outer surface of it is covered by the membrane lining the tympanum as it is reflected on the stapes.

The membrane lining the tympanum invests the small bones and the tendons of their muscles where they run free in the cavity. A fold of it fills up the space bounded by the crura and base of the stapes. The chorda tympani, also, in its passage across the tympanum, is enveloped by it. Lastly, it forms the inner borrowed layer of the membrana tympani, covering and adhering closely to the handle of the malleus.

The Eustachian tube, (tuba Eustachii, s. canalis palatinus tympani; Fr. *la trompe d'Eustachi;* Germ. *die Eustachische Röhre oder der Gaumengang des mittleren Ohrs.)* — The Eustachian tube is a passage of communication betwixt the cavity of the tympanum and the throat. In length about an inch and a half, it is directed from behind forwards, from without inwards, and from above downwards. Its guttural orifice is wider than that by which it opens into the tympanum.

Proceeding from the tympanum, its first part is an osseous canal, *the osseous part of the Eustachian tube;* the walls of the remainder of it are composed partly of cartilage, partly of fibrous membrane, *the cartilaginous and membraneous portion of the Eustachian tube.*

The osseous part of the Eustachian tube, *pars ossea tubæ Eustachii*, begins at the anterior and lower part of the tympanum, by a funnel-like orifice, and runs forwards and inwards on the outside of the carotid canal, and below that for the reception of the internal muscle of the malleus. It is about half an inch in length, and ends by a notched and irregular edge at the re-entering angle, between the squamous and petrous portions of the temporal bone. Its calibre contracts in its course forwards, and is compressed from without and below inwards

* Vindiciæ quorundam inventorum anat. in dubium vocatorum. Jenæ 1727. 4.

and upwards. In the dry bone it is wide enough to admit the end of a quill stripped of its feathery part, about one-twelfth of an inch thick. In the recent state, when lined by its mucous membrane, it is very much narrower.

The cartilaginous and membraneous portion of the Eustachian tube, pars cartilaginea et membranacea tubæ Eustachii.—In the skull it is observed that the osseous part of the Eustachian tube is continuous with a sort of gutter which is formed by the outer and anterior side of the petrous bone, and the posterior inner and lower margin of the great wing of the sphenoid bone. To this gutter the external wall of that part of the Eustachian tube under consideration, which is partly cartilaginous and partly fibro-membraneous, corresponds at its tympanic extremity; towards the guttural orifice of the tube, the membraneous wall is applied against the circumflex muscle of the palate. The inner, and also the upper wall of this portion of the Eustachian tube, is formed of a grooved cartilaginous lamina of a triangular form, fixed by dense cellular tissue to the irregular extremity of the osseous portion, to the apex of the petrous bone, and to the root of the inner plate of the pterygoid process of the sphenoid. At the guttural orifice of the Eustachian tube, it forms a semilunar prominence with its convexity turned upwards and backwards. The cartilaginous plate of the outer wall does not extend to the mouth of the tube, but only fills up that place where the outer wall of the bony groove above-mentioned as continuous with the osseous part of the Eustachian tube is defective, that is, from before the foramen spinosum of the sphenoid to the scaphoid fossa at the root of the inner plate of the pterygoid process.

The cartilaginous and membraneous portion of the Eustachian tube is about one inch long. Being compressed from within outwards, a section of it is an elliptical fissure. From its junction with the osseous portion, it goes on widening, so that the point of junction is the narrowest part of the tube;—in the recent state, about one-thirtieth of an inch in diameter, just sufficient to admit a small probe.

The mouth of the Eustachian tube in the throat forms an oval-shaped fissure, about three-eighths of an inch long, bounded anteriorly and posteriorly by prominent swollen edges. The fissure is directed obliquely from above downwards, and from before backwards, and is situated at the upper and lateral part of the pharynx behind the soft palate. In reference to the nasal passage, my observation agrees with that of Kramer,* that the *lower angle* of the guttural orifice of the Eustachian tube *lies a very little deeper* than the *horizontal line of the lowest meatus*, whilst *the upper angle is a little deeper than the horizontal line of the middle meatus.*

The Eustachian tube is essentially a tegumentary canal; through it atmospherical air is admitted into the tympanum, a condition which, by keeping up an equable pressure on either side of the membrana tympani, and giving free scope to the play of the small bones upon each other, is necessary for the perfect exercise of hearing. Its lining membrane is continuous with that of the throat on the one hand, and with that of the tympanum on the other. At the guttural orifice of the tube, it has all the properties of the mucous membrane of the nose and throat; as it approaches the tympanum it becomes thinner and finer, until it assumes all the characters of the fibro-mucous lining of the tympanum. Within the osseous portion of the tube, it no longer presents any of the mucous glands which are found in the mucous membrane of the prominent edges of the guttural orifice, and in that lining the cartilaginous and membraneous portion—mucous glands, which perform so important a part in the economy, and particularly the morbid states, of the Eustachian tube and apparatus of hearing generally.

Fig. 252.

The two muscles of the small bones, and the Eustachian tube. (From Soemmerring.)

a. b. c. d. Eustachian tube; *e.* muscle of the malleus; *f.* the muscle of the stapes.

2. *The external ear, including the auditory passage.*

A. The auricle or the ear, (auricula s. pinna,) Fr. *pavillon de l'oreille;* Germ. *das Ohr.*—The human auricle, as is known, presents on the surface directed outwards, prominences bounding gutter-like depressions, which wind like a maze in different directions; but all lead at last into the auditory passage. Considered in a general way, the surface directed outwards is concave. The surface turned towards the side of the head is, on the contrary, generally speaking, convex, but it is depressed at the places corresponding to the elevations on the outer surface, and more elevated where the depressions are.

The hem-like fold of the edge of the ear all round is called *helix*. The eminence within the helix is called *anthelix*, and the gutter-like depression between the two is called the *navicular fossa*. At its upper extremity the anthelix divides into two branches, between which is a triangular depression called *fossa innominata*. The lower extremity of the anthelix runs into a projection called *antitragus*, opposite which, and under the anterior part of the helix, is a broad projecting plate called *tragus*, which lies over the entrance of the auditory passage

* Die Erkenntniss und Heilung der Ohrenkrankheiten. Berlin, 1836. p. 243.

like a valve. The posterior margin of the tragus, and anterior margin of the antitragus, meet inferiorly; but superiorly they are separated by a considerable notch. Bounded by the anthelix, tragus, and antitragus, and traversed horizontally by the commencement of the helix, is a deep cavity, called *concha*, at the anterior part of which is the auditory passage leading from it, as the pipe from the mouth of a funnel. The lower pendulous part of the ear is called *lobule*.

Fig. 253.

a. b. c. d. e. the helix; *f. g.* the upper and lower crura of the anthelix; *h.* the point of junction of the two crura; *i. k.* the anthelix; *l.* tragus; *m.* antitragus; *n.* lobule; *o.* navicular fossa; *p.* fossa innominata; *q.* cavity of the concha; *r.* entrance of the auditory passage.

The auricle of the left side (reduced in size). (From Soemmerring.)

Stripped of the skin which invests it, the auricle is found to be composed of a cartilaginous skeleton, on which its elasticity depends. The skeleton presents, with some modifications, all the eminences and depressions we have described, except the lobule, which consists merely of a prolonged fold of skin, between the layers of which is cellular and adipose tissue.

In the skeleton of the auricle, the *helix* commences by an acute point in the excavation of the concha. Gradually becoming broader and more elevated, it proceeds obliquely upwards and forwards, then turning round the upper margin of the ear, contracts in breadth; and about the middle of the posterior margin, its hemlike fold having ceased, its simple edge is continued into a free tail-like process of cartilage, which is separated by a fissure from the antitragus. On the anterior part of the helix above the tragus, there is a mammillary process of cartilage which gives attachment to a ligament. Behind and below the root of this mammillary process, there is a small vertical fissure in the helix, *incisura helicis*.

Regarding the *anthelix* there is little more to be said, except that the lower branch of its upper extremity forms a very prominent crest; and that inferiorly the anthelix is continued into the same tail-like process that the helix runs into, and is also partly continued into the antitragus.

The *antitragus* is a small plate of cartilage, forming an angle, directed upwards and forwards. It is continuous by its base with the cartilage of the concha. The lobule hangs from the antitragus, and the tail-like process of cartilage common to the helix and anthelix.

Tragus.—Between the helix and tragus there is no connexion by cartilage. The space is merely filled by a continuation of the fibrous cellular tissue which constitutes the upper and posterior part of the cartilaginous and membraneous portion of the auditory passage.

The cartilage of the ear is covered by perichondrium, which imparts considerable strength to it. When the perichondrium is removed by dissection, the cartilage is found to be very brittle.

Fig. 254.

a. a. a. a. helix; *b.* anthelix; *c.* two crura of anthelix; *d.* cavity of the concha; *e.* antitragus; *f.* tragus; *g.* fissure between the tragus and commencement of cartilaginous portion of the auditory passage, the larger fissure of Santorini.

Skeleton of the cartilage of the external ear (diminished). (From Soemmerring.)

The skin covering the cartilage of the ear adheres intimately to its unequal surface, less so to its back and circumference. The lower part of the hem-like fold of the helix is formed entirely by it; also the lobule, as has been already said. The skin of the auricle contains a number of sebaceous follicles, particularly in the concha, and around the entrance of the auditory passage.

On the tragus is observed, especially in old people, a small tuft of hair, which has been compared to a goat's beard; whence the name tragus, (τραγος, hircus,) which the Germans translate *Bock*. The *antitragus* they call *Gegenbock*.

Ligaments of the ear. Anterior ligament, (ligamentum auriculæ anterius).—This proceeds from the root of the zygomatic process to the lower and anterior part of the helix, and to the tragus.

Posterior ligament, (ligamentum auriculæ posterius).—Extends from the outer surface of the mastoid process to the posterior surface of the cartilage of the ear, where the concha runs into the auditory passage. Besides the above ligaments binding the ear to the head, there are others which extend from one point of the cartilage of the ear to another.

Muscles of the ear.—The muscles of the ear fall into two classes: viz. those which, arising from the head, are inserted into the ear, and move it as a whole; and those which, extending from one part of the cartilage to another, are calculated, were they strong enough, to produce a change in the general form of the auricle.

Muscles which move the ear as a whole, or the extrinsic muscles.—The elevator, or superior muscle of the ear, (M. attollens auriculam s. superior auriculæ), is a broad thin muscle, composed of fibres spread out on the upper part of the side of the head. It arises from the middle part of the epicranial aponeuroses, and also from the temporal aponeuroses; thence, to its insertion into that elevation of the ear-cartilage on the surface next the head, which corresponds to the fossa innominata, the fibres become more aggregated, so that the muscle is much narrower, but thicker inferiorly than superiorly. By elevating the upper part of the ear, it will widen and straighten the auditory passage.

The retractor or posterior muscles of the ear, (M. retrahentes auriculam, s. posteriores auriculæ.) These ordinarily consist of three bundles, sometimes only two, which, taking their origin from the mastoid process, run forwards to the cartilage of the ear, into which they are inserted at the eminence on the back of the concha, corresponding to the commencement of the helix on the other side.

In drawing the ear backwards, these muscles will dilate and flatten the concha, and widen the entrance to the auditory passage.

The anterior muscle of the ear, (M. attrahens auriculam s. anterior auriculæ,) arises from the zygomatic process, and, in its course backwards to the ear, gradually contracts, until it ends in a short tendon, which is inserted into the anterior surface of the helix, immediately above the tragus. It draws the ear forwards.

Fig. 255.

The cartilage of the left auricle from behind, and the extrinsic muscles (diminished). (From Soemmerring).

a. m. attollens auriculam; *b.* m. anterior auriculæ; *c. d.* two m. retrahentes auriculam.

Intrinsic muscles of the ear.—These muscles are very delicate and weak, little adapted to produce any sensible change in the form of the ear. Five are admitted:—

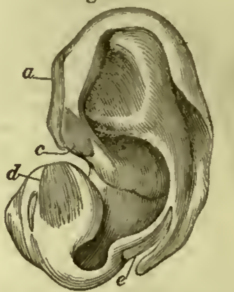
The larger muscle of the helix, (M. helicis major,) arises from the lower and anterior part of the helix, on the outer and anterior surface of which it ascends for about three quarters of an inch, and then is inserted into the helix above the point where the ear becomes free from its attachment to the head.

The smaller muscle of the helix, (M. helicis minor.)—This lies farther down and more behind than the preceding. It begins at the place where the helix rises from the concha, and is inserted into the posterior margin of the ascending portion of the helix.

The muscle of the tragus, (m. tragicus).—Of an oblong square form, this muscle covers the outer surface of the tragus, from the lower part to the upper margin of which its fibres run.

The muscle of the antitragus, (m. antitragicus).—The fibres of this muscle arise from the outer surface of the antitragus, and are inserted by a small tendon to which they converge into the lower extremity of the anthelix.

Fig. 256.

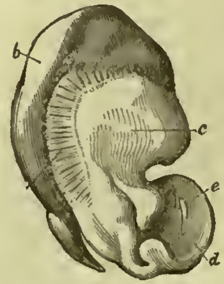


a. m. helicis major; *c.* m. helicis minor; *d.* m. tragicus; *e.* m. antitragicus.

The intrinsic muscles situated on the concave side of the auricle (diminished). (From Soemmerring).

The transverse muscle of the ear, (m. transversus auriculæ,) is situated on the back of the ear. It is composed of fasciculi not very distinctly muscular, which run from the dorsum of the concha to the back of the anthelix, and the elevation which corresponds to the navicular fossa.

Fig. 257.



a. transversus muscle; *b.* helix; *c.* back of the concha; *d.* tragus; *e.* fissure of Santorini.

The back of the cartilage of the external ear and the transversus muscle (diminished). (From Soemmerring).

B. The external auditory passage, (meatus auditorius externus s. porus acusticus; Fr. *Le conduit auditif ou auriculaire;* Germ. *Der Gehörgang.)*—Like the Eustachian tube, the external auditory passage is composed of an osseous portion, and a portion partly cartilaginous and partly membraneous. The osseous portion has been already described as a part of the outer wall of the tympanum; the other portion comes to be noticed here as a continuation of the cartilage of the auricle. The passage will then be considered as a whole.

Cartilaginous and membraneous portion of the external auditory passage, *meatus auditorius cartilagineus-membranaceus.* This portion of the auditory passage, about half an inch long, is formed in front and below by cartilage, above and behind by dense fibro-membraneous cellular tissue, in which many ceruminous glands are imbedded.

The plate of cartilage which forms the anterior and lower wall of this portion of the auditory passage is of a triangular shape with a fissure running through its base to near the apex. The base is below; the apex above. The base corresponds to the anterior surface of the mastoid process. One side is attached to the anterior and lower part of the circumference of the outer extremity of the osseous passage, by dense and strong cellular tissue. The other side corresponds to the base of the tragus. The apex or angle formed by the two sides runs into the upper part of the base of the tragus, and corresponds to the root of the zygomatic process. The angle formed by the base, and that side which is attached to the osseous part of the passage, is extended into a broad pointed tongue, which is fixed into the deep and rough depression at the lowest part of the margin of the orifice of the osseous passage. The angle formed by the base and the other side is continued into the concha.

The dense fibrous cellular tissue, which completes the passage above and behind, extends from the cartilage of the concha to the upper and posterior part of the margin of the external orifice of the osseous part of the passage.

What are called the fissures of Santorini, *incisuræ Santoriniona*, are: — 1. that fissure extending through the base of the triangular plate of cartilage to near its apex; and 2. that between the outer margin of the cartilage and the base of the tragus. These fissures are closed by fibrous cellular tissue which, particularly over the second fissure, appeared to Santorini to consist of muscular fibres. These fibres have, therefore, received the name of the muscle of the largest fissure, or the muscle of Santorini, *m. incisuræ majoris s. Santorini*. Haller considered their action to be, by approximating the cartilaginous pieces, to shorten the length of the passage.

Viewed as a whole, the auditory passage is a canal of an oval calibre. It leads from the auricle to the tympanum, from the cavity of which it is separated by the interposition of the membrana tympani. In front of it lies the joint of the lower jaw, behind is the mastoid process. In the adult its length is about an inch and a quarter, and its direction is at first somewhat forwards, then upwards and backwards, and lastly downwards and forwards again. Its lower wall is from one-tenth to one-fifth of an inch longer than the upper.

The auditory passage is lined by a continuation of the skin of the auricle. This skin becomes more and more delicate as it approaches the osseous part of the passage,—extremely so where it is continued on the outer surface of the membrana tympani. The skin of the auditory passage is covered with fine hairs, and in old persons close to the entrance, hairs like those on the tragus, sometimes of considerable length, are enrooted.

The skin of the auditory passage is connected to the subjacent cartilage and bone by rather dense and sparing cellular tissue. The epidermis readily separates by putrefaction, and may be drawn out like the finger of a glove, the blind end being the part which forms the outer borrowed layer of the membrana tympani.

From about a tenth of an inch within the auditory passage to about one-fifth of an inch from the membrana tympani, the lining integument is perforated by numerous small apertures, the terminations of the excretory ducts of the glands which secrete the ear-wax. These excretory orifices are most numerous about the middle of the passage, towards the termination of the cartilaginous and membraneous portion.

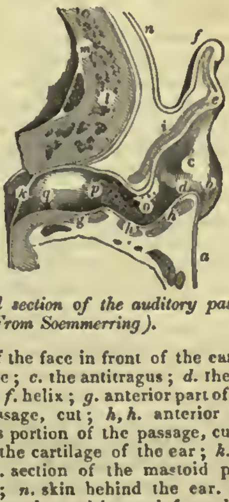
The ceruminous glands, *glandulæ ceruminosæ*, are small round or oval bodies of a brownish yellow colour, and very vascular. They are imbedded in the areolæ presented by the dense cellular tissue which connects the skin of the auditory passage to the subjacent cartilage or bone.

The ear-wax, *cerumen*, is, as is known, a thick orange-coloured or yellowish brown viscid substance, of an extremely bitter taste, and somewhat aromatic odour. When first secreted, it is a thin yellowish milky fluid. (See Cerumen.)

The auditory passage, especially in the middle, is usually covered with a more or less thick layer of it. It consists principally of a butter-like fat and albumen in combination with a peculiar animal matter; of a yellow, bitter, alcoholic extractive matter, with lactate of potass and lime and a watery extractive matter.

In irritation or diseased states of the glands, the ear-wax is changed in its properties, and is thrown out in larger quantities than usual, so that it collects and comes sometimes to fill completely the auditory passage, and thus give rise to dulness of hearing.

Fig. 258.



Horizontal section of the auditory passage (diminished). (From Soemmerring).

a. Skin of the face in front of the ear; *b.* lobule of the auricle; *c.* the antitragus; *d.* the tragus cut; *e.* anthelix; *f.* helix; *g.* anterior part of the osseous auditory passage, cut; *h, h.* anterior part of the cartilaginous portion of the passage, cut; *i.* posterior part of the cartilage of the ear; *k.* membrana tympani; *l.* section of the mastoid process; *m.* dura mater; *n.* skin behind the ear. It is seen continued over the auricle, and from that into the auditory passage; *o.* first or greater curve of the auditory passage; the end of which is directed forwards; *p.* the second or smaller curve, directed backwards; *q.* third and smallest curve; at *o.* and *p.* are seen the orifices of the ceruminous glands.

Nerves of the accessory parts of the apparatus of hearing.

Nerves of the tympanum.—The tympanum receives nerves from different sources—from the fifth, the seventh, eighth, and ninth pairs of cerebral nerves. Moreover, its nerves have communication with the sympathetic system.

The facial nerve or portio dura of the seventh pair rises from the brain by two roots, which unite together in the meatus auditorius internus, but before uniting, the smaller root sends off a delicate filament, which forms a communication, as has been mentioned, with the auditory nerve. This communication, first pointed out by Swan, has recently been very fully investigated by Arnold. According to the latter, in the middle or at the bottom of the internal auditory meatus, one or several delicate filaments go off from the smaller branch of the facial, and join the auditory nerve. After this the facial nerve enters the aqueduct of Fallopius, and issues from the cranium through the stylo-mastoid hole. In this course it receives, at the place where it forms the knee-like bend into the aqueduct of Fallopius, the superior branch of the Vidian or superficial petrosal nerve, *nervus petrosus superficialis, s. major*.

The superficial petrosal nerve comes off, along with the inferior branch of the Vidian or deep petrosal nerve, from the posterior part of the spheno-palatine ganglion or ganglion of Meckel. Leaving the deep petrosal nerve at the posterior orifice of the Vidian canal, the superficial petrosal proceeds upwards through the cartilaginous substance in the foramen lacerum medium, and then runs backwards in the groove on the anterior surface of the petrous bone leading to the hiatus of Fallopius. Having entered the latter, it joins the facial nerve, and forms, with its external fasciculi, a gangliform swelling, *intumescentia gangliformis nervi facialis*, of a grayish appearance and soft consistence.

From this swelling a filament arises by one or two roots, and runs backwards into the internal auditory passage to join the upper portion of the auditory nerve, where the first filament joined, and forms with it a small reddish gray elevation, known to and delineated by Scarpa.

Another branch, which arises from the ganglionic swelling, is the *chorda tympani*. The chorda tympani thus in reality derives its origin both from the facial and the superficial petrosal nerves. The chorda tympani accompanies the facial nerve along the aqueduct of Fallopius till within a little of the exit of the latter by the stylo-mastoid hole. The chorda tympani then leaves the facial nerve at an acute angle, and proceeds upwards in a proper canal in the bone, enters the cavity of the tympanum by the opening just within the posterior part of the groove for the membrana tympani already described. From this opening it proceeds forwards between the long process of the incus and the handle of the malleus, to the fissure of Glasser, through the canal beside which, already described, it makes its exit from the cavity of the tympanum. It then descends by the inner side of the ascending ramus of the lower jaw, and joins at an acute angle the lingual nerve. In its passage across the cavity of the tympanum, the chorda tympani anastomoses by one or several filaments with the nerve which the fifth pair sends to the membrana tympani.

Fig. 259.

The membrana tympani from within, and the course of the chorda tympani across the tympanum, together with the connexions of the malleus and incus (magnified). (From Soemmerring).

a. Membrana tympani; *b.* handle of the malleus and tendon of the internus mallei cut near its insertion; *c, c.* the chorda tympani.

To return to the facial nerve. It gives off, a little below the pyramid, a branch to the stapedius muscle.

The *pneumogastric nerve*, in its passage through the base of the skull, forms a small ganglion, from which springs a nerve which goes to the ear, *ramus auricularis nervi vagi*. This nerve is joined by a filament from the petrous ganglion of the glosso-pharyngeal; it then runs, according to Arnold, in a groove in the jugular fossa, and at last arrives at the aqueduct of Fallopius. Here it divides into three branches, the smallest of which runs upwards in the aqueduct of Fallopius towards the origin of the facial nerve, and unites with it; the second branch, which is somewhat larger, runs downwards, and also anastomoses with the facial. The third and most considerable branch will be noticed along with the nerves of the auricle and auditory passage.

The nervous anastomosis in the tympanum.—The principal nerve of this anastomosis is the nerve of Jacobson, or tympanic nerve of Arnold.

The tympanic nerve, *nervus tympanicus*, extends between the petrous ganglion of the glosso-pharyngeal nerve and the otic ganglion or ganglion of Arnold. To follow it from the glosso-pharyngeal, we find it arises from the upper part of the petrous ganglion, along with another filament, which goes to communicate with the *ganglion cervicale supremum*, and also with the pneumogastric. The tympanic nerve enters, by the tympanic canal already described, the cavity of the tympanum. Here the nerve appears near the anterior margin of the fenestra rotunda, traverses the groove on the promontory, arrives in front of the vestibular fenestra, then enters the proper osseous canal, into which the groove on the promontory is continued superiorly, and which opens on the surface of the petrous bone outside, and in front of the hiatus of Fallopius. From this the nerve advances between the anterior margin of the petrous bone and the posterior angle of the great wing of the sphenoid, between the internal muscle of the malleus and the superficial petrosal nerve. There it approaches the nerve of the internus mallei, and proceeds parallel with it, and under the name of *nervus petrosus superficialis minor Arnoldi*,* goes to join the otic ganglion.

Fig. 260.

Nervous plexus of the tympanum (from Breschet.)

a. Internal carotid artery; *b.* glosso-pharyngeal nerve; *c.* petrous ganglion of the same nerve; *d.* the principal trunk of the nervous plexus of the tympanum which extends to join, *e.* the otic ganglion or ganglion of Arnold; *f.* lower maxillary nerve to which the ganglion adheres; *g.* filaments of communication between the nerve of Jacobson and the carotid plexus; *h.* carotid plexus; *i.* filament to the fenestra rotunda, or cochlear fenestra; *k.* filament to the vestibular fenestra; *l.* filament going to anastomose with the facial nerve; *m.* filament running alongside the Eustachian tube; *n.* portio dura of the seventh pair; *o.* chorda tympani cut; *p.* nervous filament from the otic ganglion to the muscle of the malleus.

The branches given off and the communications formed by the tympanic nerve in the course described, are the following. On entering the tympanum, the tympanic nerve divides into two branches, a lower and an upper. The lower branch first gives twigs to the Eustachian tube, and then passes out of the cavity of the tympanum into the carotid canal, through a passage in the bone, where it anastomoses with the sympathetic nerve. The upper branch, the continuation of the nerve, gives a twig to the secondary membrana tympani. According to Varrentrapp, there arises from it, by two roots, a twig which runs on the inner wall of the cavity of the tympanum, then into the Eustachian tube, the cartilage of which it penetrates anteriorly, and at last loses itself in the mucous glands around its guttural orifice. A little higher up a third branch goes to the vestibular fenestra, and, according to Lauth, the tympanic nerve receives, immediately on its entrance into the canal in the upper part of the petrous bone, a filament from the facial nerve. Moreover, the tympanic nerve receives a filament of communication from the external branch of the *nervus caroticus*, the anterior and stronger branch of the first cervical ganglion of the sympathetic.

From the otic ganglion a nerve goes to the internal muscle of the malleus, *ramus ad tensorem tympani*. It arises from the upper and posterior part of the ganglion, and runs backwards on the inner side of the middle meningeal artery to the muscle.

2. *Nerves of the auricle and auditory passage.*—The auricle and auditory passage derive their nerves from the cervical plexus, from the facial, from the third branch of the fifth pair, and also from the pneumogastric.

The nerve from the cervical plexus is the great auricular nerve, *nervus auricularis magnus*. It comes off from the anterior branch of the third cervical nerve, and is distributed principally to the skin on the back of the auricle and to the posterior muscles. One branch passes between the antitragus and the tail-like process of the helix to the other surface of the ear and ramifies there.

The *facial nerve* on its exit from the stylomastoid hole gives off the posterior, inferior or deep auricular nerve, *nervus auricularis posterior, profundus inferior*, which receives a twig from the pneumogastric and another from the great auricular branch of the third cervical and then divides into two branches, a posterior larger, and an anterior smaller. The former gives twigs to the skin of the mastoid process and the retrahentes auriculam muscles, the latter spreads on the lower and posterior part of the cartilaginous auditory passage and the concha, giving twigs to the skin of these parts and the retrahentes auriculam. It sometimes sends a branch through the cartilage into the auditory passage to ramify in the integument lining that part.

The temporal branches of the facial nerve send filaments to the skin of the anterior part of the auricle, and to its anterior and superior muscles.

The superficial temporal nerve, a branch of the posterior and inferior fasciculus of the third division of the fifth pair, gives off two branches, *nervi meatus auditorii externi, inferior et superior*, the ramifications of which are distributed to the integument of the auditory passage and concha. There is one branch, *nervus tympani*, which runs under the upper wall of the osseous

* Bidder (Neurologische Beobachtungen. Dorpat, 1836,) has recently discovered a new nervus petrosus superficialis, which, for the sake of distinction, he calls *tertius*. It proceeds from the plexus accompanying the middle meningeal artery into the cavity of the cranium, passes through a proper fissure in the anterior surface of the petrous bone and under the entrance of the canal of Fallopius into the petrous bone to join the facial. It is not always present.

auditory passage to the membrana tympani, between the layers of which it glides and separates into very delicate filaments, by one or two of which it anastomoses with the chorda tympani. The last branch of the superficial temporal nerve sends filaments to the auricle and its anterior and superior muscles.

The third and most considerable branch of the auricular nerve of the pneumogastric, *ramus auricularis nervi vagi*, gets into the *canaliculus mastoideus* of Arnold, through an opening near the lower aperture of the *canalis chordæ tympani*. It here divides into two branches, one of which joins, as has been said, the posterior auricular branch of the facial nerve; the other, which is stronger, arrives at the posterior wall of the external auditory passage, gives filaments to the ceruminous glands, and in company with a branch of the posterior auricular artery penetrates the cartilage of the ear to ramify on the skin covering its convex surface.

Arteries of the external ear and tympanum. The *posterior auricular artery.* This supplies branches which ramify on the convex surface of the auricle, and also turn over the helix to spread out on the other surface. Twigs are also given off to the auditory passage.

A remarkable branch of the posterior auricular is the *stylo-mastoid artery.* This enters the stylo-mastoid hole and runs along the aqueduct of Fallopius, and ends by anastomosing with a branch of the middle meningeal, called the Vidian artery, which enters by the hiatus of Fallopius. In its course the stylo-mastoid artery transmits twigs to the mastoid cells, the external auditory passage, the membrana tympani, the stapedius muscle, and the external semicircular canal.

The twig to the membrana tympani is called *arteria tympanica superior.* This artery, together with the *arteria tympanica inferior* from the internal maxillary, supplies the membrana tympani. The arteries run round the circumference of the membrane and down along the handle of the malleus, and branching out form by their inosculations a fine net-work.

The *temporal artery* sends branches to the anterior part of the auricle, the external auditory passage, and to the ceruminous glands. It also gives off a branch which enters the tympanum by the fissure of Glasser, and ramifies in the mucous membrane of the outer wall of that cavity.

The *occipital artery* gives twigs to the auricle.

The *internal maxillary artery.*—This artery gives off a branch to the joint of the lower jaw, a twig of which, the *arteria tympanica inferior,* just mentioned, passes through the fissure of Glasser into the tympanum and inosculates on the membrana tympani with the twigs of the superior tympanic artery of the stylo-mastoid. The internal maxillary also sends a branch, the deep auricular artery, *arteria auricularis profunda,* to the cartilaginous portion of the auditory passage, where it supplies the lining integument and glands. It moreover sometimes gives small branches to the Eustachian tube.

The *middle meningeal artery* in the first part of its course gives branches to the Eustachian tube. In the cranium it sends a branch, *arteria Vidiana,* into the Fallopian canal, which has been already described as anastomosing with the stylo-mastoid. It also sends branches to the tympanum, which ramify in the mucous membrane of that cavity and in the muscles of the small bones.

The *accessory middle meningeal artery,* when present, gives branches to the Eustachian tube. The *inferior pharyngeal artery* also gives branches to the Eustachian tube, to the pyramid and cavity of the tympanum. The Eustachian tube also receives twigs from the *inferior palatine branch of the facial artery.*

The internal carotid, before entering the cranium, sometimes gives a small twig to the Eustachian tube and sends another, through a small passage leading from the carotid canal into the tympanum, to the promontory.

In some animals, such as the mole, the squirrel, the guinea-pig, the marmot, &c. there is an osseous canal like a bar of bone extending over the vestibular fenestra and running through between the crura of the stapes. This was first observed by Sir Anthony Carlisle in the marmot and guinea-pig, who describes it as "an osseous bolt to rivet it (the stapes) to its situation."* The canal is for the passage of an artery and nerve which in some other animals are unprovided with an osseous canal in their course through the stapes. The artery running through the stapes was observed about ten years ago by Professor Otto† in hybernating animals; but Professor Hyrtl of Prague‡ has shewn that the artery is by no means peculiar to those animals, as it does not occur in all, and as it occurs in animals which do not hybernate.

Mr. Shrapnell § describes in the human ear an artery accompanied by a nerve, passing through the membrane which fills up the space between the arms of the stapes. Mr. Shrapnell was led to this observation from what he had seen in the rat, viz. a nerve and artery passing through the stapes and supported by a minute channel of bone. Professor Hyrtl || has more recently described three modes of distribution of the arteries in man, which he has met with, analogous to the artery running through the stapes in the animals above mentioned.

The arteries of the external and middle ear are accompanied by corresponding veins. As to lymphatics, there are some small glands behind the auricle and in front of the mastoid process. The lymphatic vessels of the external ear accompany the arteries and veins, but principally the latter. Little or nothing is known of the lymphatics of the tympanum.

* On the Physiology of the Stapes in Philosoph. Trans. 1805, p. 204.

† Nova Acta Acad. Cæs. Leop., tom. xiii. p. 662.

‡ Ueber die Analogien der durch den Steigbügel verlaufenden Arterie, &c. in Medicinische Jahrbücher des oesterreichischen Staates, Bd. xix. p. 457, Wien 1836.

§ On the Nerves of the Ear, in London Medical Gazette, vol. x. p. 507, 1832.

|| Loc. cit.

III.

1. *Development and irregular conditions of the organ of hearing.*

A. Development and irregular conditions of the ear-bulb.—Our knowledge of the early formation of the ear-bulb is not very precise. This much we know, that it has quite a separate origin from the rest of the apparatus of hearing. Hence, in the irregular conditions of the organ depending on defective development, there is no constant and necessary relation betwixt the labyrinth and the accessory parts of the ear; for the latter may be imperfect while the former is in its natural state, and *vice versâ*. In many cases, however, it has been found that imperfect development of the one attended an irregular condition of the other. The earlier a part is formed the fewer deviations it is subject to, so a greater number of malformations affect the accessory parts than the ear-bulb, as the former are developed subsequent to the latter.

The development of the ear-bulb commences very early, soon after the appearance of the eye. It takes place by the springing forth of the auditory nerve in the form of a tubular prolongation of the brain. At its central extremity the cavity of the cerebral prolongation is continuous with that of the fourth ventricle. Its peripheral extremity, which extends into the muscular layer of the embryo, and particularly into the osseous part of it, forms a vesicular dilatation which is gradually separated from the brain. To this vesicle of nervous substance, which is the labyrinth, there grows inwards a reflection of the tegumentary layer to form the accessory parts of the organ of hearing.

Such is Baer's account of the development of the ear in the chick. Huschke, on the contrary, says that the membraneous labyrinth does not arise from the brain, but is originally a blind sac of the skin with an excretory duct, which gradually contracts, until the blind sac of skin is completely cut off from the rest of the tegumentary system.

However this may be, the labyrinth, according to the observations of Valentin* made on the embryo of the sheep, exists at a very early period, under the form of a simple elongated tube with an oblong cavity, which is the vestibule. This cavity becomes broader, assumes a rounder form, and presents in the interior a somewhat uneven surface. Soon after this, its inner end is elongated and begins to make a circular turn, which is the first rudiment of the cochlea. The turns of this cochlear vesicle become gradually more developed. A short time after the commencement of the development of the cochlea, the semicircular canals begin to show themselves as processes or diverticula of the vestibule. There first appears the posterior over and behind the vestibular fenestra; it becomes elongated from within and below outwards and upwards, then bending in the form of an arch returns to the vestibule. In a similar manner the superior and inferior semicircular canals are formed. The semicircular canals are at first proportionally very wide, but gradually contract, till at last the ampullæ present the only trace of their former width. The vestibule itself has diminished in breadth and length, and acquired a more trapezoidal form. The vestibular fenestra, which was before not very distinct and still round, has become more evident and exhibits an oval shape.

What Valentin here describes is only the basis of the future osseous labyrinth. There exist as yet no observations bearing on the mode of development of the membraneous labyrinth.

The irregular conditions which the labyrinth has been found to present, as well as the structure permanent in the lower animals, correspond in a remarkable manner with the above-described stages of development. Thus in a monstrous fœtus, Hyrtl* found, instead of a vestibule, cochlea, semicircular canals, and internal meatus, a single very capacious cavity, containing a membraneous sac, in which the auditory nerve, sufficiently well developed, terminated. There was no trace of vestibular or cochlear fenestra, and the accessory parts of the organ were entirely wanting. Röderer† describes a somewhat similar case, in which, however, some of the accessory parts presented themselves, though in a very rudimentary and imperfect form.

The cochlea has presented itself as a mere subdivision of the vestibule without any windings, a state of parts which is permanent in birds. In other cases, though presenting windings, these have been found fewer than natural, and sometimes the spiral lamina has been wanting or not extending throughout all the turns of the cochlea, so that no subdivision into scalæ or but a very imperfect one presented itself. The semicircular canals are sometimes smaller and narrower than usual; one or all of them have been found wanting or but partially present. In the latter case, after running a short way, they have been observed stopping short and terminating in a cul-de-sac. The semicircular canals, as they are formed later, more frequently present deviations from the regular structure than the vestibule and cochlea.

Our knowledge of the ear-bulb in the human embryo commences at about the third month, when the membraneous labyrinth is already very perfectly developed and surrounded by a cartilaginous shell, having a structure as complicated as at a more advanced period the bony shell presents. The membraneous labyrinth is at this early period so firm that it is not very difficult, by means of careful dissection and manipulation, to extract the whole from its cartilaginous case.

According to Meckel,‡ the membraneous labyrinth is composed at first of two perfectly

* Handbuch der Entwickelungsgeschichte des Menschen, p. 206.

* Beiträge zur pathologischen Anatomie des Gehörorgans. In the Medicinische Jahrbücher, des k. k. oestr. Staates. Wien, 1836. Bd. xx. p. 446.

† Descriptio fœtus parasitici. In Commentariis Soc. reg. Gœttiogensis. tom. iv. 1754, pp. 136—148.

‡ Manuel d'Anatomie, etc. traduit par Jourdan et Breschet, tome iii. s. 1948—30 Paris, 1825.

distinct membranes, the one simply inclosed within the other, but not connected farther. The inner membrane is thinner but firmer and more elastic than the outer. The latter, which does not adhere to the cartilaginous case any more than it does to the osseous labyrinth which succeeds it, gradually becomes thin, until at the seventh month there is no longer any trace of it. The inner membrane, on the contrary, becomes proportionally thicker and firmer.

Meckel has never found the membraneous labyrinth in a more simple form, nor has he been able to determine whether it ever exists naked in the cranium.

At a very early period the pulpy mass of the auditory nerve becomes converted into nervous bundles, and grows either by lateral additions or by an increase of its filaments. The cochlear part of it, according to Valentin,* lies free in the tube of the cochlea under the form of a thick white cord; it follows the turns of the cochlea, but gives no considerable lateral fibrils to the walls of it. As to how the auditory nerve ends in the membraneous labyrinth at this period nothing is known.

In an anencephalous fœtus described by Hyrtl,† the cochlea was represented by a cavity, from the base of which, corresponding to the internal meatus, there rose a pyramid composed of canals and extended to the roof of it. This pyramid and the canals composing it were the representative of the axis and its canals for the transmission of the fibrils of the cochlear nerve. There was no trace of a turn of the cochlea nor of a lamina spiralis.

We now enter into a more explored region, viz. the progress of ossification in the labyrinthic shell, and for the knowledge we possess on the subject we are chiefly indebted to the late J. F. Meckel.‡

The osseous labyrinth is at first merely membraneous; by-and-bye it becomes cartilaginous, and lastly ossifies. The membraneous labyrinth has not been properly distinguished from it. The former at first lies free in the cavity of the cranium; the latter has never been observed in an uncovered state.

The development of the osseous labyrinth is quite distinct from the formation of the bony substance of the petrous bone. The latter commences before the former.

Ossification commences in the labyrinth towards the end of the third month round the fenestra rotunda, first at the upper part, then at the lower part; and when a ring of bone has thus been produced, ossification extends forwards. At the same time that the process just described takes place, another osseous nucleus, quite distinct from the preceding, is developed at the outer extremity of the superior vertical semicircular canal; there then appears a third small scale nearly in the middle of the posterior vertical semicircular canal. Proceeding from the first nucleus of bone, ossification makes rapid progress backwards and downwards; whence the floor of the labyrinth is formed. The second nucleus enlarges perhaps even more quickly than the first, so that the whole superior vertical semicircular canal is soon ossified, with the exception of its lower concave surface. From the inner extremity of this semicircular canal ossification extends on the inner surface of the petrous bone, circumscribes the internal auditory meatus, penetrates into its interior, and forms the base of the cochlea. In the fifth month ossification extends from the two first nuclei to the horizontal semicircular canal.

In the ossification of the cochlea, that of the petrous bone has but a very small share. All that the petrous bone contributes is merely a thin prolongation which it sends between the turns of the cochlea. This process is at first broader than at a subsequent period. From the third month, as the cochlea widens from without inwards, the process in question becomes thinner, and, at the same time, are developed the less considerable projections which separate externally the first external turn and a half of the cochlea from each other.

The ossification of the labyrinth has been found imperfect; thus Krombholz* relates a case in which he found the semicircular canals, as well as both scalæ of the cochlea, presenting the same thinness of walls as is remarked in the fœtus. Some places were merely membraneous. I have already mentioned that the aqueducts are sometimes unusually wide, a circumstance conceivable when we consider the mode in which most likely they are developed, and which was spoken of when considering them. In certain of the lower animals, such as the pig, they are naturally wide.

At first the osseous labyrinth is quite distinct from the mass of the petrous bone, in which it is, as it were, embedded. Its outer surface is, up to the fifth month, quite smooth; the corresponding inner surface of the osseous mass of the petrous bone is smooth also, but not so much so. The two surfaces are soon confounded together, although the spongy cellular structure of the petrous bone can still, even for some time after birth, be easily enough removed from around the hard bony substance of the labyrinth. Afterwards they become inseparable, though it is still possible to perceive a trace of the line of demarcation between them, especially in the cochlea.

All the above circumstances show that the osseous labyrinth, though in the petrous bone, is not of it; and that, as has been already said, it cannot be affirmed to belong to the skeleton, but to be merely embedded in a bone which does. Moreover as Weber† remarks, the osseous labyrinth is not in all animals enclosed in the same bone of the skull; for in fishes, when a trace of the osseous labyrinth is yet to be found, the semicircular canals, or the rudimentary representative of them, are situated in the occipital bone.

* Op. cit. p. 208.
† Op. et loc. cit.
‡ Op. et loc. cit.

* Mücke, kurze Uebersicht der gegenwärtig bestehenden Lehr-und-Erziehungsanstalten für Taubstumme u. s. w. Prag. 1827, p. 19.
† Hildebrandt's Anatomie. Bd. iv. p. 40.

B. Development and irregular conditions of the tympanum and external ear.

1. *Of the tympanum and its contents.*

1. *The cavity of the tympanum.*—A prolongation or diverticulum of the mucous membrane of the throat, extending to the peripheral surface of the labyrinth, and forming, with its blind end, a dilatation there, gives us the simplest idea of a tympanum and Eustachian tube. According to Huschke*—and his views are more or less supported by Burdach,† Rathke,‡ and Valentin,§—the cavity of the tympanum with the Eustachian tube is a metamorphosis or remains of the first branchial fissure. Hence, in its origin, the tympanum has nothing in common with the labyrinth.

Valentin|| found the Eustachian tube and cavity of the tympanum, in an embryo at the seventh week, under the form of a conical or pyramidal fossa. This fossa gradually extends into a tube, at first short and wide, but afterwards longer and narrower in proportion as the cavity of the tympanum becomes developed, and recedes from the cavity of the mouth. The Eustachian tube is at first simply membraneous. About the middle of pregnancy, according to Meckel¶ and Burdach,** the third month according to Valentin, it acquires a cartilaginous investment.

The blind membraneous pouch which represents the cavity of the tympanum is at first very small and contracted, and is to be distinguished from the walls of the tympanum, which it invests. The peripheral surface of the labyrinth forms, as is known, the inner solid wall of the tympanum, and the tympanic ring and membrana tympani the outer wall. In proportion, therefore, as these parts, and also the mastoid process are developed, so does the tympanic cavity acquire its proper form, and is more and more withdrawn, both from the cavity of the mouth and the lateral surface of the head, with the integument of which it is, at an early period, in contact.

The prolongation of the mucous membrane of the pharynx forming the Eustachian tube and cavity of the tympanum, is at first very vascular, soft, and loose, like the mucous membrane of the nasal and guttural cavities; but after birth it loses its vascularity, and assumes a more simple character. United by loose cellular tissue to the subjacent osseous wall, it applies itself over all the elevations, and dips into the depressions of it, and moreover forms folds in which the ossicles are enveloped. The cavity of the tympanum is in the fœtus filled with a mucus, sometimes transparent, sometimes bloody, and varying from the consistence of water to that of a thick jelly.

The cavity of the tympanum has been found sometimes unusually contracted; sometimes, on the contrary, very much dilated. Non-development of the Eustachian tube would be necessarily attended by non-development of the tympanum, but not contrariwise. Absence of the Eustachian tube and cavity of the tympanum has only been found in fœtuses, in other respects monstrous.

In describing the development of the osseous labyrinth, it has been already mentioned that its peripheral surface, which forms the inner solid wall of the tympanum, begins to be ossified towards the end of the third month. An ossific point first appears on the promontory at the circumference of the cochlear fenestra, and gradually extends upwards, downwards, forwards and backwards. At this time there is no trace of mastoid process: In the fourth month the *sinuositas mastoidea* begins to appear, and the cavity of the tympanum becomes somewhat wider. The aqueduct of Fallopius is not yet ossified, nor the canals for the muscles of the stapes and malleus, a state of parts found permanent in most of the lower mammifera, and also frequently met with in the irregular conditions of the ear in man. When the cochlea is arrested in its developement, the promontory is small in proportion or entirely wanting.

In the fifth month the aqueduct of Fallopius and the canals for the muscles of the stapes and malleus are ossified. In this month, also, the vestibular fenestra is found completely formed, and appears proportionally larger than in the adult. In the sixth month, the temporal bone being altogether more developed, and the mastoid process having begun to appear, the cavity of the tympanum increases in capacity, especially its upper part, and the *sinuositas mastoidea.* The direction and situation of the cochlear fenestra vary much at the different periods of formation, which is owing chiefly to the degree of development of the promontory.

The vestibular and cochlear fenestræ are sometimes found unusually small, or even entirely wanting, the latter being obliterated by an extension of osseous substance, the former by the same cause, or by anchylosis of the base of the stapes. The cochlear fenestra sometimes appears to open into the vestibule, but this is when the cochlea is in a very rudimentary state. Such a condition may be compared with the state of parts found in the bird's ear.

Little or nothing is known of the origin and development of the membrana tympani. It may be looked upon as the persistence of that septum which exists at an early period at the opening of all mucous canals, and which is produced by the meeting of the indentation inwards of the skin with the diverticulum of the mucous cavity of the blastoderma. The membrana tympani is larger in proportion, and more vascular the younger the fœtus is. The form, situation, and direction of it in the fœtus is dependent on the tympanic ring, and is quite different from what is found in the adult. In regard to form, it is rounder. As to situation

* Isis von Oken, Jahrg. 1827, p. 401; Jahrg. 1828 p. 161; Jahrg. 1831, p. 951; and Meckel's Archiv für Anatomie und Physiologie, 1832, p. 40.

† Die Physiologie als Erfahrungswissenschaft. Bd. ii. p. 465.

‡ Anat. physiol. Untersuchungen über den Kiemenapparat und das Zungenbein, 1832, p. 120.

§ Handbuch der Entwickelungsgeschichte des Menschen, p. 211.

|| L. c. p. 211 and 212.

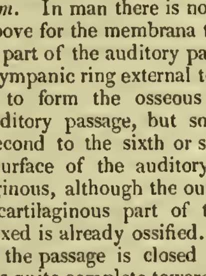
¶ Manuel d'Anatomie, &c. tom. iii. s. 1948, p. 197.

** Op. cit. Bd. ii. p. 465.

the osseous portion of the auditory passage not being yet developed, the membrana tympani is found at first closer to the surface than afterwards; and its direction is oblique from above downwards, and from without inwards, so that it has a more or less horizontal position, corresponding to the base of the cranium.

More is known of the origin and development of the tympanic ring in which the membrana tympani is framed. It appears later than the membrana tympani and the ossicles. A specimen of the tympanic ring before me, which was removed from an embryo at about the third month, is an incomplete ring of bone about one-tenth of an inch in diameter. It is about the thickness of a hair, except at its anterior extremity, which is broad and flat like a spatula, for the extent of about one-twelfth of an inch. The groove for the membrana tympani can be perceived with a magnifying glass. From the fifth month the tympanic ring is found more or less adherent to the rest of the temporal bone. In the lower Mammifera there are three parts developed from the tympanic ring, viz. 1, the groove for the membrana tympani, 2, the *bulla ossea*, and 3, the osseous part of the auditory passage. In birds the tympanic ring is represented by the *os quadratum*. In man there is no bulla ossea, only the groove for the membrana tympani and the osseous part of the auditory passage. The side of the tympanic ring external to the groove shoots out to form the osseous part of the external auditory passage, but so slowly that from the second to the sixth or seventh year, the lower surface of the auditory passage is still cartilaginous, although the outer orifice to which the cartilaginous part of the auditory passage is fixed is already ossified. About the twelfth year the passage is closed in by bone, and becomes quite complete towards manhood. The inner surface of the ring grows a little at the lower part, and helps, together with a process which extends from the petrous bone, to form the lower wall of the tympanic cavity. It is to be remarked that this inner part of the tympanic ring always remains distinct and is never changed so much as the external.

Fig. 261.



The tympanic ring, and the membrana tympani framed into it. The handle of the malleus is seen shining through the membrane.

The whole outer wall of the cavity of the tympanum has been found wanting in a monstrous fœtus. Hyrtl, who mentions the case, says that the cavity of the tympanum itself was represented only by a very shallow depression in the petrous bone, in which the skin of the auditory passage formed a cul-de-sac. The Eustachian tube was present. Hyrtl mentions another case in which the tympanic ring was much smaller than usual, and in which the membrana tympani presented in the direction of one of its radii, a large opening as if a piece had been cut out. The so-called *hiatus Rivinianus* ought, perhaps, to be looked upon, as Huschke observes, as a defect in original formation. The membrana tympani has been sometimes found congenitally too large, sometimes too small, sometimes of an elongated form, sometimes of a triangular form. A thickening and parchment appearance of the membrane, or ossification of it to a greater or less extent, if not always, appears to be more usually an acquired malformation.

2. *The small bones of the tympanum.*—The small bones are formed at a very early period. The malleus and incus appear before the stapes. The two former, according to Rathke and Valentin, appear like a small wart growing out from the posterior wall of the tympanum. The stapes is like a growth from the outer surface of the labyrinth; it appears as a small pyramidal wart flattened on the sides and thin in the middle, lying, according to Rathke, in a small funnel-like depression, the bottom of which is the future vestibular fenestra.

According to Weber* the ossicles are not developed in the cavity of the mucous membrane of the tympanic cavity, but in a sac which is a continuation of the dura mater, and comes through a fissure between the petrous bone and the squamous portion of the temporal into the tympanic cavity. This situation of the ossicles at an early period corresponds with that of those discovered by Weber in the fishes already mentioned. By this mode of development, as far as regards situation, may be explained the dislocated state of the ossicles so frequently found in the irregular conditions of the ear.

According to Meckel,† the ossicles are at the commencement of the third month proportionally very large, though still cartilaginous, and the stapes not to be distinguished from the incus. Thus, for example, the length of the malleus in a fœtus of the fourth month amounts to three lines, whilst the length of the body from the vertex to the coccyx measures four inches, hence the lenght of the malleus is to that of the trunk as one to sixteen; whereas in the adult the proportion is only as one to ninety, the malleus being four lines long, and the distance between the vertex and the coccyx amounting to two-and-a-half feet. At birth the ossicles are as large as in the adult.

Ossification of the small bones commences, according to Burdach,‡ about the twelfth week. Rathke and Valentin agree with Meckel; that ossification begins first and at the same time in the malleus and incus, and only afterwards in the stapes. In the malleus the first point of bone appears on the head, a second at the root

* Hildebrandt's Anatomie, Band. iv. p. 39.
† Op. cit. tom. iii. p. 197. s. 1948.
‡ Op. cit. Band. ii. p. 384.

of the long process. In the incus the first point of ossification occurs in the longer crus near the body, and from this point it extends during the fourth and fifth months, so far that the whole is ossified with the exception of the point of the short process. The long crus Meckel always found completely ossified, whilst the short crus was still cartilaginous.

The stapes is still cartilaginous when ossification has made considerable progress in the other two bones. According to Meckel ossification does not commence at any determinate point of the stapes; only he never observed it first on the head. According to Rathke there are three particular nuclei, one for each of the sides of the triangle which the stapes represents.

The opening between the crura of the stapes is at first very inconsiderable,—a condition analogous to what is found permanent in the Cetacea, &c.

The ossicles are not unfrequently irregular in their form, size, and situation. They may even be wanting. The stapes, as it is the last formed, presents the most numerous and most varied malformations; the malleus the fewest. The stapes has been found, by Tiedemann, as it is at first, like a pyramid without any opening; again, it has been found with but a very small opening, or presenting indeed the crura, but the space between them filled up by a thin plate of bone. Only one crus has been found rising from the middle of the base in the form of a slender pedicle of bone as in the bird, and presenting no trace of an articular cavity for the reception of the lenticular process of the incus, &c.

A remarkable circumstance connected with the early formation of the malleus is the existence, as Meckel* first observed, of a straight cartilaginous process, having the shape of a very elongated cone, which extends from the anterior part of the head of the malleus to the place where the two halves of the lower jaw unite in front. The cartilaginous process passes out of the cavity of the tympanum between the petrous bone and tympanic ring. This process, though having much the same situation, must not be confounded with the *processus gracilis*. The former lies above the latter, and both parts are quite distinct from each other. Moreover the cartilaginous process never ossifies, but disappears in the eighth month. Huschke† has discovered a similar process extending between the short crus of the incus and the superior horn of the hyoid bone through the medium of the styloid process.

The most interesting irregular formation of the malleus is what appears to be connected in some manner with the above described early condition of the malleus and incus. Such cases are related by Hyrtl,* Heusinger,† and Hesselbach.‡

2. *Of the external ear.*—The external ear soon disappears in the animal series. It is the last part of the apparatus of hearing which makes its appearance in the human embryo. It is very subject to irregular development. It is only about the middle of the second month that a trace of it can be observed. It is at first merely a slight elevation of the skin, broad above, narrow below. In the middle of this elevation is a longitudinal fissure of the same form, which is narrower and at the same time deeper from above downwards. The prominence soon becomes more elevated and thinner at its posterior part, and projects above the surface of the side of the head, from which circumstance the middle depression is a little exposed. At the same time or soon after, the anterior part of the prominence is found divided into two halves by a transverse fissure running forwards; the inferior half is the antitragus, and the superior the commencement of the helix. At the same time this anterior part of the external ear rises also, and the posterior spreads more out. In the third month the anthelix and tragus are developed; the concha is not yet perfectly distinct; it is only indicated by the middle depression. In the fourth and fifth month the hollow of the concha appears, and is completely formed in the sixth. The lobule is the last part which presents itself.

The cartilage begins to be formed in the third month, but is developed slowly. Towards the end of pregnancy, though thicker, harder, and firmer, it is still incomplete.

The cartilaginous portion of the auditory passage as well as the auricle is at first proportionally much smaller than afterwards. The skin lining the auditory passage is softer and thicker than in the adult, and is covered with a thickly set down. In the fœtus the auditory passage is rounder, straighter, and shorter than in the adult.

The auricles may not be formed at all, or their development may be so arrested that they shall be represented merely by unshapely folds of skin with or without cartilage, or they may deviate more or less from their usual form, size, and situation. Imperfect formation of the auricle is frequently accompanied by absence or closure of the auditory passage. Professor Samuel Cooper mentions the case of a child in which there was not the slightest trace either of external ear or auditory passage.

* Op. cit. tom. iii. p. 199. s. 1948. See also Huschke Beiträge zur Physiologie und Naturgeschichte, p. 48. Taf. ii. Fig. 1. Isis von Oken, 1833. Heft. vii. p. 678. Serres, Annales des Sciences Naturelles, 1827, p. 112. Weber, Hildebrandt's Anatomie, 4te. Ausgabe. Band. iv. p. 47. Rathke, op. cit. p. 122, and Valentin, op. cit. p. 214.

† Isis von Oken, loc. cit. and Valentin, op. et loc. cit.

* Op. et loc. cit.

† Specimen malæ conformationis organorum auditus humani rarissimum et memoratu dignissimum, cum tribus tabulis æri incisis. Jenæ, 1824.

‡ Beschreibung der pathologischen Präparate, welche in der königlichen anatomischen Anstalt zu Würzburg aufbewahrt werden. Giessen, 1824.

Sometimes, however, the auditory passage has been found regular though the auricles were wanting.

The auditory passage is sometimes found too wide, sometimes too narrow, sometimes too short. Closure of the auditory passage may be either partial or through its whole extent. It is more rarely the effect of disease than of irregular primitive formation. Partial closure may be by an extension of the skin over the mouth of the passage. Authors mention cases of a membraneous septum sometimes deep in the auditory passage and before the membrana tympani, sometimes nearer the entrance of the passage.

In monstrous fœtuses all the accessory parts of the apparatus of hearing together have been found wanting.

II. PARALLEL BETWEEN THE EAR AND THE EYE.

A parallel has often been drawn betwixt the ear and the eye. Breschet, in his memoir, already so often cited in the course of this article, compares the perilymph to the aqueous humour, the endolymph to the vitreous humour, and the calcareous concretions to the crystalline body.

The comparison which I should institute between the component parts of the ear and the eye is the following:—

The osseous labyrinth may be compared to the sclerotica, and the fenestra rotunda, or cochlear fenestra, to the cornea.

To find a part in the eye analogous to the vestibular fenestra, we must first consider that the latter is a yielding part of the otherwise solid wall of the labyrinth; that through the medium of it, the chain of small bones and their muscles in the tympanum exercise on the soft parts contained in the labyrinthic cavity, a certain degree of tension or compression fitted probably to accommodate in some manner the ear to the perception of different degrees of sound. In the case of the eye, the sclerotica, which corresponds to the osseous labyrinth, is thinner and more yielding at the middle of its circumference, (remarkably so in the Greenland seal). From this it has been supposed that the action of the muscles of the eye-ball might by their compression produce a change of shape fitted to accommodate the eye to distances. Hence the vestibular fenestra and middle thin part of the sclerotica might be compared to each other in as far as regards the function which each performs in the economy of its own organ. However this may be, the vestibular fenestra of the ear and the thin part of the sclerotica correspond to each other as far as can be in relative position; and if we admit the action just mentioned of the muscles upon the eye-ball, we have, as I shall immediately show, their counterparts in the muscles of the small bones of the tympanum.

The tympanic scala of the cochlea may be compared to the anterior chamber of the aqueous humour, and the vestibular scala to the posterior chamber.

The spiral lamina, considering its vascularity and richness in nerves, and its forming a partition between two chambers containing an aqueous humour, may, as I have already said in a former part of this article, be considered the counterpart of the iris, and the helicotrema that of the pupil.

The membrane lining the labyrinthic cavity bears the same relation to the latter as the *arachnoidea oculi** does to the sclerotica. The space filled with perilymph, between the osseous and membraneous labyrinth, may be considered analogous to that between the sclerotica and choroid. It however communicates with the scalæ of the cochlea, the parts analogous to the chambers of the aqueous humour, because there is nothing in the ear to be compared to the ciliary ligament.

Forming the membraneous labyrinth we find, 1. a delicate cellular tissue supporting the branches of the bloodvessels, and which is sometimes found containing black pigment; 2. a firm transparent membraneous coat, within which, 3. is a nervous expansion; 4. the endolymph; 5. suspended in the latter the mass of calcareous matter. The cellulo-vascular layer containing pigment, together with the rest of the walls of the membraneous labyrinth, may be compared to the choroid coat of the eye, the nervous expansion to the retina, the endolymph to the vitreous humour, and the calcareous mass to the lens.

In the lower animals the cochlea is the first part of the ear-bulb to disappear; in regard to the eye-ball, the aqueous chambers to which I have compared the scalæ of the cochlea, are in like manner the first parts which in the depreciation of the structure of the eye, in the animal series, disappear, e. g. the eye of the Cephalopodous Mollusca.

Is the cochlear nerve the same in function with the vestibular? The vestibular nerve is the special nerve of hearing; but does not the cochlear nerve perform some function in the economy of the ear analogous to what the ciliary nerves perform in that of the eye?

If an example is required in which the optic nervous filaments enter the eye separately as do the nervous filaments of the ear-bulb, it is to be found in the Cephalopodous Mollusca.†

As in front of the eyeball there is, or rather would be, if it was not that the eyelids are constantly in contact with the eyeball, a space lined by a mucous membrane, the conjunctiva, so at the peripheral surface of the ear-bulb, there is a space, the *tympanic cavity*, lined by a mucous membrane also. Moreover, as there is a passage into the nose from the space bounded by the conjunctiva, so does the tym-

* See my figure and description of a horizontal section of the human eye, in Mackenzie's Practical Treatise on Diseases of the Eye. *Second Edition.* London, 1835.

† See a paper "On the Retina of the Cuttlefish," in the London and Edinburgh Philosophical Magazine for January, 1836.

panic cavity communicate with the throat by the Eustachian tube. In the tympanic cavity there is a chain of small bones, articulated to each other and moved by muscles, which serves to produce some change in the state of tension of the soft parts of the ear-bulb; in the conjunctival space there is nothing analogous, although, without pushing the point too far, we might compare the muscles of the eye-ball with those of the ossicles of the tympanum, both being equally, in fact, *outside* their respective mucous membranes. In regard to the ossicles I would remark that, according to the views of Weber,* they must be reckoned among those which do not belong to the skeleton, and which are of very inconstant occurrence. Such are the bone of the penis in many animals, the teeth, *the ring of bony plates round the front of the sclerotica of the bird's eye, &c.*

A part in the composition of the appendages of the eye analogous to the membrana tympani is only to be conceived by supposing the existence of a *mediate anchyloblepharon*, that is, an irregular membrane stretched between the edges of the eyelids, uniting them together and closing in the space lined by the conjunctiva, which space would now communicate with the exterior, only by the lachrymal canalicules and nasal duct, in the same way that the tympanic cavity communicates with the exterior only by the Eustachian tube. A congenital fissure or total absence of the membrana tympani is an irregularity of structure in the ear, which may be compared to what is regular in the eye. A mind accustomed to trace analogies will perceive a resemblance :— to the external auditory passage in that short space at the opening of the eyelids extending from the inner edge of the tarsal margin to the outer; to the ceruminous glands in the Meibomian follicles; and to the hairs at the entrance of the auditory passage in the eyelashes. The auricle, if it is necessary to look for a part corresponding to it, may be placed in the same category with the eyebrows.

BIBLIOGRAPHY.—General Works on the Organ of Hearing.

Gabriel Fallopius, Observationes Anatomicæ. Coloniæ, 1562, 8vo. *Bartholomeus Eustachius*, Epistola de organis auditus. In ejus Opusculis Anatomicis. Venetiis, 1563, 4to. pp. 148-164. *Volcher Koiter*, De auditus instrumento. In ejus extern. et intern. princip. c. h. partium tabulæ, &c. Noribergæ, 1573, fol. pp. 88-105. *Hieronymus Fabricius ab Aquapendente*, Libellus de visione, voce et auditu. Rec. in ejus Opp. a B. S. Albino editis. Lugd. Batav. 1737, fol. *Julius Casserius*, De vocis auditusque organis historia anatomica. Ferrariæ, 1600, fol. Et in ejus Pentaestheseion, h. e. de quinque sensibus liber. Francof. 1610, fol. lib. iv. pp. 148-255. *Cæcilius Folius*, Nova internæ auris delineatio. Venetiis, 1645. 4. Recus. in Bartholini epistolis et in Halleri collect. dissert. anat. vol. iv. p. 365. *Jean Mery*, Description exacte de l'oreille; ed. cum Lamy explic. mechan. des fonctions de l'ame. Paris, 1687, 12mo. *Guichard Joseph du Verney*, Observation sur l'organe de l'ouie, Mém. de Paris, vol. i. p. 395. *Ditto*, Traité de l'organe de l'ouie, contenant la structure, les usages et les maladies de toutes les parties de l'oreille. Paris, 1683-1718, 12mo. Leide, 1731, 8vo. Treatise on the organ of hearing. London, 1737, 8vo. *G. C. Schelhammer*, De auditu liber unus, &c. Lugd. Batav. 1684, 8vo. Rec. in Mangeti Bibl. anat. tom. ii. *A. M. Valsalva*, De aure humana tractatus, &c. Genevæ, 1716, 4to. *Ditto*, Opera, h. e. tractatus de aure humana editione hac quarta accuratissime descriptus tabulisque archetypis exornatus, &c. Omnia recensuit, &c. Joannes Baptista Morgagnus: tomi duo. Venetiis, 1740, 4to. *R. Vieussens*, Epistola ad Societatem Reg. Lond. missa de organo auditus. Philosophical Transactions, 1699, vol. xxi. p. 370. *Ditto*, Traité de la structure de l'oreille. Toulouse, 1714, 4to. *J. F. Cassebohm*, Disp. anat. inaug. de aure interna. Francof. cis Viadr. 1730, 4to. *Ditto*, Tractatus quatuor anatomici de aure humana, tribus figurarum tabulis illustrati. Halæ Magd., 1734, 4to. *Ditto*, Tractatus quintus de aure humana, cui accedit tractatus sextus anatomicus de aure monstri humani c. tribus figurarum tabulis. Halæ Magd. 1735, 4to. *B. S. Albinus*, De aure humana interiore. In ejus Academicarum annotationum, lib. iv. Leidæ, 1758, 4to. cap. ii. p. 14-15, tab. i. ii. *Geoffroy*, Dissertations sur l'organe de l'ouie; 1o. de l'homme; 2o. des reptiles; 3o. des poissons. Amsterdam, 1778, 8vo. *A. Scarpa*, Disquisitiones anatomicæ de auditu et olfactu. Ticini et Mediolani, 1789, fol. c. tab. æn. *A. Comparetti*, Observationes anatomicæ de aure interna comparata, c. tab. iii. æn. Patavii, 4to. The date, 1789, is on the title-page, but the book did not appear until 1791. *C. F. L. Wildberg*, Versuch einer anatomisch - physiologisch - pathologischen Abhandlung über die Gehörwerkzeuge des Menschen. Mit Kupfern. Jena, 1795. *S. T. Soemmerring*, Abbildungen des menschlichen Hörorgans. Frankf. a M. 1806, fol. Icones organi auditus humani. Francof. 1806, fol. *J. C. Saunders*, The anatomy of the human ear, &c. with a treatise on the diseases of that organ, &c. Lond. 1829. *C. E. Pohl*, Expositio generalis anatomica organi auditus per classes animalium. Accedunt quinque tabulæ lithographicæ. Vindobonæ, 1818, 4to. *T. H. Weber*, De aure et auditu hominis et animalium. Lipsiæ, 1820. *D. De Blainville*, Traité de l'organisation des Animaux, &c. vol. i. Aesthesciologie. Paris, 1822. *J. van der Hoeven*, Disput. anat. phys. de organo auditus in homine. Traj. ad Rhen. 1822, 8vo. Exposé sommaire des nouvelles recherches du Dr. Ribes sur quelques parties de l'oreille interne, in Magendie, Journal de Physiologie Experimentale, vol. ii. p. 237. *A. Fischer*, Tractatus anatomico-physiologicus de auditu hominis, cum tribus tabul. æri incis. Mosquæ, 1825, 8vo. *J. C. Teule*, De l'oreille, essai d'anatomie et de physiologie précédé d'un exposé des lois de l'acoustique. Paris, 1828, 8vo. *G. Breschet*, Recherches anatomiques et physiologiques sur l'organe de l'ouie et sur l'audition, dans l'homme et les animaux vertebrès, 4to. Paris, 1836. Also in Mémoires de l'Academie Royale de Médecine, tom. v. 3e fascicule. Paris, 1836. *C. G. Lincke*, Das Gehörorgan in anatomischer, physiologischer und pathologisch-anatomischer Hinsicht; also, under the title, Handbuch der theoretischen und praktischen Ohrenheilkunde. 1str. Band. Leipzig, 1837.

Works on particular parts of the organ of hearing. *On the labyrinth.*—*J. G. Brendel*, Progr. de auditu in apice conchæ. Goetting. 1747. Recus. in Halleri Collect. diss. anat. vol. iv. p. 399. Progr. quædam analecta de concha auris humanæ. Gœttingæ, 1747, 4to.; also in his Opusc. edit. Wrisberg. Goett. 1769, 4to. vol. i. *J. G. Zinn*, Observationes de vasis subtilioribus oculi et cochleæ auris internæ. Goettingæ, 1753, 4to. *D. Cotunni*, De aquæductibus auris humanæ internæ anatomica dissertatio. Neapoli, 1761, 8vo. Viennæ, 1774, 8vo. Recus. in Sandifort Thesaur. dissert. vol. i. p. 389. *P. F. Meckel*, Diss. de labyrinthi auris contentis.

* Hildebrandt's Anatomie, Band. iv. p. 39.

Argentorati, 1777, 4to. *A. Monro*, Three treatises on the brain, the eye, and the ear. Edinb. 1794, tract iii. *Brugnone*, Observations anatomico-physiologiques sur le labyrinthe de l'oreille. In Mémoires de l'Acad. Imper. des Sciences, litt. et beaux arts de Turin, pour les ann. 1805-1808. Sciences phys. et mathém. Turin, 1809, pp. 167-176. *W. Krimer*, Chemische Untersuchungen des Labyrinthwassers. In his Physiologische Abhandlungen. Leipzig, 1820, p. 256. *J. G. Ilg*, Einige anatomische Beobachtungen, enthaltend eine Berichtigung des zeitherigen Lehre vom Baue der Schnecke des menschlichen Gehörorgans, nebst einer anatomischen Beschreibung und Abbildung eines durch ausserordentliche Knochenwucherung sehr merkwürdigen Schädels. Prag. 1821, 4to. *F. Rosenthal*, Ueber den Bau der Spindel in menschlichen Ohr. In Meckel's deutschem Archiv. für die Physiologie. B. viii. p. 74-78. *Huschke*, Tausende von Krystallen im Gehörorgan der Vögel. In Froriep's Notizen. Bd. xxxiii. 1833. No. 3. 36. *Ditto*, Ueber Kalkkrystalle im Ohr und anderen Theilen des Fisches. In the Isis of Oken. 1833. Heft. vii. p. 675. *Ditto*, Berichtigung die Kalkkrystalle im Labyrinth betreffend. In the Isis, 1834. Heft. i. p. 107. *Karl Steifensand*, Untersuchungen über die Ampullen des Gehörorgans. In Müller's Archiv. f. Anatomie, physiologie und wissenschaftliche Medicin. Jahrg. 1835. Heft. ii. p. 171-189, and taf. ii.

On the cavity of the tympanum.—D. Santorini, Opp. posth. tab. v. *A. Scarpa*, De structura fenestræ rotundæ auris et de tympano secundario anatomicæ observationes. Mutinæ, 1772.

On the membrana tympani.—A. Q. Rivinus, Diss. de auditus vitiis. Lipsiæ, 1717, 4to. p. 28, et tab. adj. Recus. in Halleri collect. dissert. anat. vol. iv. p. 309. *A. F. Walther*, Resp. Casp. Bose, Diss. anat. de membrana tympani. Lipsiæ, 1725, 4to. *F. Caldani*, Osservazioni sulla membrana del timpano e nuove ricerche sulla ellettricità animale, lette nell' Academia di Scienze di Padova. Padova, 1794, 8vo. *Everard Home*, On the structure and uses of the membrana tympani of the ear. In Philosophical Transactions, vol. xc. p. i. 1800, p. 1; also, On the difference of structure and uses of the human membrana tympani and that of the elephant. In Philos. Trans. 1823, p. i. p. 23. *Brugnone*, Observations anatomiques sur l'origine de la membrane du tympan et de celle de la caisse. In Mémoires de l'Acad. des Sciences littérat. et beaux arts de Turin; pour les ann. x et xi. Scienc. Phys. et Math. 1 Part. Turin, an xii. pp. 1-10. *Vest*, Ueber die Wittmannsche Trommelfellklappe. In medic. Jahrbücher des oester. Staates. B. v. Wien, 1819, p. 123-133. *H. J. Shrapnell*, On the form and structure of the membrana tympani. In London Medical Gazette, vol. x. p. 120.

On the ossicles.—P. Manfredi, Novæ circa aurem observationes. In Mangeti Bibliothec. anatom. tom. ii. p. 454. *J. A. Schmid*, Diss. de periosteo ossiculorum auditus ejusque vasculis. Lugd. Bat. 1719, 4to. *H. F. Teichmeyer*, Diss. sist. vindicias quorundam inventorum meorum anatomicorum a nonnullis celeberrimis anatomicis in dubium vocatorum, 1o. de tribus ossiculis auditus majoribus, malleo, incude et stapede; 2o. de ossiculis auditus minoribus, ovali, semilunari, lenticulari et triangulari; 3o. de foramine tympani. Jenæ, 1727, 4to. Rec. in Halleri collect. diss. anat. vol. iv. p. 396. *A. Carlisle*, The physiology of the stapes, &c. In Philos. Trans. 1805, p. 193. *T. W. Chevalier*, On the ligaments of the human ossicula auditus. In the Medico-Chirurgical Transactions, vol. xiii. p. i. 1825, p. 61. *H. J. Shrapnell*, On the structure of the os incus, in Lond. Med. Gaz. vol. xii. p. 171.

On the muscles of the ossicles.—Magendie, Sur les organes, qui tendent ou relâchent la membrane du tympan et la chaine des osselets de l'ouie dans l'homme et les animaux mammifères, in Journ. de Physiol. exp. tom. i. p. 341. *E. Hagenbach*, Disquisitiones anatomicæ circa musculos auris internæ hominis et mammalium adjectis animadversionibus nonnullis de ganglio auriculari sive otico, cum tab. iv. æri incis. Basileæ, 1833, 4to. *Bonnafont*, Nouvelle exposition des mouvemens de la chaine des osselets de l'ouie. In Journal des Sciences Médicales de Montpellier. Prem. ann. tom. ii. livr. iii. 1834, p. 93, 97, and livr. v. p. 175-176.

On the Eustachian tube.—J. Senac, Observation sur la trompe d'Eustache. In Mém. de l'Acad. de Paris, 1724. Hist. p. 37, edit. 8. Hist. p. 52. *J. Köllner*, Ueber den Zweck der Eustachischen Trompete. In Reil's Archiv. für d. Physiologie. Bd. ii. Heft. 1. p. 18. *J. D. Herholdt*, Eine Anmerkung ueber die Physiologie des Gehörs. Ein Seitenstück zur Abhandlung des Herrn Köllner. In Reil's Archiv. f. d. Physiologie. Bd. iii. Heft. ii. p. 165. *J. Köllner*, Prüfung des Bemerkungen ueber die Physiologie des Gehörs von Joh. Dan. Herholdt, in Reil's Archiv. Bd. iv. Heft. i. p. 105. *C. Bressa*, Ueber den Hauptnutzen der Eustachischen Röhre. Pavia, 1808. Communicated by Meckel, in Reil's Archiv. Bd. viii. p. 67. *A. H. Westrumb*, Ueber die Bedeutung der Eustachischen Trompete. In Meckel's Archiv. für Anatomie und Physiologie. Jahrg. 1828, p. 126-143. *P. F. A. Lieboldt*, Commentatio de usu tubæ Eustachianæ ex anatome tam humana quam comparata et phænomenis pathologicis illustratis. Goettingæ, 1829, 4to.

On the external ear.— J. D. Santorini, De aure exteriore. In ejus Observat. anatom. Venetiis, 1724, 4to. cap. ii. p. 37. *B. S. Albinus*, De cartilagine auriculæ. V. ejus Annotat. Academ. lib. vi. Leidæ, 1764, 4to. cap. vii. p. 55, tab. iv. fig. 1, 2.

On the muscles of the external ear.—J. D. Santorini, Observ. anatom. cap. i. tab. i, ejusdem tabulæ xvii. posthom. ex edit. M. Girardi. Parm. 1775, fol. tab. i. *A. F. Walther*, Anatome musculorum teneriorum humani corporis repetita. Lipsiæ, 1731, 4to. with the table of Santorini.

On the ear-wax.— Haygarth, in Medical Observations and Inquiries, vol. iv. edit. 2, 1772, p. 198-205. *Berzelius*, Lehrbuch der Thierchemie. Dresden, 1831, 8vo. p. 440.

On the comparative anatomy of the ear.—J. Hunter, An account of the organ of hearing in fishes, in Phil. Trans. and Animal Economy. The works of Scarpa, Comparetti, Monro, Pohl, Weber, and De Blainville, already mentioned. *G. R. Treviranus*, Ueber den inneren Bau der Schnecke des Ohrs der Vögel, in Tiedemann und Treviranus Zeitschrift für Physiologie. B. i. 188-196. *C. J. H. Windischmann*, De penitiore auris in Amphibiis structura. Lipsiæ, 1831. *G. Breschet*, Recherches anatomiques et physiologiques sur l'organe de l'audition chez les oiseaux. Paris, 1836, in 8vo. and atlas in fol. *Ditto*, Sur l'organe de l'Audition chez les Poissons. Paris, 1837.

(T. Wharton Jones.)

HEARING (in Physiology,) *audition*; Lat. *auditus*; Fr. *l'audition, sens de l'ouie*; Germ. *das Gehör, Gehörsinn*.—Of all the senses, that of hearing is the most valuable to man in his social condition, for without it all interchange of ideas through the medium of a spoken language would be impossible. To it indeed, as a distinguished metaphysician has remarked, we are indirectly indebted for the use of verbal language. By the sense of hearing men and animals take cognizance of sounds and distinguish their varieties, the almost innumerable multitude of which may well excite our admiration of the sense. "Who," says the excellent Derham, "who but an intelligent Being, what less than an omnipotent and infinitely wise God, could contrive and make such a fine body, such a medium, so susceptible of every impression that the sense of hearing hath occasion for, to empower all animals to express their sense and meaning to others; to make known their fears, their wants, their pains and sorrows in melancholick tones; their joys and pleasures in more harmonious notes; to send their minds at great distances in a short time in loud boations; or to express their thoughts near at hand with a gentle voice or in secret whispers. And to say no more, who less than the same most wise and indulgent Creator could form such an œconomy as that of melody and musick is; that the medium should, as I said, so readily receive every impression of sound, and convey the melodious vibration of every musical string, the harmonious pulses of every animal voice, and of every musical pipe; and the ear be as well adapted and ready to receive all these impressions as the medium to convey them. And lastly, that by means of the curious lodgment and inosculation of the auditory nerves, the orgasms of the spirits should be allayed and perturbations of the mind in a great measure quieted and stilled; or to express it in the words of the last-cited famous author (Willis), 'that musick should not only affect the fancy with delight, but also give relief to the grief and sadness of the heart; yea, appease all those turbulent passions which are excited in the breast by an immoderate ferment and fluctuation of the blood.'"

*Preliminary observations on sound.**—Sound is the result of an impulse of any kind conveyed by the air to our ears. The analysis of what takes place on the production of various familiar sounds or noises abundantly explains this. If the ear be applied to one extremity of a long beam of timber and a person tap with his finger on the other, the impulse is distinctly perceived by the impression of sound which is conveyed. A fine probe introduced carefully through the meatus externus, and made to impinge upon the membrana tympani, however gently, will occasion the sensation of sound. To produce the sensation, then, of sound, an impulse is necessary either of some solid directly upon the membrane of the tympanum itself, or of the air which is always in contact with that membrane. The body by which the sound is produced, denominated by Professor Wheatstone† *a phonic*, occasions in the surrounding air vibrations or oscillations, corresponding in number and extent to those which exist in itself; and these vibrations or oscillations being propagated to the organ of hearing, give rise to the sensation. This agitation of the air surrounding the body from whence the sound emanates is manifest in numerous instances;—the report of a cannon, the rushing of waters, the rattling of carriages, which in the crowded thoroughfares of London communicate their vibrations to the walls and floors of the houses and even to the furniture. In the familiar instance of eliciting sound from a finger-glass partly full of water by rubbing the wetted finger round its brim, the vibrations which this friction excites in the glass are rendered evident by the crispations produced in the water immediately in contact with it. The vibration of the water, as indicated by these crispations, corresponds with that of the glass—the greater the intensity of the sound elicited, the more considerable are the vibrations in the glass, and consequently the more manifest are those of the water, and vice versâ. "In musical sounds we may also observe an agitation which is often felt communicating itself to the surrounding bodies. If, for example, we stand under or near a piano-forte when it is sounding, we feel a sensible tremor in the floor of the apartment. If we lay the finger or hand on the instrument or touch any other, such as a violin when it is sounding, or a bell, we feel the same sort of tremor in every part of them; and this is well observed in the case of any glass vessel, such as a tumbler or large cup. If we strike it so as to make it sound, and then touch the mouth of it with the finger, we feel a sensible tremor in the glass; and when this internal agitation is stopped, as it generally is by the contact with the finger, then the sound ceases along with it."*

The disturbance produced in the air by a sounding body has been from a very early period illustrated by a reference to the waves formed in still water by a stone falling into it. "Voice," says Vitruvius, "is breath flowing and made sensible to the hearing by striking the air. It moves in infinite circumferences of circles, as when, by throwing a stone into still water, you produce innumerable circles of waves, increasing from the centre and spreading outwards, till the boundary of the space or some obstacle prevents their outlines from going further. In the same manner the voice makes its motions in circles. But in water the circles move breadthways upon a level plane; the voice proceeds in breadth, and also successively ascends in height."† That the presence of air is necessary for the production of sound is proved by the experiment first tried by Hauksbee‡ and repeated by Biot. A bell was made to ring in the receiver of an air-pump, and in proportion as the air was exhausted it was found that the sound died away, and it again returned as the air was re-admitted. On the other hand, the bell sounded more strongly when the air within the receiver was condensed, and the greater the condensation of the air, the louder was the sound.

Any irregular impulse communicated to the air produces a noise, in contradistinction to a *musical sound*. This latter results from a succession of impulses, which occur at exactly equal intervals of time, and which are exactly similar in duration and intensity. When these impulses succeed each other with great rapidity, the sound appears continuous,

* It will be perceived that in the ensuing observations the writer has borrowed largely from Sir John Herschel's admirable essay on sound in the Encyclopædia Metropolitana. He has also to acknowledge his obligations to the article on Acoustics in Pouillet's Elemens de Physique.

† Annals of Philosophy, new series, vol. vi.

* Encycl. Britann. art. Acoustics.

† Vitruvius de Arch. v. 3, quoted in Whewell's History of the Inductive Sciences.

‡ Phil. Trans. 1705.

in consequence of the duration of the impression upon the auditory nerve. The frequency of repetition necessary for the production of a continued sound from single impulses is, according to Sir J. Herschel, probably not less than sixteen times in a second, though the limit would appear to differ in different ears.

We distinguish in musical sounds, 1, the *pitch;* 2, the *intensity* or *loudness;* 3, the *quality.* The pitch of the sound depends on the rapidity with which the vibrations succeed each other, and any two sounds produced by the same number of vibrations or impulses in the same time are said to be *in unison.* The loudness or intensity depends upon the violence and extent of the primitive impulse. The quality is supposed by Sir J. Herschel to depend on the greater or less abruptness of the impulses, or generally, on the law which regulates the excursions of the molecules of air originally set in motion.

Sound may be communicated by air, aeriform fluids, liquids or solids, with variable degrees of velocity. In air at the temperature of 62° Fahr. sound travels at the rate of 1125 feet in a second, or 1090 feet in a second in dry air at the freezing temperature.

The velocity with which sound travels is, however, quite independent of its intensity or its tone; sounds of all pitches and of every quality travel with equal speed, as is proved by the fact that distance does not destroy the harmony of a rapid piece of music played by a band. If notes of a different pitch travelled with different velocities, they would not reach the ear in the order in which they were played. Moreover, Biot put it to the test of direct experiment; he caused several tunes to be played on a flute at the end of a pipe 3120 feet long, and found that they could be distinctly heard without the slightest derangement.

Neither is the velocity of sound affected by an increase of density in the air. It is, however, greater in warm than in cold air in consequence of the greater elasticity of the former. In the different gases much variety has been observed in the velocity of sound; through carbonic gas the rate of the velocity is said to be one-third slower than ordinary, but through hydrogen gas, which is twelve times more elastic than common air, the speed exceeds the usual rate three and a half times. A more striking difference is as regards the intensity of sound or the impression it is capable of producing on our organs of hearing. This varies considerably with the increase or diminution in the density of the transmitting gas. By means of a piece of clock-work, which caused a hammer to strike at regular intervals, the conducting power of the gas could be estimated, the clock-work being placed in a glass receiver filled with the gas. It was thus that Priestley ascertained that in hydrogen the sound was scarcely louder than in vacuo; in carbonic acid and in oxygen it was somewhat louder than in air.

Water can transmit sound, as the anatomist would infer must be the case from the fact that fishes are provided with distinct and highly developed organs of hearing. Hauksbee, Anderon, the Abbé Nollet, and Franklin have abundantly proved this by their experiments. M. Colladon, by means of a tin cylinder three yards long and eight inches in diameter, closed at its lower end but open to the air above, plunged vertically in the water, was enabled to hear the sound of a bell at a distance of about nine miles, and from numerous observations he concluded that the velocity of sound in water at about 46° Fahr. was equal to 4708 feet in the second.

Solids convey sound as well as or even better than air or liquids. Elasticity and homogeneousness are the qualities which best adapt solids for the conveyance of sound: hard substances, then, which are the most elastic, conduct sound best. An interesting experiment of Hassenfratz and Gay Lussac, in the quarries of Paris, affords a striking contrast of the relative conducting powers of air and solids. A blow of a hammer against the rock produced two sounds which separated in their progress; that propagated through the stone arrived almost instantly, while the sound conveyed by the air lagged behind. A more remarkable experiment was that of Herhold and Rahn, related by Chladni:—a metallic wire 600 feet long was stretched horizontally, and at one end a plate of sonorous metal was attached; when the plate was slightly struck, a person at the opposite end, holding the wire in his teeth, heard at every blow two distinct sounds, the first transmitted almost simultaneously by the metal, the other arriving later through the air. Biot, with the assistance of Messrs. Boulard and Malus, concluded the velocity of sound in cast iron at the temperature 51° Fah. to be 11,090 feet in a second.

Reflexion of sound.—Sonorous undulations in passing from one medium to another always experience a partial reflexion, and when they encounter a fixed obstacle, they are wholly reflected; and in both cases the angle of incidence is, as in the reflexion of light, equal to the angle of reflexion.

Echos are sounds reflected from some obstacle which is placed in their way, as the wall of a house, or those of an apartment, or the surface of a rock, or the vaulted roof of a church, &c.; and a sound thus reflected may, by meeting another similar obstacle, be again reflected, and thus the echo may be repeated many times in succession, becoming, however, fainter at each repetition till it dies away altogether. The phenomena of echos illustrate beautifully the analogy between sound and light. Thus, the reflexion of sound from concave and convex surfaces takes place exactly as in the case of light: if a reflecting surface be concave towards an auditor, the sounds reflected from its several points will converge towards him, exactly as reflected rays of light do; and he will receive a sound more intense than if the surface were plane, and the more so the nearer it approaches to a sphere concentric with himself; the contrary is the case if the echoing surface be convex. If the echo of a sound excited at one station be required to be heard most intensely at another, the two stations ought to be *conjugate foci* of the reflecting surface, i. e. such that if the reflecting surface were polished, rays of light diverging from one would be made after reflexion to converge to the other. Hence, if a vault be in the form of a hollow ellipsoid of revolution, and a speaker be placed in one focus, his words will be heard by an auditor in the other, as if his ears were close to the other's lips. The same will hold good if the vault be composed of two segments of paraboloids having a common axis, and their concavities turned towards each other; only in this case sounds excited in the focus of one segment will be collected in the focus of the other after two reflexions.

The most favourable circumstances for the production of a distinct echo from plane surfaces is when the auditor is placed between two such exactly half-way. In this situation the sounds reverberated from both will reach him at the same instant, and reinforce each other: if nearer to one surface than the other, the one will reach him sooner than the other, and the echo will be double and confused.*

We propose to enquire the part which each portion of the complex auditory apparatus of man performs in the function of hearing.

I. *Of the internal ear.*—The fact that a part, answering precisely to the vestibule, is to be met with in every class of animals in whom an auditory apparatus can be detected, affords a strong presumption that this portion of the labyrinth is the essential part of the organ. Here is the seat of the principal expansion of the auditory nerve upon the saccule and common sinus, which floating in the perilymph communicate, through the medium of that fluid, with the membrane of the fenestra ovalis, and consequently with the air contained in the tympanum. Any vibrations or oscillations then excited in the membrane of the fenestra ovalis, cannot fail to affect the perilymph to a proportional extent, and through it the membranous vestibule. In the simple ear of Crustaceans as well as that of Cephalopods and the lowest Cyclostomous fishes, the sonorous impressions are conveyed directly to the vestibular cavity through the solid material in which that cavity is formed, or, as in some Crustaceans, through the vibration of an external membrane.

In the higher organized fishes, too, the labyrinth constitutes the whole of the auditory apparatus, nor has it any kind of opening to or communication with the external air, being lodged in the walls or cavity of the cranium, the sonorous impressions must be conveyed through the solid cranial parietes; for, in truth, there is no other mode in which they can be conveyed, and we know that solids are even better conductors of sound than either liquids or aërial fluids.†

As to the function performed by the *otolithes*, or the calcareous dust, *otokonies*, which are found in the sacculus vestibuli of the ears of Cephalopods and Fishes, no satisfactory theory has as yet been offered by any physiologist. Although it is now admitted that similar calcareous particles exist in the vestibules of all vertebrated animals, still they are only in a rudimental condition when compared with those of fishes; indeed it seems not unreasonable to suppose that the calcareous dust or otokonie of cartilaginous fishes (the ray or shark for example) is rudimental of the hard, porcellaneous, and artfully formed otolithe of the osseous fishes.* A sort of loose notion seems to prevail, that the presence of this hard body in the vestibule favours the communication of sound, by impinging upon the expansion of the auditory nerve. The following observations of Camper no doubt propagated this idea, if they did not originally give rise to it: "Pour être convaincû," says this distinguished physiologist, "qu'un corps plus ou moins dur, mais flottant dans une substance gélatineuse reçoit la plus légère commotion ou mouvement extérieur, on n'a qu'à remplir un verre de gelée de corne de cerf, et y plonger quelque corps, on sentira aux doigts le mouvement de ce corps dès qu'on remuera le verre, ou qu'on lui donnera un petit choc avec un doigt de l'autre main. Quand on enferme dans une petite vessie quelque corps dur, le moindre mouvement de la vessie fait branler ce corps, qui produit une sensation très forte sur le doigt qui tient la vessie."†

Sir A. Carlisle thinks that the nature of this substance has reference to the habits of the particular class of fishes in which it exists. "Fishes," he says, "are only provided with more simple organs of hearing, ordained to inform them of collisions among rocks and stones, or the rushing of water or moving bodies in that element: and since the collisions of stones or of water are only variable in their magnitude or intensity, fishes are provided with these dense ossicles to repeat the semblable acute tones of similarly dense substances, such as rocks, stones, gravel, &c." Again, "There is an especial sac of calcareous pulp given to skates and some other cartilaginous fishes in the place of the dense ossicles, apparently intended to respond to the movements of sand and muddy strata on which they are doomed to reside; and it is remarkable that the sturgeon has its auditory ossicles consisting partly of hard substance and partly of calcareous pulp."‡

Weber believes that the otolithes in fishes supply the place of the cochlea which is wanting in these animals: the auditory nerves being connected with them receive the vibrations

* Herschel, Encycl. Metrop.

† Hunter, Monro, Weber, and Treviranus, however, describe a communication with the exterior in Rays and the Shark by two long canals; but Scarpa, Bell, and Blainville positively deny that these ducts perform the office of auditory canals.

* So definite does the form of these otolithes appear to be in osseous fishes, that Cuvier says the osseous fishes may be determined by their otolithes as well as by any other character.

† Mém. de l'Acad. des Sciences, an. 1779, and quoted in Scarpa De auditu et olfactu, p. 23.

‡ Quoted from a Mss. Essay on sound, in the Hunterian Catalogue, vol. iii. p. 193. Müller calls the otolithe "Eine freier solider Schwingungen repercutirender Körper."

direct from them, or sometimes the otolithes are so placed with reference to the expansion of the vestibular nerve, as to be able to compress it against the cranium.

But in man and those animals in whom, in addition to a more complicated labyrinth, there is also an external auditory passage and tympanum, it would appear that the sonorous vibrations are conducted in two ways; first, through the meatus externus and tympanum to the vestibule and semicircular canals; and, secondly, through the bones of the head directly to the auditory nerve. Sounds proceeding from external bodies, as Weber observes, are conveyed in the former way; but the oscillations of one's own voice, although they in part find their way by the external passage, are chiefly conducted by the cranial bones; and, as Professor Wheatstone has remarked, those sounds are best heard which are articulated most in the mouth, and with that cavity least open, as *e*, *ou*, *te*, *kew*. Closing both ears by firmly pressing the hands upon them, one's own voice is not heard less distinctly, but on the contrary more loud and clear than when both ears are left open; and if only one ear be closed, the voice is heard more distinctly and louder in that ear than in the open one.*

The observations and experiments of Weber render it very probable that the cochlea is that part of the labyrinth which is more particularly suited to appreciate sounds communicated through the solid case of the head, or, to use his words, that sounds propagated through the bones of the head are heard specially by the cochlea, but that sounds conducted through the external meatus are perceived by the membranous vestibule and semicircular canals more easily than by the cochlea. The following considerations favour these views.

It is an admitted fact in acoustics that sounds are most perfectly conducted by substances of uniform elasticity, and that when propagated from air or water to a solid, or from a solid to air or water, they are conducted much less completely. Now, inasmuch as the cochlea may be regarded as part and parcel of the cranial bones, the sounds which are propagated by these bones would reach the nervous expansion in that portion of the labyrinth by the most direct route; whereas, to affect the remaining parts of the labyrinth, the sound must be conducted from the bone through the perilymph to the membranous vestibule and semicircular canals. Moreover, when it is considered that the cochlear nerves are disposed in a radiated manner in the lamina spiralis, it will appear evident that the oscillations propagated to the petrous portion of the temporal bone must exert a direct influence on the cochlear portion of the auditory nerve.

One or two experiments with the tuning-fork show not only that the cranial bones do conduct, but also that sounds, inaudible or imperfectly audible through the meatus externus, may be distinctly heard when the sounding body is brought into contact with a bone of the cranium or face. When the tuning-fork is put into vibration by striking it against any solid body, if held near the external ear its vibrations are heard distinctly, but let the handle be applied to the teeth or to the superior maxilla, and the sound appears much louder; or if the fork be held near the ear until the sound has almost died away, and then its handle be applied to the superior maxilla or the teeth, the sound seems greatly to revive and continues for a considerable period, the handle being kept in contact with the bone.

When the conducting stem of the sounding tuning fork is placed on any part of the head, if both ears be closed by being covered with the hands, a considerable augmentation of the sound will be observed.* If the sounding-fork be kept in contact with the head for a short time, both ears remaining open, and then one ear be closed, the sound will be greatly augmented in the closed ear, and will appear to be heard exclusively by it. This experiment is more striking if the stem of the tuning-fork be applied to the mastoid process on one side: when both ears remain open, the sound seems to be heard chiefly by the ear in the vicinity of which the stem is placed, but when the opposite ear is closed, it appears as if the sound were transferred from the open to the closed ear; and if the ear be alternately opened and closed, the sound will alternately appear to be transferred from the one to the other. Similar phenomena may be observed if both ears are closed on the first application of the tuning-fork. The sound is at first heard in the adjacent ear, and either remains in it or is transferred to the opposite one, according as the former remains closed or is opened. Mr. Wheatstone adds that if the meatus and concha of one ear be filled with water, the sound from the tuning-fork will be referred to the cavity containing the water in the same way as when it contained air and was closed by the hand.

These phenomena afford obvious examples of the communication of sound through the bones of the head. The augmentation of the sound in the closed ear appears to result, as Mr. Wheatstone explains,† from the reciprocation of the vibrations by the air contained within the closed cavity, and this explanation is confirmed by the fact that when the meatus is closed by a fibrous substance, such as wool, no increase is obtained.

The following rationale may be offered of what occurs when the sound from the tuning-fork is communicated to a closed ear, in accordance with the views of Weber respecting the function of the cochlea. The vibrations of the fork are propagated by the bones of the head to the cochlea, the fluid of which being thus thrown into vibration causes the membrane of the fenestra rotunda to vibrate,

* E. H. Weber De Auditu in Annotat. Anatom. et Physiolog. Lips. 1834.

* These experiments were first suggested by Professor Wheatstone.—See his experiments on audition in the Journal of the Royal Institution for July 1827.

† Loc. cit.

by which as well as by the vibrations of the bones, the air in the tympanum is made to vibrate, and that cavity being closed the sonorous vibrations are reflected from its walls so as to give rise to the augmentation of the sound.

Autenrieth and Kerner believed the cochlea to be that part of the auditory apparatus by which we perceive what the French call the "timbre" of sounds; that quality, namely, which depends on the nature of the material of which the sounding body is constituted, as well as on its form and size, and in some degree on the manner in which sound is elicited from it; and they considered it the office of the vestibule to convey to the sensorium the pitch and strength of sounds. Their opinion as to the function of the cochlea was founded on some experiments as to the extent to which certain of the lower animals were affected by particular instruments of music: the results obtained from these experiments, when taken in connexion with certain differences in the form and other characteristics of the cochlea in those animals, led these authors to the conclusion that "those animals alone seemed to perceive a difference of the 'timbre' of sounds of pretty uniform pitch and loudness, in whom the cochlea was very long and projected considerably into the cavity of the tympanum, and was not much concealed by the surrounding bony substance. Thus it appeared that a dog (the cochlea of dogs being longer than that of cats), upon hearing a certain note of the clarionet, set up a howl, but seemed in no way affected at hearing the same note from the flute or violin; but the cat continued undisturbed, although a variety of instruments was sounded in her hearing. A rabbit (in which the cochlea is prominent) ran away at the note C elicited from a glass tumbler or from a string, but remained still when the same note was sounded even more loudly by the flute."* But it is abundantly evident that these experiments do not fairly lead to the conclusion which these physiologists endeavoured to establish; for, as Weber has remarked, it is one thing to be disagreeably affected by the peculiar tone of a given note in an instrument of music, and another thing to distinguish the timbre of the notes of different musical instruments. As well might we conclude that dogs excel in the power of distinguishing scents and savours, because the smell and taste of spirits of wine seem to be peculiarly disagreeable to them, and they reject instantly, although hungry, any food offered to them with which that has been mixed.

It seems evident that the cochlea is an indication of a very advanced condition of the organ of hearing; beyond this we can arrive at no definite conclusion in the present state of our knowledge, unless indeed we admit the very general one of Weber, that it is the primary seat of those auditory impressions which are conveyed through the vibrations of the cranial bones. But this view, however probable, and supported by much sound reasoning, throws no light on the object of the peculiar form and mechanism of the cochlea. We must not omit to notice that a portion of the vestibule is regarded by Weber as performing a similar function to that of the cochlea, and on similar grounds. That portion which is known under the name of the *sacculus* is so adherent to the bony wall of the vestibule, corresponding to the *fovea hemispherica*, according to Scarpa, that it cannot be separated without laceration, and consequently it seems to be better adapted to receive the sonorous vibrations which are conveyed by the cranial bones.

The remaining parts of the labyrinth, namely, the three semicircular canals and the common sinus, are most affected by those sounds which are conveyed through the external meatus: it seems evident at least that they must be more affected than the cochlea from the connexion between the membrana tympani and fenestra ovalis through the chain of tympanic ossicles, by which that membrane is brought into direct communication with the perilymph surrounding the membranous labyrinth. On the other hand these parts are badly adapted to receive the impression of vibrations direct from the cranial bones, being separated from the corresponding osseous parts by the peri lymph, and that part of the auditory nerve which is distributed to them, having no connexion with the bone. An experiment of Weber illustrates the relation of the perilymph to the membranous labyrinth, and shows that an impulse upon the membrana tympani is capable of affecting it. In some birds, the falcon for example, the semicircular canals are so large, that the membranous canals may be easily seen. If in such a bird one osseous semicircular canal be opened by a small opening, care being taken not to injure the membranous canal, and then we press the membrane of the tympanum inwards, at each com pression we observe the water contained in the bony canal to flow out with a jerk. He therefore concludes that the sonorous undulations conveyed by the cranial bones are communicated more immediately to the nerve of the cochlea, but those conveyed by the external meatus to the nerve of the vestibule.

The semicircular canals are remarkable for the constancy of their number, and of their relative position with respect to each other, in all animals in whom they are found. They exist in almost all fishes, and in all the other vertebrate classes, and in these they are never less than three in number, two of which are always placed vertically and one horizontally. The opinion that the arrangement of these canals has reference to conveying the sensation of the direction of sounds, I find expressed by Autenrieth and Kerner in the paper already referred to. "In no animal," they say, "are these canals ever more or fewer on each side than

* See these experiments quoted at greater length in Weber's paper before referred to. Autenrieth's paper is to be found in Reil's and Autenrieth's Archiv. fur die Physiologie, B. ix. 1809; and contains much valuable and highly interesting matter relative to all the parts of the organ of hearing in several of the Mammalia.

three, which are so situated that they correspond to the three dimensions of a cube, its length, breadth, and depth, and that every sound arriving in one of these three directions will always strike one canal at right angles to its axis, and another in its length. The position of these canals is likewise such, that the corresponding canals of opposite sides cannot be parallel, and that therefore any sound which strikes the head in any given direction affects the semicircular canal of one side much more than the corresponding one of the opposite side, whereby it may be determined whether the sound coming in a straight line (from west to east for example,) has really moved from west to east, or from east to west."* They state that in animals in whom the semicircular canals are highly developed, the power of distinguishing the direction of sounds is marked to a proportionate degree. Thus in the mole, the development of these canals is very considerable, and from a simple experiment it appears that this animal readily distinguishes the direction of sounds. A mole was introduced into a wide but flat vessel filled with earth, in which he was allowed to burrow, and it was found that the mole could be made to move about by sounding an instrument outside the vessel; if the instrument were sounded on one side, the animal would always immediately turn to the other.† The fox seemed to distinguish the direction of sounds better than cats: if at the same time, and at opposite sides, the high tones of a little bell and the deep tones of a bass viol were sounded, the fox always turned to the side whence the high notes came. Cats seem to be sensible of the direction of high notes only. When upon a violin, or a flageolet, or upon a glass goblet containing water, high notes were sounded, the cats always turned towards the place whence the sound came, even although the instrument was concealed from them: on the other hand, when a person seated on the ground sounded the low notes of a bass viol before several cats in a garden, they seemed to seek in all directions for the place of the sounding body, without hitting upon the right one. The cow, the horse, the pig, and the rabbit seemed to manifest particularly little sensibility to the direction of sounds. The dog appears to have less power to distinguish the direction of sound than man; his smell seems to assist him, and it is well known that when a dog is called by his master, he commonly runs backwards and forwards for some time before he finds out the right direction. The human semicircular canals greatly exceed in width all others examined by Autenrieth and Kerner, but this excess is more as regards the canals properly so called, but does not apply to the ampullæ. Scarpa had already remarked, that although the canals of oxen and horses were narrower than those of man, the ampullæ were scarcely at all smaller than in the human subject. These observers further remarked, in many animals they examined, an inverse ratio between the width of the ampulla and that of the canals; that the former were wider in proportion as the latter were narrow. In fine, they conclude that the wider the semicircular canals, the size of the animal being taken into account, the greater is the power of distinguishing the direction of sound. Of the lower animals, the first in order as regards this power is the hedge-hog, which, after the human subject, has, relatively to its size, the widest semicircular canals; we may form some idea of the width of these canals from the fact that in their centre they are nearly as wide as the semicircular canals of the pig, which is so very much larger an animal. Next to the hedge-hog stands the mole, whose canals are, proportionally to the size of the animal, both remarkably wide and long; they are peculiar also as projecting free (visible without any prepation) into the cavity of the cranium. The mouse and the bat come next, then the fox and the dog,* the rabbit, the cat, the pig, the cow, the horse, and lastly the sheep.

Professor Wheatstone advocates the theory that our notions of audible direction depend upon the excitation of those portions of the auditory nerve which belong to the semicircular canals. He conceives that we distinguish best the direction of those sounds which are sufficiently intense to affect the bones of the head, and that it is from the portion which is transmitted through those bones that our perception of the direction is obtained. Thus, we always find it difficult to tell by the ear the position whence the feeble tones of the Œolian harp proceed. The three semicircular canals, then, being situated in planes at right angles with each other, are affected by the sound transmitted through the bones of the head with different degrees of intensity according to the direction in which the sound is transmitted; for instance, if the sound be transmitted in the plane of any one canal, the nervous matter in that canal will be more strongly acted on than that in either of the other two; or if it be transmitted in the plane intermediate between the planes of this canal and the adjacent one, the relative intensity with which those two canals will be affected will depend upon the direction of the intermediate plane. The direction suggested to the mind will correspond with the position of the canal upon which the strongest impression has been made.†

* Op. cit. p. 363.

† This experiment, however, was repeated by Esser, who assures us that the direction of the movements of the mole was not influenced by the direction of the tones of the instrument. Kastner's Archiv. fur die gesammte Naturlehre, B. 12, s. 56. quoted in Treviranus, Erschein. und Gesetze des Organischen Lebens.

* The width of the canals in dogs was found to vary in the different races. Autenrieth and Kerner, loc. cit.

† Dr. Young thought that the semicircular canals seemed very capable of assisting in the estimation of the acuteness or pitch of a sound by receiving its impression at their opposite ends, and occasioning a recurrence of similar effects at different points of their length, according to the different character of the sound; while the greater or less

No conclusions can be derived from the experiments of Flourens with respect to the functions of the several parts of the labyrinth. The effects of disease had already sufficiently indicated the relative importance of the different parts of the ear, and even to a certain extent of those of the labyrinth. Thus we knew that stoppage or destruction of the external parts does no more than impair the sense of hearing, and that so long as the labyrinth remains perfect, or at least the vestibule, the sense is not destroyed. Sound may be conveyed to the auditory nerve through the bones of the head, as may be proved by the sensation of sound produced by the application of a tuning-fork in vibration to the teeth or to some one of the cranial bones. By a parity of reasoning, Flourens having successively destroyed the several parts of the ear in pigeons, inferred that the nervous expansion in the vestibule was the part of the organ most essential to audition: "that in strictness, it is the only indispensable part, for all the others may be removed; yet if this continue, audition is not destroyed." Partial destruction of the nervous expansion in the vestibule only partially destroys the sense, and complete destruction of this expansion involves total deafness. The vestibule may be laid open without any very considerable alteration in the sense; but rupture of the semicircular canals rendered the hearing confused and painful, and was moreover accompanied with a quick and violent tossing of the head.*

One can scarcely imagine vivisections less likely to lead to useful results than those which involve the exposure of the deep-seated internal parts of the ear, a dissection which even on the dead subject demands no ordinary skill; nor can we refrain from expressing our opinion that had M. Flourens never attempted these experiments, physiology would have been none the worse, and our respect for his humanity would have been all the greater.

II. *Of the accessory parts of the organ.*—We shall consider in succession the parts which the external ear—the tympanum, its membrane and ossicles, and the Eustachian tube, play in the process of audition.

The external ear may be regarded as consisting of two parts, the auricle and the meatus auditorius externus. The complete developement of the former is found only in Mammiferous animals, and exists pretty generally throughout the class; with, however, considerable diversity of form, varying from an almost flat cartilaginous lamella, scarcely at all under the influence of its muscles, to an elongated funnel-shaped ear-trumpet, very moveable and completely at the command of numerous large muscles. Man and the Quadrumana are at one extremity of this scale; the Solipeds, Ruminants, and Cheiroptera at the other. Some, however, are devoid of the auricle, as the mole, the zemni-rat, the mole-rat, the seal, the walrus, &c. It is said that those animals which are remarkable for the large developement of the auricle are almost all timid or nocturnal, and consequently require an acute sense of hearing.

That the auricle performs the office of an acoustic instrument to collect and reinforce the sounds which fall upon it, cannot be doubted in those cases in which it is large and fully developed, as in the horse, ass, &c. Here, indeed, we see that the animal employs it as we might expect such an instrument would be used; the open part is directed towards the quarter whence the sound comes, and continues so directed as long as the animal appears to listen. So far, however, from this part being mainly the instrument for enabling the animal to judge of the direction of sound, it appears to me that it cannot be applied to its full use until the direction of the sound has been in some measure determined; until the hearing-trumpet has been favourably placed with respect to the quarter whence the sound emanates, its value is not fully experienced. If we watch the movements of the auricle of a horse, we shall see that he uses it altogether for concentrating sounds from particular quarters: when he moves it about quickly, it often seems as if he were feeling for sounds coming from certain directions, having already acquired a tolerable notion, if I may so speak, as to what those directions are. Treviranus,* however, thinks that the reinforcement of the sound is not its principal use: "to what end," he asks, "have its various eminences and depressions been formed, if it have no other use than this, and why are these particularly developed in the human ear, which can have little or no influence as an ear-trumpet in increasing the influence of sounds?" He supposes that in the lower animals, but *especially in man*, the auricle serves more for forming a judgment respecting the direction of sounds than for assisting in hearing. We cannot understand in what way the fixed auricle of man can aid for this purpose, being almost immoveable, and indeed altogether so for the purposes of collecting sonorous undulations from different quarters; nor indeed does it appear that the opinion in question of Treviranus is any thing more than a mere hypothesis. A remark of Mr. Gough, the author of a highly interesting paper in the Manchester Memoirs "on the method of judging by the ear of the position of sonorous bodies," offers a strong argument against this notion. He observes that whatever may be the direction of a sound in the open air, as soon as it enters the auditory passage, it is compelled to follow the course of that duct until it reaches the apparatus in which the sense of hearing resides.†

The experimental researches of Savart throw some light upon the function of this part of the auditory apparatus.‡ These experiments

pressure of the stapes must serve to moderate the tension of the fluid within the vestibule, which serves to convey the impression. The cochlea seems to be pretty evidently a micrometer of sound.—See Med. Lit. p. 98.

* Conditions de l'Audition in Experiences sur le Systeme nerveux, p. 49. Par. 1825.

* Loc. cit. B. ii. p. 137.

† Manchester Memoirs, New Series, vol. v.

‡ Majendie's Journal de Physiologie, tom. iv.

were suggested by the result of several observations which he made upon the communication of vibrations through the air from a vibrating body to one placed even at a great distance from it, and susceptible of undergoing vibrations. The effect is best seen by using a thin membrane, such as very fine paper, carefully stretched in a horizontal position over the mouth of a glass, or of a small delft basin: a thin layer of sand is spread on this, and a glass thrown into vibration by a violin bow is held at a little distance from it; that the paper immediately begins to vibrate is shewn by the motions excited in the sand, the particles of which arrange themselves into figures, which are sometimes perfectly regular, and which form with so much rapidity that the eye can scarcely follow "the circumstances which accompany the transformation of the thin layer of sand into a greater or less number of lines of repose."

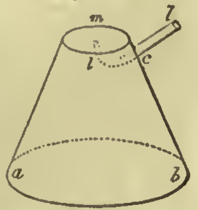
By a series of experiments to be hereafter detailed, Savart showed that the tympanic membrane is capable of being thrown into vibrations by the sonorous impulses from a vibrating body communicated to it by the interposed air. How far the external ear and auditory canal serve to increase these vibrations of the tympanic membrane, he sought to ascertain by the following experiments. He formed a conical tube of pasteboard, with a very wide mouth at its base, the opening at the smaller end being closed by a thin paper stretched over it and glued to the margins of the opening. This tube is placed resting on its base, the membrane being upwards and perfectly horizontal, so that a layer of sand may be spread over it. When a vibrating glass is brought near and parallel to the upper surface of this membrane, it immediately begins to vibrate, and the grains of sand are tossed about but raised but very slightly from the surface. If, however, the vibrating glass be placed near the base or the wide and open extremity of the tube, the vibrations of the membrane will be found to be much more manifest, and the excursions of the grains of sand so considerable, that they are often raised to a height of three or four centimetres; so that there is a manifest difference in the influence produced upon the membrane by the sonorous undulations excited in the air according as they impinge upon the external surface of the membrane or upon that which is turned towards the interior of the tube. This phenomenon, Savart adds, may depend upon two causes, namely, upon the concentration of the sonorous undulations by the tube, or upon the communication of motion to the parietes of the tube, which again would communicate it to the membrane. With a view to ascertain which of these causes was the effective one, a second conical tube, open at both ends, was held with its narrow extremity a little above and corresponding to the narrow extremity of the former one, but so that there was no contact between them. If now the glass is made to vibrate successively at the large orifices of the two tubes, it will be found that when placed at the orifice of the tube to which the membrane is attached, the oscillations of that membrane are considerably greater than when the aerial undulations reach it through the other tube. Whence it may be inferred that in all probability the external ear and auditory canal have, besides any influence they may exert in modifying the movements of the particles of the air, the additional function of presenting a large surface to the aerial undulations, consequently to enter into vibration under their influence, and thus to contribute to increase the excursions of the vibrating parts of the membrane with which they are immediately in contact; the auricle, by the variety of the direction and the inclination of its surfaces to one another, can always present to the air a certain number of parts, whose direction is normal (at right angles with) to that of the molecular movement of that fluid.

We get a general notion of the value of this external part of the auditory apparatus in collecting and directing the sonorous undulations, from the assistance often derived in hearing from increasing the concavity of the external ear by placing the hand behind it, so as to draw it forward and shorten it by pressure at its upper and lower part; by the dulness of hearing which it is said follows the loss of the auricle, and from the fact, so stated, that the seal and walrus are extremely dull of hearing. As regards the loss of the auricle, it is said by Kerner that this loss is followed by the greatest dulness of hearing in those animals in whom the osseous meatus is wanting. In a cat, from whom the right ear was cut close to the skull, after the wound had healed without any stoppage of the meatus, there was a remarkable disposition always to keep its head turned so as to be ready to receive sounds with the left ear, and this continued even after the tympanic membrane of the opposite side had been frequently perforated, that of the right side remaining whole; and when the left ear was stopped (although the right tympanic membrane was sound, and the only injury on that side was the removal of the auricle,) a total deafness was manifested except to the loudest and clearest sounds.

The tympanum and its contents.—We have already stated that Savart had demonstrated that the membrana tympani is thrown into vibrations by undulations of the air excited by a sonorous body. This he demonstrated experimentally upon the membrana tympani itself. The temporal bone having been separated, he sawed away the osseous meatus so as to expose the membrane on a level with the rest of the bone, and when it was sufficiently dry, he covered it with a thin layer of sand. A vibrating glass held parallel and very near to the surface of the membrane occasioned a slight movement of the grains of sand; but owing to the slight extent and the shape of the membrane, it was impossible to determine the existence of any nodal line. In a second experiment, the cavity of the tympanum was opened, so as to expose the ossicles of the ear and their muscles; and it was observed that when the internus mallei muscle acted and rendered the membrane tense, it was much more difficult to produce manifest movements in the grains of sand; thus affording much reason to suppose the tensor tympani muscle is analogous in its use to the iris, and destined to preserve the organ from too strong impressions. This experiment can be best tried on the membrana tympani of the calf.

In imitation of the mechanism by which the tension of the membrana tympani is effected, and with a view to determine more decisively the effects produced by variation of the tension of that membrane, Savart constructed a conical tube (*fig.* 262), with its apex truncated and covered by a layer of very thin paper (*m*), which was glued to the edge of the opening. A little wooden lever (*l l*), introduced through an opening in the side of the tube, and resting on the lower margin of this opening (*c*) as a fulcrum,

Fig. 262.



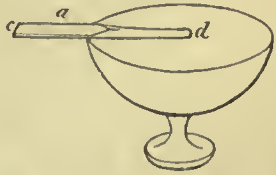
was used to vary the tension of the membrane, one of its extremities being applied to the under surface of the membrane. It is evident that, by depressing the extremity of the lever that was external to the tube, the inner one would be raised, and thus the membrane stretched to a greater or less degree according to the force used; on the other hand, by elevating the outer extremity, the inner one was separated from the membrane, which was accordingly restored to its original tension. This little lever was employed in imitation of the handle of the malleus, which under the influence of its muscles causes the variation in the tension of the membrana tympani. The artificial tympanic membrane then having been covered with a layer of sand, it was found that, under the influence of a vibrating glass, used as in the former experiments, a manifest difference was produced in the movements of the grains of sand, by increasing the tension of the paper; the greater the tension, the less the height to which the grains of sand were raised; and these movements were most extensive when the lever was withdrawn from contact, and the membrane left to itself.

From these experiments Savart concludes that the membrana tympani may be considered as a body thrown into vibration by the air, and always executing vibrations equal in number to those of the sonorous body which gave rise to the oscillations of the air. But what is the condition of the ossicles of the tympanum whilst the membrane is thus in vibration? The result of the following experiment affords a clue to the answer of this question. To a membrane stretched over a vessel, as in *fig.* 263, a piece of wood (*a b*) uniform in thickness is attached, so that the adherent part shall extend from the circumference to the centre of the membrane, while the free portion may project beyond the circumference. When a vibrating glass is brought near this membrane, very regular figures are produced, which

Fig. 263.

however are modified by the presence of the piece of wood, and the vibrations of the membrane are communicated to the piece of wood, on which likewise regular figures may be produced. The more extensive the membrane, the longer and thicker may be the piece of wood in which it can excite oscillations, and Savart states that, with membranes of a considerable diameter, he has produced regular vibrations in rods of glass of large dimensions. The oscillations of the piece of wood are much more distinct when the adherent portion is thinned down, as in c *d*, *fig.* 264, by which it

Fig. 264.



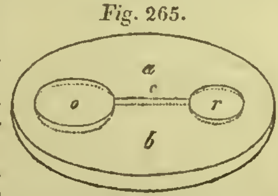
seems, as it were, more completely identified with the membrane, and consequently the oscillations of this latter are communicated directly to the thinned portion of the wood, and thence extended to the thick portion *a*: sand spread upon *a* will exhibit active movements, and will produce very distinct nodal lines. Thus it may be inferred that the malleus participates in the oscillations of the tympanic membrane; and these vibrations are propagated to the incus and stapes, and thus to the membrane of the fenestra ovalis. The chain of ossicles then evidently performs the office of a conductor of oscillations from the membrana tympani to the membrane of the fenestra ovalis; but the malleus likewise has the important function under the influence of its muscles of regulating the tension of the tympanic membrane; and to allow of the changes in the position of this bone necessary for that purpose, we find it articulated with the incus by a distinct diarthrodial joint, and between this latter bone again and the stapes there exists another and a similar joint. This mobility then of the chain of bones, and the muscular apparatus of the malleus and stapes are totally irrespective of the conducting office of the bones, but have reference to the regulation of the tension of the membrane of the tympanum as well as of that of the fenestra ovalis.*

We have already seen how the muscle of

* The experiments of Savart above detailed have been several times carefully repeated by me with results precisely similar.

the malleus regulates the membrana tympani, increases its tension, and thus limits the extent of the excursions of its vibrations. The contraction of the stapedius muscle causes the base of the stapes to compress the membrane of the fenestra ovalis to a greater or less extent, so that the degree of tension of that membrane depends on the condition of this muscle. Compression exerted upon the membrane of the fenestra ovalis extends to the perilymph and through it is propagated to the membrane of the fenestra rotunda, and in this way the same apparatus which regulates the tension of the membrane of the fenestra ovalis performs that office for that of the fenestra rotunda, and Savart has devised a little apparatus which very prettily illustrates the manner in which this may take place. In a disc of wood (*a b*, *fig.* 265) of a sufficient thickness, he hollows out two cavities, *o* and *r*, which communicate at their bottoms with each other by a narrow canal (*c*) hollowed in the wood, but not open on its surface; a thin membrane is extended over each of the cavities. Thus, the air contained in these cavities may pass easily from one to the other, and may always maintain the same degree of elastic tension in both. If, then, a vibrating glass be brought near the membrane *r* covered with a layer of sand, it will be found to enter freely into vibration, as evinced by the active movements of the grains of sand. If now pressure be made with the finger on *o*, *r* will become convex in proportion as *o* is rendered concave by the pressure, and when in this state, the movements of the sand will be much less considerable than before, presenting an effect precisely similar to that produced on the tympanic membrane by an increase of tension. Thus, the extent of the excursions of the vibrations of the membrane *r* is limited by the pressure exerted upon *o*, and as the membranes of the two fenestræ are related to each other in an analogous manner, we may argue that pressure upon the larger one, that of the fenestra ovalis, will occasion tension of the smaller, that of the fenestra rotunda, thereby limiting the extent of the excursions of its vibrations.

Fig. 265.



Moreover it appears, upon reference to the anatomy of these parts, (see *fig.* 252, p. 550,) that the only muscles which have been satisfactorily demonstrated are tensors of the tympanum; and that at whatever extremity of the chain of ossicles muscular effort be first exerted, a corresponding effect will be produced at the other; that when the stapedius muscle acts, the malleus is thrown into a position favourable to the tension of the membrana tympani, and, on the other hand, the contraction of the internus mallei depresses the stapes, and consequently increases the tension of the membranes of the two fenestræ. The cessation of muscular action restores all three membranes to their original laxity, nor does it appear that they admit of any further degree of relaxation through the influence of any vital process. The incus forms a bond of connexion between the two other bones, and its motions depend entirely upon theirs in consequence of its articulation with both, while from the fixedness of its connexion with the mastoid cells, as well as its intermediate position, and its not having any muscles inserted into it, it is obvious that its motions must be much more limited than those of the other bones. Its use seems to be to complete the chain in such a way, that by reason of its double articulation with the malleus on the one hand and the stapes on the other, the tension of the tympanic membranes may be regulated without any sudden or violent motion, which could scarcely be avoided were the conductor between the membranes of the tympanum and fenestra ovalis one piece of bone.

But whence the necessity of at all adding to the ear this complex apparatus of tympanum and tympanic membrane, and why might not the sonorous impressions have been made directly upon the membranes which close the openings to the labyrinth? Upon this point Savart has offered a conjecture which seems to afford the most probable explanation as to the true object of these parts. If the membranes of the fenestra, he says, had been in immediate contact with the atmosphere, their elastic state would have been constantly undergoing changes, under the influence of the vicissitudes of temperature of the air, a circumstance which would, in all probability, impair the power of the organ in detecting differences of sounds. He presumes therefore that the membrana tympani prevents this contact of the atmosphere with the membranes of the labyrinth, and that the cavity of the tympanum and the mastoid cells form a kind of receptacle in which the air, which finds its way into the tympanum through the Eustachian tube, acquires the constant temperature of the body, and establishes in front of the openings of the labyrinth a sort of atmosphere proper to themselves, the temperature of which does not vary.

This same acute observer remarks that the size of the membrana tympani in all probability, in the different species of animals, exerts much influence upon the number of sounds which they can perceive, and at the same time upon the limits at which those sounds begin or cease to be audible. Were the tympanic membrane in man of greater size than it is, there is no doubt that instead of beginning to hear sounds which result from about thirty vibrations in a second, we should be able to hear only sounds of a higher pitch. Moreover it may be reasonably presumed that animals who have the membrana tympani much larger than that of man, hear much graver sounds than those which result from thirty vibrations in a second; and, on the other hand, there must be other animals who hear very acute sounds only.

Even in the human species, we observe in different individuals a similar variation in the limits of sensibility to sounds, that is, we find, in the words of Dr. Wollaston, that "an ear which would be considered as perfect with regard to the generality of sounds, may at the same time be completely insensible to such as are at one or the other extremity of the scale of musical notes, the hearing or not hearing of which seems to depend wholly on the pitch or frequency of vibration constituting the note, and not upon the intensity or loudness of the noise."* And we owe to this distinguished man the knowledge of the interesting fact, that an insensibility of the ear to low sounds may be artificially induced, by exhausting the cavity of the tympanum to a great degree. This may be effected by forcibly attempting to take breath by expansion of the chest, the mouth and nose being kept shut; after one or two attempts, the pressure of the external air is strongly felt upon the membrana tympani, which is thus from the external pressure thrown into a state of considerable tension. An ear in this state becomes insensible to grave tones, without losing in any degree the perception of more acute ones. This induced defective state of the ear, from exhaustion of the tympanum, may even be preserved for some time without the continued effort of inspiration and without even stopping the breath, and may in an instant be removed by the act of swallowing. In repeating this experiment as I sit writing at my desk, I perceive that a great degree of stillness ensues immediately the sensation of pressure upon the tympanic membrane is felt, owing no doubt to the low rumbling noise of the waggons and carriages in the street being imperfectly audible. A similar observation was made by Dr. Wollaston: "If I strike the table before me with the end of my finger," he says, "the whole board sounds with a deep dull note. If I strike it with my nail, there is also at the same time a sharp sound produced by quicker vibrations of parts around the point of contact. When the ear is exhausted, it hears only the latter sound, without perceiving in any degree the deeper note of the whole table. In the same manner, in listening to the sound of a carriage the deeper rumbling noise of the body is no longer heard by an exhausted ear; but the rattle of a chain or screw remains at least as audible as before exhaustion." Dr. Wollaston refers to the curious effect produced by trying this experiment at a concert: "none of the sharper sounds are lost, but by the suppression of a great mass of louder sounds the shriller ones are so much the more distinctly perceived, even to the rattling of the keys of a bad instrument, or scraping of catgut unskilfully touched." Another very interesting circumstance connected with this subject is the production of the same condition of the tympanum by the sudden increase of external pressure as well as by the decrease of that within, as occurs in the diving-bell as soon as it touches the water, the pressure of which, according to Wollaston, upon the included air closes the Eustachian tube, and in proportion to the descent occasions a degree of tension on the tympanum, that becomes distressing to persons who have not learned to obviate this inconvenience."

From one opportunity which I had of descending in the diving-bell now exhibiting at the Polytechnic Institution in Regent-street, I experienced this sensation very strongly, and exactly as Dr. Wollaston describes it. The first effect of the pressure on the tympanic membrane was the production of a crackling noise, which was immediately succeeded by a painful sense of pressure in both ears; but this is immediately relieved by the act of swallowing; it soon however recurs, and may be in a like manner again relieved. I had no means of judging exactly as to the limits of audition; but I distinctly observed in conversation with those who descended with me, that grave tones were those least distinctly heard; the grave tones of my own voice also were less distinct as well as the low notes in whistling.

In such cases then it would appear that from the strong compression exerted on the membrana tympani, that membrane cannot vibrate in unison with tones which result from a small number of vibrations. On the other hand we may infer, from Dr. Wollaston's observations, that "human hearing, in general, is more confined than is generally supposed with regard to its perception of very acute sounds, and has probably in every instance some definite limit at no great distance beyond the sounds ordinarily heard." The ordinary range of human hearing comprised between the lowest notes of the organ and the highest known cry of insects, includes, according to Wollaston, more than nine octaves, the whole of which are distinctly perceptible by most ears. Dr. Wollaston has, however, related some cases in which the range was much less, and limited as regards the perception of high notes; in one case, the sense of hearing terminated at a note four octaves above the middle E of the piano-forte; this note he appeared to hear rather imperfectly, but the F above it was inaudible, although his hearing in other respects was as perfect as that of ordinary ears; another case was that of a lady who could never hear the chirping of the gryllus campestris; and in a third case the limit was so low that the chirping of the common house-sparrow could not be heard. Dr. Wollaston supposes that inability to hear the piercing squeak of a bat is not very rare, as he met with several instances of persons not aware of such a sound.

The opinion prevailed for a long time that rupture or destruction of the membrana tympani is necessarily followed by the loss of the sense. But Sir A. Cooper proved distinctly that not only was hearing not destroyed, but that in some cases of deafness it might be punctured with considerable benefit to the patient.* The most frequent cause of destruction of the tympanum is otitis, and provided

* Wollaston on Sounds inaudible by certain Ears. Phil. Trans. 1820.

* Phil. Trans. for 1800 and 1801.

the suppurative process does not extend so far as to destroy the stapes, the hearing is only impaired; but should that bone and its attached membrane suffer, then a total deafness is the consequence. In one case, related by Sir A. Cooper, the membrana tympani was entirely destroyed on the left side, and partially so on the right, yet this gentleman, if his attention were excited, was capable, when in company, of hearing whatever was said in the usual tone of conversation, but it was remarkable that he heard better with the left ear than with the right, although in the former there were no traces of a membrana tympani. He could not hear from as great a distance as others, and he stated that, in a voyage he had made to the East Indies, while others, when ships were hailed at sea, could catch words with accuracy, his organ of hearing received only an indistinct impression. His musical ear was not impaired, "for he played well on the flute and had frequently borne a part in a concert." The external ear too had acquired a considerable degree of mobility under the direction of the will, so that it could at pleasure be raised or drawn backwards, and this motion was observed to take place whenever the attention was directed to sounds not very distinctly audible.

The Eustachian tube evidently performs a two-fold office:—it is the passage for the entrance of air into the tympanic cavity from the throat, thus affording a provision for keeping that cavity constantly full of air in order to allow of the free vibration of the membranes as well as of the chain of bones; and it seems obvious that the tube communicates with the throat in order that the air introduced through it shall have acquired the temperature of the body. It likewise affords an outlet for the escape of such sonorous undulations as do not impinge upon the labyrinthic wall of the tympanum, which, were there no such communication with the external air, would cause an echo, and in this respect it performs a function similar to that of the mastoid cells. The necessity of such a provision as is afforded by the first office which the Eustachian tube performs, is manifest from the frequency of deafness resulting from a stoppage either in the tube or at its extremity. Bressa supposed that the Eustachian tube conducted the sonorous impulses excited by one's own voice from the cavity of the mouth to the labyrinth;* but the incorrectness of this notion is abundantly proved by the fact that persons who labour under obstruction of this tube can hear their own voices plainly enough, while they are deaf to those of others. Moreover, if we introduce into the mouth a watch or a vibrating tuning fork, care being taken that they do not touch any of the walls of the mouth, they are heard gradually less distinctly as they are approximated to the Eustachian tube; indeed when held far back in the mouth they are totally inaudible. In some birds the air of the tympanum finds its way not only into the mastoid cells, but also between the two tables of the skull, as in the owl and in singing birds. The arrangement of the osseous structure corresponding to the diploë is exceedingly beautiful in the canary, in which I have examined it. The two tables seem as it were connected by very fine and numerous bony pillars, the extremities of which are attached to each table; cells freely communicating with each other surround these pillars every where, and the air from the tympanum thus traverses the whole of this cellular structure. The superfluous sonorous undulations find their way into these cells, and being repeatedly reflected from their parietes become greatly weakened, so that they can exert no further influence upon the hearing.

Functions of the nerves.—The nervous apparatus connected with the organ of hearing consists of the nerve which receives the sonorous impressions, and of other nerves which are connected with the mechanism of the organ. That the portio mollis of the seventh pair answers to the former office, anatomy alone abundantly proves. With respect to the latter nerves some few remarks seem necessary. The muscular apparatus of the tympanic ossicles receives its nerves partly from the facial and partly from the otic ganglion, thus exhibiting an analogous arrangement to that of the muscular structure of the iris. Such an analogy renders it extremely probable that the actions of the muscles of the ossicles are excited in a similar way to that in which the iris is prompted to act. The stimulus of sound conveyed to that portion of the nervous centre with which it is connected, excites by reflection the motor power of the facial nerve, which, through its connexion direct or indirect with the muscles of the ossicles, causes them to act, and the action is in proportion to the intensity of the sound, inasmuch as the more tense the membrane of the tympanum, the less will be the excursions of its vibrations; as in the iris the more intense the light, the more contracted will the pupil be. It is impossible in the present state of our knowledge to say what is the office of the chorda tympani, or whether indeed it has any office in connexion with hearing; but we may easily conceive that from its connexion with the facial, an irritation of it may excite that nerve. Equally ignorant are we of the function of the tympanic anastomosis.

I shall conclude with the following brief summary of the present state of our knowledge respecting the functions of the several portions of the organ of hearing.

* Reil and Autenrieth, Archiv. für die Physiologie, B. viii. This was a modification of an opinion expressed by Boerhaave, viz., that those sounds from without which entered the mouth were conveyed to the labyrinth through the Eustachian tube. An English physiologist advocates the opinion that some sounds are conveyed through the Eustachian tube, and particularly as he supposes in the Cetacea, from the great development of that tube in these animals compared with the external auditory passage, and the erroneous notion propagated by Home that the malleus had no connexion with the tympanum, but now disproved by the careful examination of Professor Owen. See Fletcher's Physiology, and Owen's Edition of Hunter's Animal Economy.

1. The *vestibule* is the essential part of the organ. It detects the presence and intensity of sound, and especially of those sounds conveyed through the external ear and tympanum.

2. The *cochlea*, lying in immediate connection with the bone, receives those sounds which are propagated through the bones of the head. According to Kerner it is the medium of the perception of the *timbre* or quality of sounds.*

3. Of the function of the *semicircular canals* we know nothing. That they aid in forming a judgment of the direction of sounds is conjectured by Autenrieth and Kerner, and more recently by Wheatstone.

4. The *tympanum* and its membrane render the internal ear independent of atmospheric vicissitudes, and the former affords a non-reciprocating cavity for the free vibration of the latter, as well as of the chain of ossicles.

5. The *chain of ossicles* acts as a conductor of vibrations from the membrana tympani to the fenestra ovalis, and under the influence of the muscles regulates the tension of the membrana tympani, as well as the membrane of the fenestra rotunda, so as to protect the ear against the effects of sounds of great intensity.

6. The *external ear* and *meatus* are conductors of vibrations; the former in some degree collects them as a hearing-trumpet would do, and probably assists in enabling us to judge of the direction of sounds.†

(R. B. Todd.)

HEART (in anatomy). Gr. κιαρ, καρδια; Lat. *cor;* Fr. *cœur;* Germ. *Herz;* Ital. *cuore.* The movement of nutritious juices through the texture or textures of which an organized body is composed, is a fundamental law in Physiology. In proportion as the vital actions become more complex and energetic, the more a rapid and certain circulation of these fluids, which is intimately connected with this condition, becomes indispensable, and for this purpose we have a pulsatory sac or sacs, called *hearts*, superadded to the circulatory apparatus. Another invariable concomitant of this energetic manifestation of the vital phenomena is the more perfect exposure of the nutritious fluids to the atmospheric air, and this, combined with the dissimilar media in which different animals live and move, necessitates very important modifications in the number, position, and structure of these pulsatory sacs. These hearts were until lately supposed to be exclusively confined to the sanguiferous vessels, but Müller and Panizza have discovered distinct pulsating sacs placed upon the lymphatic vessels in several of the reptile tribe, and these may be considered *lymphatic hearts.*

In the lowest organized plants, as the Fungi, Algæ, &c. and in the lower classes of animals, as the Polypi, Actiniæ, and a great part of the intestinal worms, the nutritious fluids are transmitted through their substance without any distinct canals or tubes; while in the higher classes of plants, and in the Medusæ, &c. among animals, vessels are present, but these are unprovided with any pulsatory cavities. In the articulated animals generally, the vessels are still without any pulsatory cavities; but to make up for the deficiency, the dorsal vessel itself has a distinct movement of contraction and relaxation. Various pulsatory dilatations are placed upon the vascular system of the common worm *(Lumbricus terrestris);* one or two upon the vascular system of the Holothuria; and one in the Talpa cristata, where the dorsal vessel is reflected upon itself at the posterior extremity of the body to become continuous with an analogous ventral vessel; all of which may be considered as rudimentary hearts.

As we rise in the scale of animals, we find that the heart consists of two distinct portions—of a stronger and more muscular cavity called a *ventricle*, and of a weaker and less muscular cavity called an *auricle.* The latter not only serves as a kind of reservoir to the former, but also, by the contraction of its muscular fibres, drives the blood into it. This heart is placed within a sac or pericardium, and possesses valves to prevent the regurgitation of the blood from the ventricle into the auricle, and from the aorta back again into the ventricle. This may be considered as a perfect *single heart.* This single heart in some of the Mollusca and in Fishes which have a double circulation, propels the blood not only through the lungs, but also through the body. In the Batrachian Reptiles, as in the Frog, though the circulation is single, the heart becomes more complicated; for instead of a single auricle we have two, one of which receives the blood returning from the respiratory apparatus, the other receives the venous blood of the body. The pulmonic and systemic circulations are here separated as far as the auricles are concerned; but a single ventricle in which the venous and arterialized blood are intermixed, still continues to propel the sanguineous current both through the lungs and through the body. In the Ophidia or serpent tribe the heart possesses the same number of cavities as in the Batrachian Reptiles; but we have a still nearer approach to the double circulation in the presence of a rudimentary septum ventriculorum. In some of the Sauria, as the Crocodile, the ventricle is divided by partitions into distinct chambers, which never-

* Muller, who seems to regard the cochlea as an apparatus for distinguishing the pitch of notes, accounts for its peculiar form thus:—He supposes it an organ in which the separate parts of the nerve may be exposed to excitation; for this purpose all the finest fibres of the nerve lie exposed to the influence of the sound-conducting medium, and that it has assumed the spiral form in order that the nerves may be arranged in the most convenient manner and within the smallest space. See his Fragment on the sense of hearing appended to his work, Zur vergleichenden Physiologie des Gesichtssinnes.

† Much remains to be done to determine the true means by which we judge of the direction of sound. The reader who may be interested on the subject will find some valuable observations and experiments in Autenrieth and Kerner's paper already quoted, Mr. Gough's paper in the Manchester Memoirs, vol. v., new series, and one by Venturi in Voigt's Magazin f. d. Neueste aus der Physik. Mr. Wheatstone's views are very briefly stated in Dr. Elliotson's Physiology.

theless communicate freely with each other. It would appear, however, from Meckel's description, that the ventricle is divided by a complete septum into two separate and distinct chambers in the *Crocodilus lucius*. In the Mammalia and Birds, where no intermixture of the venous and arterialized blood takes place, but where all the blood sent along the aorta has been previously subjected freely to the influence of the atmospheric air, we find two distinct hearts, which in the adult have no communication with each other; one the respiratory heart for the transmission of the blood through the lungs, the other the systemic heart for the transmission of the arterialized blood through all the textures of the body. These are not placed separate from each other, as in some of the Mollusca, which with a double circulation have an aquatic respiration, but are in juxta-position, and in fact many of the muscular fibres are common to both.

Human Heart *(normal anatomy)*.

Position.—The heart in the human species is lodged within the cavity of the thorax, occupies the middle mediastinum, and is enclosed in a fibro-serous capsule called pericardium. It is placed obliquely from above downwards and from behind forwards, in front of the spine and behind the sternum. The apex is directed downwards, forwards, and to the left side, projects into the notch on the anterior margin of the left lung, and in the quiescent state of the organ corresponds to the posterior surface of the cartilage of the sixth rib. The base looks upwards, backwards, and to the right side; is separated from the anterior part of the spine by the pericardium, œsophagus, aorta, and other parts which lie in the posterior mediastinum; and extends from about the fourth to the eighth dorsal vertebra. Its right margin rests upon the upper surface of the cordiform tendon of the diaphragm, by which it is separated from the stomach and liver; its left margin, which is more vertical, looks upwards and to the left side, and occupies an excavation on the inner surface of the left lung. Its posterior or flat surface rests partly upon the cordiform tendon of the diaphragm, having the pericardium interposed between them, and partly upon the inner concave surface of the left lung.* Its position corresponds to the union of the superior third of the body with the two inferior thirds. The lungs overlap the lateral, and part (rarely the whole) of the anterior portion of the heart, leaving only in general about an inch and a half or two square inches of the anterior surface of the right ventricle uncovered by the lung. It is of importance to remember this fact in percussing this region. The two sacs of the pleuræ, as they pass between the spine and sternum to form the mediastina, are interposed between the lungs and the heart. The heart is subject to slight change of position from the influence of the contiguous organs. It is carried a little downwards during violent contraction of the diaphragm, and is pressed upwards when the abdominal viscera are strongly compressed by the powerful contraction of the abdominal muscles. During expiration it has been seen to recede deeper into the thorax, and during inspiration again to come forward. When the body is bent to the right side, the apex recedes from the inner side of the left wall of the thorax; when bent to the left side, it is still more closely approximated to it.

* In the lower animals its position is vertical, occupying the mesial line of the body.

Form and external surface.—Its form is that of a flattened cone, and it is neither symmetrical as regards the mesial line of the body, nor (as we shall afterwards find) is the organ itself symmetrical. It presents an anterior and a posterior surface; a right inferior or acute margin; a left superior or obtuse margin; a base, and an apex. Its anterior surface, which is also turned towards the left side, is convex and considerably longer than the posterior and right, which is flattened. On the anterior surface of the heart we find a distinct groove, running nearly in the axis of the organ, passing from above downwards and from right to left, and containing the left coronary artery. A larger portion of the heart appears to lie to the right than to the left of this groove. There is a similar groove on the posterior surface, which is nearly vertical, shorter than the anterior, and contains a branch of the right coronary artery. These two grooves are connected with each other at or near the apex generally by a small notch, which is sometimes of sufficient depth to give the heart a bifid appearance.* These grooves mark the division of the heart into right and left sides. These terms are, however, more applicable when describing the organ in the lower animals; for in the human species the right side is also anterior and inferior, and the left side posterior and superior. Near the base of the heart and at the commencement of the longitudinal grooves, we find a circular groove deeper anteriorly than posteriorly, which contains in its posterior part the coronary vein and branches of the coronary arteries. This circular groove points out the division between the auricular and ventricular portions of the heart. Two large arteries are placed in front of the anterior part of this groove, the one posterior to the other. That nearest to the groove is the aorta, which springs from the base of the left ventricle; the one placed anterior is the pulmonary artery, which arises from the upper part of the right ventricle, and at its origin covers, along with that part of the ventricle to which it is attached, the commencement of the aorta. The ventricles form the principal part of the heart, and occupy the middle and apex, while the auricles are placed at the base. The base of the ventricles is connected to the base of the auricles. Two large veins, the superior and inferior venæ cavæ,

* This notch in the human heart looks like the rudiments of the fissure which in the Dugong and Rytina separates the two ventricles from each other nearly up to the base. This bifid form of the heart, which is merely a temporary condition in the human species, is permanent in the Dugong and Rytina. See *fig.* 264, vol. i. p. 576.

enter the right, and the four pulmonary veins pass into the left auricle. The apex of the heart is in general formed by the left ventricle alone. The base of the ventricles is cut obliquely from before backwards and from above downwards, and this explains how the anterior surface of the ventricles should be longer than the posterior. I have found the difference of length between the two surfaces in a considerable number of uninjected hearts to vary from half an inch, or rather less, to an inch. There is little difference between the length of the two ventricles in the uninjected heart. In the injected heart the anterior wall not only becomes elongated but much more convex, while the posterior wall is simply elongated, so that the difference in length between the anterior and posterior surfaces becomes increased. This change is more marked in the right ventricle than in the left. Cruveilhier states that he found the anterior surface of the left ventricle to exceed the posterior by nine or ten lines, and the anterior surface of the right to exceed the posterior by fifteen lines. These measurements have evidently been taken from injected hearts. On the surface of the heart, but more particularly upon the anterior surface of the right ventricle, a white spot, varying in size, is frequently observed. According to Baillie it is placed on the free or inner surface of the external serous membrane.* These spots are so common an appearance that it is somewhat difficult to believe that they are morbid. It is, however, very probable that they are the result of some inflammatory action.

Except in very emaciated subjects there is a greater or less quantity of fat occupying the auricular and ventricular grooves. This fat is generally in greater abundance in old subjects than in young, in accordance with the general law, that the adipose tissue in young persons is principally collected on the surface, and in old persons around the internal organs. When in greater quantity, it is deposited along the ramifications of the coronary vessels, and may, in cases of great obesity, almost completely envelope the surface of the heart. It is generally placed in greater quantities on the right side than on the left.

The human heart may be considered as consisting of two distinct hearts separated from each other by a fleshy septum, and which in the adult have in general no communication. The position of the fleshy septum separating the ventricles is marked by the ventricular grooves. Each heart consists of an auricle and ventricle which communicate by a large orifice. The right heart is occasionally termed the *pulmonic heart*, from its circulating the blood through the lungs; and as it circulates the dark blood it was termed the *cœur à sang noir* by Bichat. The left is occasionally called *systemic heart*, as it circulates the blood through the body generally, and is the *cœur à sang rouge* of Bichat. The auricles, from their immediate connexion with the large veins of the heart, sometimes receive the name of venous portion of the heart *(pars cordis venosa)*; and in the same manner the term arterial portion of the heart *(pars cordis arteriosa)* has been applied to the ventricles from their connexion with the large arteries. In describing the different cavities of the heart we shall take them in the order in which the blood passes through them.

Right auricle (auricula dextra vel inferior, atrium venarum cavarum). External surface.—To see the external form of the auricles properly it is necessary that they be first filled with injection. The right auricle is of an irregular figure, having some resemblance to a cube, and occupies the anterior, right, and inferior part of the base of the heart. It receives all the systemic venous blood of the body. Its inferior portion rests upon the diaphragm. Its largest diameter runs in a direction from behind forward, and from right to left. It is broadest posteriorly, becoming narrow and prolonged anteriorly, where it terminates in a small and free appendix, which, from its resemblance to the external ear of the dog, has been termed auricle. This appendix is generally serrated on the edges, more particularly on the external, and projects between the aorta and the upper and anterior margin of the right ventricle. To this smaller portion the term *proper auricle* has been given, while the larger portion has been called *sinus venosus*. This division of the auricle into proper auricle and sinus venosus is more distinct in the left than in the right auricle. The posterior surface of the right auricle is connected with the entrance of the two cavæ; its inferior with the base of the right ventricle; its internal with the left auricle; its outer surface is free; and anteriorly it is prolonged into the proper auricle. The junction of its internal surface with the corresponding surface of the opposite auricle is marked by an indistinct groove, which corresponds to the attachment of the septum separating the two auricles. Its external surface is placed on a plane internal to the outer edge of the right ventricle.

Internal surface.—The inner surface of the right auricle can be satisfactorily examined only when it is opened *in situ*. Its interior can be best exposed by making a longitudinal incision from the appendix to the orifice of the inferior cava, then opening the superior cava along its anterior surface and connecting the two incisions. The inner aspect of the right auricle presents four surfaces:—1. a posterior, where the two venæ cavæ enter; 2. an outer, upon which numerous muscular bands are seen standing in relief; 3. an internal, which is nearly smooth, forms the septum between the two auricles, and presents an oval depression, about the size of the point of the finger, called the *fossa ovalis*; 4. an anterior, formed by the appendix, and which also presents numerous muscular bundles. The superior or descending vena cava enters at the upper and posterior angle, the inferior or ascending cava at the

* In three hearts in which I carefully examined these white patches, I could distinctly trace the serous membrane over them. See the observations of M. Bizot (Mémoires de la Société Médicale d'Observation de Paris, tom. i. p. 347, 1836,) on these spots.

posterior and inferior. The entrance of the superior cava looks downwards and forwards in the direction of the body of the auricle; the entrance of the cava inferior is directed upwards, backwards, and inwards. These two orifices are circular, and that of the cava inferior is larger than that of the cava superior. The right margins of these veins are continuous with each other; the left or anterior margins are continuous with the auricle, which in fact appears at first sight to be formed by an expansion of the veins; hence the term sinus venosus. Around the left margin of the entrance of the cava superior there is a prominent band of muscular fibres; and around its right and posterior margin there is another but less prominent band placed at its angle of junction with the right margin of the inferior cava. This last band occupies the position of the supposed tubercle of Lower *(tuberculum Loweri)*. The cava inferior occasionally forms a dilatation immediately before it enters into the auricle. The venæ cavæ have properly no valves at their entrance into the auricles.* The fossa ovalis *(valvula foraminis ovalis, vestigium foraminis ovalis)*, which marks the position of the foramen ovale by which the two auricles communicated freely with each other in the fœtus, is seen at the lower and right portion of the auricle, partly placed in a notch in the posterior and lower part of the fleshy portion of the septum, and partly in the upper part of the vena cava ascendens as it passes in to form the sinus venosus. The upper and anterior margins of this depression are thick and projecting *(annulus seu isthmus Vieusseni, columnæ foraminis ovalis)*. This was supposed by Vieussens to prevent the blood of the cava superior from falling into the cava inferior, an effect which Lower also imagined might be produced by the tubercle which he supposed was placed at the junction of the two veins. We have already pointed out that the orifices of the two veins are placed in different directions, which is sufficient to prevent the descending column of blood falling directly upon the ascending. The posterior and lower margins of the fossa ovalis are ill-defined. The surface of the depression is sometimes smooth, at other times uneven and reticulated. Between the upper margin of the depression and the annulus or thickened edge of the fossa ovalis we frequently find a small slit passing from below upwards, and forming a valvular opening between the two auricles. The remains of the Eustachian valve *(foraminis ovalis anterior valvula)* may be seen running from the anterior and left side of the entrance of the cava inferior to the left side of the fossa ovalis, where it attaches itself to the annulus. This valve exhibits very various appearances in the adult: sometimes it is very indistinctly marked, at other times it is sufficiently apparent, and much more rarely it approaches the size which it presents in fœtal life. It is frequently reticulated. Its convex margin is attached to the surface of the vein and auricle; its concave margin is free; its superior and convex surface looks towards the auricle, and its lower and concave surface towards the entrance of the vein. Placed to the left of the Eustachian valve, and between it and the upper and outer part of the base of the ventricle, is the orifice of the coronary vein. A valve *(valvula Thebesii)*, the free and concave margin of which is directed upwards, covers the entrance of this vein. It is sometimes imperfect, occasionally reticulated. Instead of one coronary valve we may have two or more, one placed behind another. These two valves, viz. the Eustachian and Thebesian, are formed by a reduplicature of the lining serous membrane of the heart.

* The Eustachian valve cannot be considered as essentially connected with the cava inferior in the adult.

The Eustachian valve frequently, however, contains some muscular fibres at its fixed margin. A number of small openings *(foramina Thebesii)* may be seen on the inner surface of the auricle, some of which lead into depressions; others are the orifices of small veins. The muscular fibres projecting from the anterior and outer surface, already alluded to, pass vertically from the auricle to the edges of the auriculo-ventricular opening. These, from their supposed resemblance to the teeth of a comb, are termed *musculi pectinati*. Smaller bundles cross among the larger, giving the inner surface at this part a reticulated appearance. At the places where the transverse fibres are deficient, the outer and inner serous membranes of the heart lie in close contact. In the floor or base of the auricle there is a large oval opening leading into the ventricle *(right auriculo-ventricular opening)*, having its upper margin surrounded by a white ring. The upper part of this ring has a yellowish colour from the auricular tendinous ring being here translucent, so that the fat lying in the auricular groove is seen through it.

Right ventricle (ventriculus anterior, v. dexter, v. pulmonalis.) External surface.—The right ventricle occupies the anterior and inferior portion of the right side of the heart. Its form is pyramidal, the base looking towards the auricle, its apex towards the apex of the heart. Its walls are much thicker than those of the auricle. This thickness arises from the increased number of its muscular fibres.

Internal surface.—The right ventricle may be best opened by making an incision along its right edge from the base to the apex, and another from the root of the pulmonary artery along its anterior surface near the septum to join the other at the apex. On examining the interior, its internal and posterior walls are seen to be common to it and the opposite ventricle, the anterior and external walls to belong exclusively to itself. Its posterior and internal walls are convex, its anterior and internal concave. Its posterior and external walls are decidedly shorter than its internal and anterior. Its parietes are rather thinner at their attachment to the anterior margin of the septum than along its posterior margin. They are also considerably thinner at the apex than towards the base. A number of fleshy columns *(columnæ carneæ, teretes lacerti)* project from the inner surface. We will find that they present three different appearances in both ventricles. 1. The more numerous are attached to the walls of the ventricles by their two extremities, so that we can introduce a probe under the middle part. These divide and subdivide in a variety of ways. 2. Others are attached to the walls of the ventricles by the whole of their external surface, while their internal surface stands in relief from these walls. 3. Others are fixed to the walls of the ventricle by their lower extremities, are perfectly free in the rest of their course, and terminate either in a blunt extremity or in several short processes. These last are few in number, nearly vertical, and have received the name of *musculi papillares.* These columnæ carneæ form an intricate network on the inner surface of the ventricle, and some of them occasionally cross its cavity near the apex. They are more numerous on the anterior and external than on the posterior and internal walls. Two large openings are placed at the base of the ventricle. The larger, oval in the empty, somewhat circular in the distended heart, is the right auriculo-ventricular opening, the upper margin of which was already seen in the right auricle. The smaller is circular, is placed anterior and to the left, is about three-quarters of an inch higher than the larger, and is the orifice of the pulmonary artery. That portion of the ventricle from which the pulmonary artery springs is prolonged upwards above the level of the rest of the ventricle. To this prolongation Cruveilhier has given the name of the infundibulum.*

The inner surface, particularly the posterior part of this infundibulum, is smooth and deprived of columnæ carneæ. Around the auriculo-ventricular opening a valve is placed, the fixed margin of which is attached to the circumference of the opening; the free margin projects into the ventricle. This valve, which forms a complete ring at its attachment, terminates in several apices, three of which are much more prominent than the rest, and on this account it receives the name of the tricuspid or triglochin valve *(valvula triglochis v. tricuspis).* The anterior of these three portions, which is placed on the side nearest to the orifice of the pulmonary artery, is more prominent and broader than the posterior and internal portions, and is separated from them by deeper notches than these two are from each other. From this circumstance some are inclined to consider this valve as consisting of two portions only. It contains several small tubercles at its free margin. This valve, like the other valves at the arterial and left auricular orifices, to be afterwards described, is composed of a reduplicature of the lining membrane containing some tendinous fibres between them. It is translucent and of great toughness. A number of tendinous cords *(chordæ tendineæ)* pass between the apices of these valves and the inner surface of the ventricle. Though the arrangement of these chordæ tendineæ is not uniform in all cases, yet it is of importance to remark, as prominently bearing upon the discussions connected with the manner in which these valves at the auriculo-ventricular opening perform their office, that their general distribution is the same, and evidently intended for a specific purpose.* The greater part of these chordæ tendineæ spring from the free and blunt extremities of the third kind of columnæ carneæ *(musculi papillares)* which we have described; some from the other two kinds, and others again from the smooth portion of the septum, and more particularly from the lower part of the smooth surface which leads into the infundibulum. These tendinous cords diverge to reach their insertion, some of them dividing and subdividing two or three times, occasionally crossing each other, and are inserted principally into the apices and margins of the notches which separate the valve into its three portions. A few of these cords pass between the columnæ and inner surface of the ventricle without being attached to the valve. The internal lip of the valve has its lower margin tied more closely down to the surface of the ventricle by these cords than the other two lips; besides several short cords frequently pass between the internal surface of the ventricle and the ventricular surface of that portion of the valve. At the exit of the pulmonary artery from the upper, anterior, and left part of the ventricle, three valves are placed *(fig.* 268). These from their form have received the name of semilunar or sigmoid valves. Their fixed margins are convex, and adhere to the tendinous ring to which the origin of the artery is attached; their free edges, from the presence of a small triangular tubercle in the middle of each *(corpus Arantii, corpusculum Morgagni, corpus sesamoideum,)* form two slight semilunar curves *(fig.* 268). The extremities of the curved attached edges look in the course of the artery. When the blood rushes from the ventricle into the pulmonary artery, the valves are laid against the sides of the vessel, and the free edge becomes vertical; when, on the other hand, a portion of the blood falls back towards the ventricle, the valves are thrown inwards and completely occupy the calibre of the artery. At this time the concave surfaces of the valves are directed in the course of the artery, the convex surfaces towards the ventricle. These valves may be distinguished by the terms anterior, posterior or left, and superior or right. The suggestion of

* This part is very minutely described by Wolff under the term *conus arteriosus.* Under the term *infundibulum* Wolff included a larger portion of the ventricle, apparently that portion placed above a line drawn from the upper and right margin of the ventricle obliquely downwards to the anterior fissure. As the upper part of the right ventricle becomes gradually narrower, he supposed that it increases the velocity and impetus of the blood as it is driven from the ventricle.—Acta Acad. Imper. Petropol. pro anno 1780, tom. vi. p. 200. 1784.

* Mr. T. W. King states (Guy's Hospital Reports, no. iv. p. 123.) that there is a disposition in the chordæ tendineæ from each fleshy column to attach themselves to the adjoining edges of two lips of the valve, as in the left ventricle.

Fantonus, that as three circular valves meeting in the axis of a canal would leave a small space in the axis itself, so the use of these corpora Arantii may be to fill up the interval which would thus otherwise be left, has generally been adopted.* These valves are thin and transparent, yet of considerable strength. Their attached are thicker than their free margins. That portion of the pulmonary artery which is placed immediately above the attachment of the semilunar valves bulges out and forms three projections, named from their discoverer *sinuses of Valsalva.* These sinuses are more apparent in old than in young persons.

Left auricle (auricula sinistra; a. posterior; atrium seu sinus venarum pulmonalium, a. aorticum). External surface.—It occupies the upper, posterior, and left part of the base of the heart, and receives the blood brought back from the lungs by the pulmonary veins. The only part of the left auricle that can be fairly seen after the pericardium has been opened, and none of the parts disturbed, is the appendix. To see it properly the pulmonary artery and aorta must be cut through and thrown forwards. It is of a very irregular shape, some anatomists comparing it to an oblong quadrilateral, others to an irregular cuboidal figure. Posteriorly it rests upon the spinal column, from which it is separated by the parts mentioned in describing the position of the heart itself, and appears as if confined between the spine and base of the heart,—a fact which has been considerably insisted upon in some of the explanations of the tilting motion of the heart. Superiorly and to the right it is connected to the auricle of the opposite side. More anteriorly and still to the right it is free, and is separated from the right auricle by the aorta and pulmonary artery. Its base is connected to the base of the corresponding ventricle. The auricle is prolonged forwards at first to the left, but bends towards the right before terminating. This prolongation is the appendix or proper auricle. This appendix is longer, narrower, more curved, more denticulated on the edges, and more capacious than the corresponding part of the right auricle, and projects along the left side of the pulmonary artery, a little beyond and below the anterior margin of the left ventricle. The two left pulmonary veins enter the posterior and left side, and the two right pulmonary veins enter the posterior and right side of the auricle.

The left auricle, like the right, has been divided into sinus venosus and proper auricle. *Inner surface.*—The inner surface may be divided into, 1st, a posterior, which is smooth, and which belongs exclusively to itself; 2d, an anterior, which communicates by a round opening with the cavity of the appendix; 3d, a right, the anterior and greater part of which is formed by the septum of the auricles. Upon this is observed the fossa ovalis, but without the distinct depression which it presented in the right auricle. The upper margin of the valve, between which and the upper thick edge of the fossa ovalis the oblique aperture exists, which we formerly stated to be frequently observed here, is often distinctly seen in the left auricle. The valvular nature of this small slit must prevent any intermixture of the blood of the two sides. This margin, when present, looks forwards and to the left. The two right pulmonary veins open upon this surface immediately posterior to the septum, and between the septum and posterior surface. 4th, A left, into which the two pulmonary veins of the left side open.

The pulmonary veins of the two lungs are thus separated from each other by the whole breadth of the auricle. The veins of the same side open into the auricle, the one immediately below the other, so that they occupy the whole height of the auricle. The superior is generally the larger. The two veins of the same side occasionally enter by a common opening, or this may occur on one side only. At other times we may have five openings. These veins, like the cavæ, have no valves at their termination in the auricle. At the lower and anterior part of the auricle a large oval opening presents itself. This is the left auriculo-ventricular opening, and like that on the right side it has its upper margin surrounded by a white tendinous ring. This ring, unlike that of the right side, is everywhere sufficiently opaque to prevent the fat placed in the auricular groove to be seen through it.

The inner surface of the left auricle differs materially from that of the right in its greater smoothness, and the consequently smaller number of its musculi pectinati. In fact, the only place in which these are observed, and that too to a comparatively smaller extent than in the corresponding portion of the right, is the appendix. This arises from the greater strength of the left auricle, the muscular fibres being so closely laid together as not to leave any interval between them.

Left ventricle (ventriculus sinister, v. posterior, v. aorticus.) External surface.—It is of a conical shape, and occupies the posterior and left part of the heart. It is rounded and does not present the flattened appearance of the right ventricle. It projects downwards beyond the right, and forms the apex of the heart. Though the left proceeds lower down than the right ventricle, that portion of the right called infundibulum or conus arteriosus mounts higher than any part of the left. The left is on the whole a little longer than the right. The circumference of the base of the right ventricle is greater than that of the left, exceeding it in some cases in the injected heart by about two inches.

Internal surface.—This ventricle is best opened by making an incision close upon the

* I find that the late Dr. A. Duncan, jun. has justly remarked that there is no necessity for calling in the aid of the corpora Arantii to produce the complete obstruction of the calibre of the artery, as the free edges of these valves, when they are thrown inwards, do not exactly lie in close apposition but overlap each other. Besides these bodies are occasionally very indistinct, and frequently do not project beyond the free margin of the valves, especially in the pulmonary semilunar valves.

anterior fissure from the apex near to the commencement of the aorta, then another incision midway between the posterior fissure and left edge of the ventricle, commencing near the base and carrying it downwards to join the other at the apex. The anterior and right parietes of the internal surface are formed by the septum; the posterior and left belong exclusively to itself. The walls of the left ventricle are considerably thicker than those of the right, and remain apart, while those of the right fall together. As connected with this we may observe that the septum is concave towards the left ventricle and convex towards the right. As the obstacles to be overcome in transmitting the blood through the body are greater than those to be overcome in transmitting it through the lungs, so is the left ventricle thicker than the right. It is important to remark, as connected with the pathology of spontaneous rupture of the heart, that the walls of the left, like those of the right ventricle, are considerably thinner at the apex than towards the base.* The anterior and right parietes are longer than the posterior and left. The columnæ may be arranged into three kinds, such as we have described in the right ventricle. They are not so numerous in the left ventricle as in the right. The greater number are also smaller, and are principally placed upon the posterior and left wall, near the apex of which they form deep areolæ.† The upper part of the septum which leads to the aortic opening, which we shall presently describe, is quite smooth. In the base of the ventricle we find two openings placed closely together; one of these, the smaller, is placed to the right and a little anterior, is the commencement of the aorta, and occupies the upper and right corner of the ventricle; the other is larger and placed to the left and a little posterior, and is the auriculo-ventricular opening of this side. The aortic opening is only separated from the auriculo-ventricular opening by the tendinous ring, and from the orifice of the pulmonary artery by the upper part of the septum. A valve resembling the tricuspid is attached to the tendinous ring around the auriculo-ventricular opening, which, from being more decidedly divided into two lips, is termed *bicuspid*, and from its fanciful resemblance to a bishop's mitre has generally received the name of *mitral valve*. Like the tricuspid it forms a complete ring around the margin of the auriculo-ventricular opening. The anterior lip of the valve in the quiescent state of the heart hangs suspended between the auriculo-ventricular opening and the origin of the aorta, and is considerably larger and more moveable than the posterior, which is smaller and more limited in its movements. The mitral valve is formed in the same manner as the tricuspid, and is somewhat thicker and stronger, and like it contains a number of tubercles in its free margin. The large anterior lip of the mitral valve projecting downwards into the ventricle was described by Lieutaud and by others since his time as dividing the ventricle into two portions, an aortic and a ventricular. These are separated from each other at the upper part by the valve only; at every other part they communicate with each other. The same authors have described the larger lip of the tricuspid valve as effecting a similar division of the pulmonic ventricle. Two of the columnæ carneæ in the left ventricle belong to the third kind (musculi papillares) already described, and are much stronger than any to be found in the right ventricle. They are attached to the lower part of its cavity, pass upwards, and about the middle of the ventricle terminate in a blunt extremity, from which a number of chordæ tendineæ pass to be attached to the margins of the mitral valve. Bouillaud describes these two columnæ as uniformly occupying the same position, one being placed at the junction of its left and posterior walls to form the left margin of the heart; the other on the posterior wall near its junction with the posterior margin of the septum.* Each of these fleshy columns consists of two fasciculi, of an anterior and superior, and of a posterior and inferior. The posterior and inferior fasciculus is shorter and less strong than the anterior. The chordæ tendineæ of the two anterior or internal fasciculi proceed to attach themselves to the margins of the anterior or larger lip of the valves, those from one fasciculus passing to one edge of the lip, and those of the other fasciculus to the other edge. As these chordæ tendineæ proceed from the fasciculi to the valve, they diverge from those of the same fasciculus, but converge towards those of the other fasciculus. (*Fig.* 269 shews the attachment of the chordæ tendineæ of the two anterior or internal fasciculi.) The chordæ tendineæ from the posterior fasciculi pass in a similar manner to be attached to the posterior lip. The posterior lip is fixed closer in its situation than the anterior, by the chordæ tendineæ, and this is frequently increased by some of these cords passing from the walls of the ventricle to be attached to the ventricular surface of the valve, sometimes nearly as high as the fixed margin of the valve. These chordæ tendineæ are stronger, fewer in number, and less subdivided than those in the right ventricle. Several of them pass between the fleshy columns without being attached to the valves, as in the right ventricle. Though the description here given is not perfectly uniform in every case, but is liable to frequent varieties,—by the non-divi-

* The circular arrangement of the muscular fibres around the apex (*fig.* 274) must have the effect of rapidly approximating the inner surfaces of the ventricles at the apex during their systole, more particularly when the apex is elongated, as in the heart of the horse, and thus prevent the pressure from falling upon the extremity of the apex, where it is very weakly protected.

† Laennec has erroneously stated in general terms that the columnæ of the right ventricle are larger than those of the left.

* I have satisfied myself by numerous examinations, of the accuracy of Bouillaud's account of the position of these musculi papillares and the arrangement of the chordæ tendineæ in the human heart. I have found them occupying a similar position in the heart of the horse, ox, ass, sheep, pig, dog, rabbit, hedge-hog, and some birds, and suspect that this will be found a general law in all the warm-blooded animals.

sion of the musculi papillares into two fasciculi; by their subdivision, on the other hand, into several smaller bundles, but so grouped that the position of the smaller corresponds to the larger; and by the smaller columns furnishing a certain number of the cords usually given off by the larger; yet there appears to be a remarkable similarity between the course and arrangement of the chordæ tendineæ in all cases. The object of this we will afterwards see when inquiring into the precise manner in which these valves prevent regurgitation into the auricle during the systole of the ventricle. The origin of the aorta is furnished with three semilunar valves (*fig.* 269), which very exactly resemble in their position, shape, and appearance those placed at the commencement of the pulmonary artery. They are somewhat stronger, and have the corpora sesamoidea generally larger than those in the pulmonary artery. Behind these valves are three dilatations (*sinuses of Valsalva*) upon the commencement of the aorta, similar to, but more prominent, than those at the commencement of the pulmonary artery (*fig.* 269).

It was maintained by several of the older eminent anatomists that the semilunar valves must necessarily cover the entrance of the coronary arteries,* and that they were filled, not during the passage of the blood along the aorta, but by the falling back of part of it during the diastole of the heart, or as Boerhaave expressed it, "Hæ arteriæ sunt in diastole, dum reliquæ corporis arteriæ in systole constituuntur."† Haller mentions two circumstances which must satisfy every one, if any thing more than the bare inspection of the parts was necessary, that the coronary arteries are at least *generally* filled in the same manner as the other arteries which arise from the aorta, and these are—1st, the result of experiments on living animals, where the blood is seen to spring per saltum from the cut coronary arteries during the systole of the heart; 2d, when a fœtus is injected by the umbilical vein, the coronary arteries are also filled. More lately, however, Vaust‡ has maintained that the origin of the coronary arteries is generally covered by the semilunar valves. He states that he has injected a great number of hearts from the pulmonary veins; in some of these the injection passed into the coronary arteries, but in by much the greater number these vessels did not contain a single drop of injection. On examination of these cases he found that the semilunar valves entirely covered the origin of the coronary arteries. In attempting to ascertain this point on the uninjected heart, we must bear in mind the different conditions of the aorta in the living body and after death. In the dead body the sinuses of Valsalva are collapsed, so that the semilunar valves can be laid over the origin of the coronary arteries in some cases, where they would become free when the sinuses are distended as they are with blood in the living body. Making every allowance for this source of fallacy, I am satisfied that I have seen one or two cases in which these valves appeared fairly to cover the origin of the coronary arteries. Supposing that the origin of the coronary arteries were covered in some instances by the valves, it would in all probability be a matter of little moment, as far as the efficiency of the circulation through these arteries was concerned, as long as the aorta retained its elasticity, for the force with which it drives the distending fluid backwards during the diastole of the heart (a force which can be ascertained in the dead body) would be sufficient to carry on the circulation. The circumstances would, however, become very much altered in those cases which are sufficiently common in advanced age, where the aorta has from disease of its coats entirely lost its elasticity, and the coronary arteries have also become studded with calcareous matter, unless we suppose what could scarcely happen, that the blood contained in the sinuses is forced along the arteries when the valves are thrown outwards.*

Septum of the ventricles.—The septum between the ventricles is triangular, and the apex extends to the point of the heart. It is of considerable thickness at the base, but becomes thinner at the apex. Its position is oblique like that of the heart. It is concave towards the right ventricle, and convex towards the left. From the slight rotation of the heart on its axis, the anterior surface of the septum is directed towards the right side, and the posterior towards the left. It is composed, like the other walls of the ventricle, principally of muscular fibres, lined on the one side by the internal serous membrane of the right ventricle, and on the other side by the corresponding membrane of the left.

We have preferred considering the relative thickness of the parietes, the different capacities of the several cavities of the heart, the relative dimensions of the auriculo-ventricular, aortic, and pulmonary orifices, and the size and weight of the heart under distinct heads, not only as this enables us to obtain a more connected view than we could otherwise have done of points upon which there are many conflicting opinions, and upon which it is so frequently necessary to possess, as far as we possibly can, accurate notions in deciding upon the normal or abnormal state of the organ, but we were also afraid that if mixed up with the other parts of the descriptive anatomy they would have

* Morgagni was doubtful in this matter, and thought that he had observed them sometimes covered by the valves, at other times free. *Advers.* v., *Animadver.* xxv.

† Institut. Med. 183.

‡ Recherches sur la Structure et les Mouvements du Cœur, p. 22, (1821.)

* Among the numerous and striking examples which the history of medical science furnishes us of the powerful tendency which preconceived notions have, if not powerfully guarded against, of influencing our observations of the plainest facts, we may instance the statements of Petriolus on this question. He, apparently deeply imbued with the old hypothesis that the heart is the seat of courage, maintained that in bold and carnivorous animals the coronary arteries were above the valves; in timid and herbivorous animals, on the contrary, they arose behind the valves, while in man they were of uncertain origin, as he was bold or timid.

rendered it more complicated. We will find that considerable differences in these respects may exist between different hearts and between different parts of the same heart, which, to judge from the perfect regularity with which all its functions proceeded before death, must be considered as perfectly healthy; and it is from this want of uniformity in the different parts of apparently healthy hearts that we can in some measure account for the discrepant statements on this subject which exist in the works of the most celebrated and accurate anatomists.

Thickness of the walls of the several cavities of the heart.—The left auricle is somewhat thicker than the right, and the left ventricle very considerably thicker than the right. Bouillaud* found the average thickness of the walls of the left auricle in four healthy hearts to be $1\frac{1}{2}$ lines, and that of the right auricle to be 1 line. Lobstein has rather strangely stated that the right auricle is twice the thickness of the left. He makes the thickness of the right auricle to be 1 line, and that of the left to be only $\frac{1}{2}$ line. Laennec reckons the relative proportion of the thickness of the left ventricle to the right as rather more than 2 to 1. Bouillaud found the average thickness of the right ventricle at its base in a great number of cases to be $2\frac{1}{2}$ lines, and that of the left ventricle at the same part to be 7 lines. Cruveilhier† states the proportionate thickness of the right to the left ventricle as 1 to 4, or even as 1 to 5. According to Soemmerring,‡ the relative thickness of the two ventricles is as 1 to 3. Andral§ states that in the adult the thickness of the left to the right ventricle is as 2 to 1, but in infancy and in old age it is as 3 or 4 to 1.

M. Bizot has lately published the results of the careful measurements of the healthy heart in one hundred and fifty-seven individuals of all ages.‖ The greater part of these observations were collected at La Pitié, under the auspices of Louis. According to M. Bizot, the heart goes on increasing in all its dimensions—length, breadth, and thickness—up to the latest periods of life. The growth is, however, more rapid before twenty-nine years than after that age. While, then, the muscles of animal life are diminishing in size in advanced life, the heart is still increasing in bulk. The heart of the male is, on an average, larger than that of the female at all the different stages of life. M. Bizot remarks that the longitudinal section of the left ventricle is fusiform, the thickest part being situated at the junction of the superior third with the middle third.¶ The thickness of this ventricle goes on increasing from youth up to advanced age. The following are a few of the measurements of the thickness of the walls of the ventricles given by M. Bizot.

Left ventricle, male.

Age.	Base.	Middle part.	Apex.
1 to 4 years	3 lines.	$2\frac{9}{10}$ lines.	$1\frac{9}{10}$ line.
50 to 79 years ..	$4\frac{37}{38}$ „	$5\frac{29}{38}$ „	$4\frac{1}{39}$ „
Average from 16 to 79 years ..	$4\frac{65}{122}$ „	$5\frac{19}{122}$ „	$3\frac{95}{122}$ „

Left ventricle, female.

Age.	Base.	Middle part.	Apex.
1 to 4 years	$2\frac{9}{10}$ lines.	$2\frac{7}{8}$ lines.	$2\frac{1}{10}$ lines.
50 to 89 years ..	$4\frac{1}{2}$ „	5 „	$3\frac{3}{4}$ „
Average from 16 to 89 years ..	$4\frac{7}{8}$ „	$4\frac{1}{5}$ „	$3\frac{13}{30}$ „

Thickness of right ventricle.—The thickest portion of the right ventricle is not placed, as M. Bizot remarks, at the same point as in the left. In the right ventricle it is at the base of the heart, 4 lines below the tendinous ring. The thickness of the walls of the right ventricle, unlike the left, remains more nearly stationary at the different periods of life. They are, however, a little thicker in advanced age than at an earlier period of life.

Right ventricle, male.

Age.	Base.	Middle part.	Apex.
1 to 4 years	$\frac{9}{10}$ line.	$\frac{6}{10}$ line.	$\frac{5}{10}$ line.
30 to 49 years ..	$1\frac{39}{46}$ „	$1\frac{7}{23}$ „	$\frac{43}{46}$ „
50 to 79 years ..	$2\frac{1}{19}$ „	$1\frac{53}{100}$ „	$\frac{51}{64}$ „
Average from 16 to 79 years ..	$1\frac{113}{124}$ „	$1\frac{99}{244}$ „	$1\frac{2}{61}$ „

Right ventricle, female.

Age.	Base.	Middle part.	Apex.
1 to 4 years	$1\frac{3}{10}$ line.	$\frac{7}{8}$ line.	$\frac{13}{24}$ line.
30 to 49 years ..	$1\frac{19}{22}$ „	$1\frac{13}{31}$ „	$\frac{23}{27}$ „
50 to 79 years .	$1\frac{1}{4}$ „	$1\frac{1}{4}$ „	1 „
Average from 15 to 59 years ..	$1\frac{3}{5}$ „	$1\frac{7}{24}$ „	$\frac{673}{720}$ „

Care was taken to make all these measurements at points where there were no columnæ carneæ.

The thickness of the septum ventriculorum, according to Meckel, is 11 lines at its base. Bouillaud obtained the same results in the only case in which he appears to have measured the thickness of the septum. M. Bizot has given measurements of the ventricular septum at six different periods of life, from which I have selected the following.

	Male.	*Female.*
Age.	Middle part.	Middle part.
1 to 4 years......	$3\frac{1}{10}$ lines.	$2\frac{3}{5}$ lines.
16 to 29 years....	$4\frac{17}{18}$ „	$4\frac{11}{14}$ „
50 to 79 years....	$5\frac{1}{3}$ „	$5\frac{3}{19}$ „

The thickness of the septum ventriculorum goes on increasing in thickness from infancy to an advanced period of life.

Relative capacities of the several cavities.—The most conflicting statements exist upon this point, and we find it perfectly impossible to come to any satisfactory decision. Each cavity of the heart is supposed, when moderately distended, to contain rather more than two ounces of fluid. The auricles may be safely said to be of less capacity than the ventricles; and this disparity is strikingly marked in the larger animals, as the horse and ox. The right auricle is generally allowed to be larger than the left, and the difference,

* Traité Clinique des Maladies du Cœur, t. i. p. 53. 1835.

† Anatomie Descriptive, t. iii. p. 17.

‡ De Corporis Humani Fabrica, t. v.

§ Anatomie Pathologique, t. ii. p. 283.

‖ Mémoires de la Société Médic. d'Observation de Paris, t. i. p. 262. 1836.

¶ Op. cit. p. 269 and 284.

as stated by Cloquet and Cruveilhier, is as 5 to 4. The right ventricle is generally found larger than the left after death. This difference has been very variously estimated by different anatomists. Some, as Winslow, Senac, Haller, Lieutaud,* and Boyer, have maintained that there is a marked disparity between the capacities of the two cavities, while Meckel, Laennec, Bouillaud, Portal, and others believed that this difference is to a smaller extent. Lower was the first to maintain that both ventricles are of equal size. Sabatier, Andral, and others have supported this opinion; while Cruveilhier† states that he has satisfied himself, from comparative injections of the two cavities, that the left ventricle is a little larger than the right. Gordon has occasionally found both ventricles of equal size, and Portal has seen them of the same size in young persons. Santorini and Michelattus believed that, though the capacity of the left ventricle appears a little smaller than that of the right, yet that the superior force of the left auricle over the right dilates the left ventricle sufficiently to render it equal to the right.

The majority of anatomists, however, have always maintained that the capacity of the right ventricle is greater than that of the left, and have adduced the following arguments in support of this opinion: 1, that the right auricle, right auriculo-ventricular orifice, and origin of the pulmonary artery are larger than the auricle and corresponding orifices of the opposite side: 2, that when both ventricles have been filled with water, mercury, or wax, more of these substances is found contained within the right than the left: 3, the experiment of Legallois‡ shew that when an animal is bled to death, this disparity between the size of the ventricles is still found. Those who maintain that the capacity of these two cavities is equal do so on the following grounds:—1, that as the walls of the right ventricle are weaker than those of the left, when the same force is used in injecting both, the right must, as a matter of course, be more dilated than the left. 2. Sabatier ingeniously suggested that, as during the last moments of life the passage of the blood from the right side of the heart is generally impeded, producing engorgement of that side, while the left side was generally empty, this might account for the greater size of the right ventricle. 3. Sabatier and Weiss§ maintained that in those cases where the kind of death was such that the right side of the heart could not be engorged as in fatal hæmorrhage, no difference between the capacity of the two sides could be observed. 4. The experiments of Sabatier, in which, after tying the aorta and producing engorgement of the left side of the heart, while the right side was emptied by a wound made into the vena cava or pulmonary artery, the left ventricle was found to be of greater capacity than the right.

M. Bizot maintains that the capacity of the ventricles goes on increasing from youth up to old age; and that this, contrary to the opinion of Beclard, is not so rapid in old age as in the earlier periods of life. The following are a few of M. Bizot's measurements:—

Age.	Length.	Breadth.
Left ventricle, male.		
1 to 4 years	20 lines.	31 lines.
50 to 79 years	36 „	$56\frac{2}{3}$ „
Average from 15 to 79 years	$34\frac{24}{61}$ „	$54\frac{9}{61}$ „
Left ventricle, female.		
1 to 4 years	$18\frac{1}{2}$ lines.	$29\frac{5}{8}$ lines.
50 to 79 years	31 „	$49\frac{1}{2}$ „
Average from 15 to 89 years	$31\frac{1}{30}$ „	$48\frac{23}{30}$ „
Right ventricle, male.		
1 to 4 years	$20\frac{1}{5}$ lines.	$47\frac{4}{5}$ lines.
50 to 79 years	$37\frac{1}{3}$ „	87 „
Average from 15 to 79 years	$37\frac{14}{61}$ „	$82\frac{11}{60}$ „
Right ventricle, female.		
1 to 4 years	$18\frac{7}{8}$ lines.	$44\frac{1}{8}$ lines.
50 to 79 years	$35\frac{11}{19}$ „	76 „
Average from 15 to 89 years	34 „	$76\frac{2}{3}$ „

Every one must confess that the right ventricle is generally found larger after a natural death in the human subject than the left; and it appears exceedingly probable that these two cavities, in the healthy state of the organ, contain different quantities of blood during life. As the capacity of the auricles is rather smaller than that of the ventricles, it may be asked how can the auricles furnish blood sufficient to distend the ventricles? We shall afterwards more particularly explain that the blood passes from the auricles into the ventricles at two different times during the interval between each contraction, viz. at the moment of its relaxation, and again during the contraction of the auricles. Various attempts have been made by those who maintain that the right side of the heart is larger than the left, to explain how the equilibrium of the circulation can be maintained. Helvetius* supposed that this could be accounted for by the diminution which the blood suffered in passing through the lungs; and in proof of this he erroneously maintained that the pulmonary arteries were larger than the pulmonary veins. Legallois believed that this could be explained (as appears very probable) by the greater size of the right auriculo-ventricular opening, allowing a greater reflux of blood back again into the auricle, during the systole of the ventricles.

* Mémoires de l'Academie Roy. des Sciences, t. viii. p. 561, 1754. Lieutaud's authority is sometimes quoted in support of the opinion that these cavities are of equal capacity.

† Anatomie Descriptive, t. iii.

‡ Dictionnaire des Sciences Méd. t. v. p. 436. These experiments were performed upon dogs, cats, guinea-pigs, and rabbits.

§ De dextro cordis ventriculo post mortem ampliore.

* Mémoire de l'Acad. Roy. 1718, p. 285.

Relative dimensions of the auriculo-ventricular orifices.—The right auriculo-ventricular orifice is larger than the left, as was correctly stated by Portal.* According to Cruveilhier, the largest diameter of the right auriculo-ventricular opening which is antero-posterior is from 16 to 18 lines, and its smallest diameter is 12 lines; while the largest diameter of the left auriculo-ventricular opening, which is directed almost transversely, is from 13 to 14, and its smallest is from 9 to 10 lines. Bouillaud gives the results which he obtained from the accurate measurement of the circumference of these two openings in three perfectly healthy hearts. The average circumference of the left auriculo-ventricular opening was 3 inches $6\frac{1}{3}$ lines: the maximum was 3 inches 10 lines, and the minimum was 3 inches 3 lines. The average circumference of the right auriculo-ventricular opening was 3 inches 10 lines: the maximum was 4 inches, and the minimum was 3 inches 9 lines.

Circumference of the aortic and pulmonary orifices.—The circumference of the aortic and ventriculo-pulmonary orifices is sometimes nearly equal; more generally, however, the ventriculo-pulmonary is the larger. Bouillaud gives the following measurements of these openings taken from four healthy hearts:—Average circumference of the aortic opening, 2 inches $5\frac{1}{2}$ lines: the maximum 2 inches 8 lines, and the minimum 2 inches 4 lines. Average circumference of the ventriculo-pulmonary opening, 2 inches $7\frac{3}{4}$ lines: the maximum 2 inches 10 lines, and the minimum 2 inches 6 lines. I have found this difference between the circumference of these two openings marked distinctly at seven years of age. M. Bizot has given measurements of the arterial orifices, of which the following is the average.

Aartic orifice, male.

Average from 16 to 79 years.. $45\frac{17}{33}$ lines.

Aortic orifice, female.

Average from 16 to 89 years .. $41\frac{1}{3}$ lines.

Pulmonary orifice, male.

Average from 16 to 79 years .. $54\frac{17}{61}$ lines.

Pulmonary orifice, female.

Average from 16 to 89 years .. $48\frac{1}{4}$ lines.

Size and weight.—Laennec has stated that the *size* of the heart in general nearly corresponds to the closed fist of the individual. This can only be considered as a loose approximation, as the size of the hand may vary in different individuals otherways resembling each other, either from original conformation or from dissimilar modes of life; and, besides, the size and form of the healthy heart itself may vary sufficiently to effect an apparent difference in these respects.

The average length of the heart, according to Meckel, is $5\frac{1}{2}$ inches, of which about 4 inches are to be allowed for the ventricles, and $1\frac{1}{2}$ inch for the auricles. Bouillaud found that a line drawn from the origin of the aorta to the point of the heart ranged, in nine healthy hearts, from 4 inches to 3 inches $2\frac{1}{2}$ lines. The average length was 3 inches $7\frac{1}{2}$ lines.

The *weight* of the heart, according to Meckel, is about 10 ounces, and its proportionate weight to the whole body is as 1 to 200. Tiedemann is of opinion that the proportionate weight of the heart to the body is as 1 to 160.* The weight of the healthy and empty heart, according to Cruveilhier, is from 7 to 8 ounces. Bouillaud found the average weight in thirteen healthy hearts to be 8 ounces 3 drachms. According to Lobstein it weighs between 9 and 10 ounces. The size and weight of the heart must generally be to a great extent in conformity with the size and weight of the body. In an athletic male we would expect it to weigh about 10 ounces, in an ordinary-sized individual about 8 ounces, and in weakly persons, or in cases of protracted debility, it would be still more diminished in weight. For the same reason it is generally larger and heavier in males than in females.

Structure of the heart.—The heart consists of muscular and tendinous textures, of cellular tissue, of bloodvessels, of nerves, and of lymphatics, enclosed between two serous membranes.

Tendinous texture.—The tendinous texture of the heart is placed, 1, around the auriculo-ventricular and arterial orifices; 2, within the reduplicature of the lining membrane forming the auriculo-ventricular and arterial valves; 3, it forms the chordæ tendineæ.

Auriculo-ventricular tendinous rings.—Around each auriculo-ventricular opening we find a tendinous circle or ring, from the upper part of which the muscular fibres of the auricles arise, and from the lower part those of the ventricles, thus affording perhaps the only example in the human body of a strictly involuntary muscle having tendinous attachments. The tendinous ring surrounding the left auriculo-ventricular opening is stronger than that surrounding the right. These tendinous zones are thicker along the lower edge where the muscular fibres of the ventricle are attached, and become thinner along the upper edge where the muscular fibres of the auricles are attached, so that the fat occupying the auricular groove is seen through the upper portion of the ring on the right side. The right margin of the left auriculo-ventricular ring is connected with that surrounding the aortic opening. The existence of the auriculo-ventricular and arterial tendinous rings was well known to Lower.†

Arterial tendinous rings.—The form of the tendinous rings surrounding the arterial openings, and the manner in which the large arteries are attached to their upper edges, have not, I think, been described with sufficient accuracy. These textures are very plainly observed

* Anatomie Médicale, t. iii. p. 69.

* If we consider the ordinary weight of an adult heart to be 8 ounces, and the average weight of the whole body to be 150 lbs. the proportionate weight of the heart to the body would be as 1 to 225.

† Tractatus De Corde, p. 29. 1669.

in the heart of the ox and horse after a little dissection. The following description is drawn up from numerous dissections of these parts made on the human heart. The tendinous ring surrounding the aortic opening is stronger and thicker than that surrounding the orifice of the pulmonary artery. Both of them are stronger than the auriculo-ventricular rings. Each of the arterial rings appears as if composed of three semilunar portions placed on the same plane, the convexities of which are turned towards the ventricles and the concavities towards the vessels *(fig. 266, a a)*.* Each of

Fig. 266.

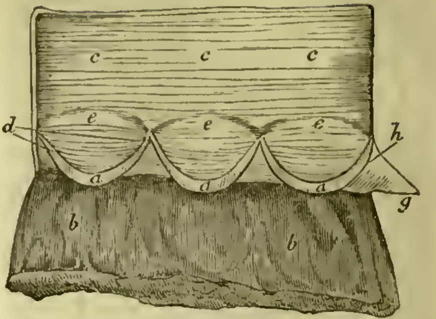
Appearance of tendinous ring at the origin of the pulmonary artery. In slitting open the artery, one of the three projecting extremities of the tendinous ring has been divided.

these semilunar portions has its projecting extremities intimately blended at their terminations with the corresponding projecting extremities of those next to it, *(fig. 266, b b,)* so that the three form a complete circle, with three triangular portions projecting from its upper edge. The semilunar portions approach fibro-cartilage in their structure, and have the intervals left between their convex edges filled with a texture more decidedly fibrous, *(fig. 266, d,)* and which is considerably weaker than the semilunar portions, more particularly on the left side of the heart.† The thinness of the tendinous structure filling up these intervals has led some anatomists erroneously to describe these portions of the heart as protected only by the two serous membranes. The right tendinous zone is broader than the left and very thin, particularly at its inner margin, at which part in both sides of the heart it assumes more of the tendinous than of the fibro-cartilaginous structure. These tendinous rings are placed obliquely from without inwards and from above downwards, so that the outer edge is on a plane superior to the inner. The sigmoid valves are attached to the inner edge of the upper surface, *(fig. 267, a,)* and the tendinous fibres placed in the fixed margins of these valves contribute to the thickening of the ring at this part; the middle coat of the arteries is connected to the outer edge of the same surface, and to the anterior part of the projecting extremities, *(fig. 267, b;)* while the muscular fibres of the ventricles *(fig. 266, f; fig. 267, f,)* are attached to the lower surface of the projecting portion of the convexity, and to the lower margin of the fibrous tissue filling up the space between the convexities of the projecting ends, *(fig.*

* These tendinous festoons are represented stronger in the woodcut than they are naturally.

† These intervals are occupied by muscular fibres in the heart of the ox and horse.

Fig. 267.



Pulmonary artery slit open at its origin, its internal membrane stripped off, and two of the sigmoid valves completely removed.

a a a, tendinous festoons.

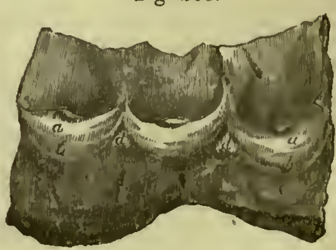
b b, muscular fibres of the right ventricle.

c c c, middle fibrous coat of the artery after the internal serous membrane has been stripped off.

g, small portion of one of the semilunar valves left to show its attachment to the inner edge of the upper surface of the tendinous festoon.

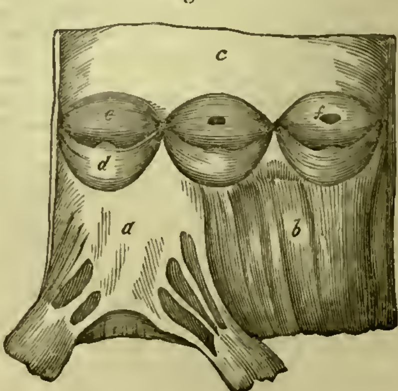
267, d.) There is, however, this difference between the right and left arterial openings with respect to the attachment of the muscular fibres;—on the right side the muscular fibres arise from the projecting portion of the convexity of the whole three tendinous festoons, *(fig. 268, c, c,)* while in the left side the mus-

Fig. 268.



cular fibres are attached only to one and part of a second, *(fig. 269, b b,)* as the larger lip of the mitral valve *(fig. 269, a)* is suspended

Fig. 269.



from the posterior or left, and a great part of the anterior,—in fact to that part of the tendinous ring which separates the aortic from the auriculo-ventricular opening. From the posterior part of that portion of the tendinous ring to which the mitral valve is connected, the anterior fibres of both auricles, near the septum, arise. As the left tendinous ring is thicker and narrower than the right, there is a larger space left between the fixed edge of the valves and the attachment of the middle coat of the arteries than there is on the left side. This space is of some importance, as upon it a considerable part of the pressure of the column of blood in the large arteries must be thrown during the diastole of the ventricles.

There is a good representation of these tendinous rings given in Tab. II. Opera Valsalvæ, tom. i. At page 129 they are thus described: "In horum sinuum ambitu quà valvulæ sinubus annectuntur quidem quasi Agger videtur occurrere substantiæ durioris ad similitudinem cartilaginis tarsi palpebrarum." I find also that Gerdy* appears to have had an accurate notion of the form and appearance of these tendinous rings. He was aware of the existence of the projecting angles of the tendinous ring which pass up between the festoons of the middle coat of the arteries, and which have been overlooked in succeeding descriptions. I find also that the late Dr. A. Duncan, jun. has, in his unpublished manuscript, given a very accurate account of these structures in the heart of the ox.

Tendinous structure in the auriculo-ventricular valves.—Distinct tendinous fibres exist in the auriculo-ventricular valves enclosed between the reduplication of the lining serous membrane. These are continuous with the auriculo-ventricular tendinous zones, and are most distinct and of great strength at the base. I could never observe any distinct traces of muscular fibres in these valves in the human heart either when fresh or after long boiling. Bouillaud has, from the examination of one inconclusive case, but principally from analogy with the corresponding valves of the heart of the ox, supposed that they may exist in some cases in hypertrophy of the valves. In making examinations of this kind we must be exceedingly careful not to mistake the tendinous fibres when tinged with blood for muscular fibres, for under these circumstances they certainly at all times assume the appearance of muscular fibres.†

* Journal Complementaire, tom. x.

† In the heart of the dog I have seen a distinct band of transverse muscular fibres in the base of the larger lip of the mitral valve, but could never satisfy myself of the existence of any longitudinal muscular fibres. In the heart of the ox and horse very distinct longitudinal muscular fibres are seen in the valves of both sides of the heart, principally, if not entirely, continuous with the inner layer of the fibres of the auricles. A greater part pass over the inner surface of the tendinous rings, and are firmly attached to the tendinous structure of the valves, reaching nearly to the lower margin of the smaller segments of the valves. The effect of these fibres upon the movements of the valves would form an interesting subject of investigation.

Tendinous structure in the arterial valves.—Distinct tendinous fibres also exist in the arterial valves, which must add considerably to their strength and prevent their more frequent rupture. Three of these tendinous bands in each valve are stronger than the others, and their position deserves attention, as they are often the seat of disease. One of these bands occupies the free margin of the valve, and passes between the projecting extremities of the tendinous festoons (*fig.* 270, *a*). Upon the middle of this band the corpus Arantii, which is formed of a similar texture, is placed. The other band comes from a point a little above the middle of the projecting end of the tendinous festoon (*fig.* 270, *b*), and passes up in a curved manner towards the corpus Arantii, leaving between it and the superior band a triangular space on each side, in which, if any tendinous fibres exist, they are exceedingly obscure. These two tendinous bands were well known to Morgagni. The third band is placed in the attached margin of the valve, and renders this part the thickest and strongest. Between the middle band and the attached margin of the valve a number of weaker bands are placed, which also pass upwards, generally assuming a curved form. Morgagni termed these lower and weaker fibres *fibræ carneæ*, but they evidently belong to the same structure as the stronger bands. The arrangement of these tendinous fibres is best seen in the aortic valves, and the appearance exhibited in the accompanying representation, (*fig.* 270,)

Fig. 270.

which has been taken from Morgagni, is not always distinctly observed, where the valves are perfectly healthy, but become sufficiently obvious in certain cases of disease.

Attachment of the middle coat of the arteries to the arterial tendinous rings.—The inner and outer serous membranes are continued from the heart upon the arteries; the one becoming the inner coat of the arteries, and the other is continued for a short distance upon their external surface. A thin layer of cellular tissue also passes from the heart along the arteries between their middle coat and their external serous membrane. These are, however, so far unimportant compared with the attachment of the middle coat of the arteries to the tendinous festoons which we have just described. The middle coat is so very firmly and strongly attached both to the external edges and to the anterior portion of the upper part of these projecting extremities, (*fig.* 267, *d*,) that it can be detached with great difficulty. Those fibres of the middle coat attached to the projecting extremities, which are apparently of the same number and thickness as in that portion of the artery immediately above, form a distinct curved edge (*fig.* 267, *e*), as they pass from the extremity of one festoon to the other. As we trace the middle coat of the artery downwards into the concavities formed by each festoon, we find that below this curved edge they become strikingly thinner and continue to diminish in thickness and in length, (since they can only stretch between the projecting extremities,) until we arrive at the bottom of the concavity. These three thin portions of the middle coat must then be placed behind the semilunar valves, and correspond to the sinuses of Valsalva.* The thinness of the middle coat at the sinuses of Valsalva will render this portion of the artery more dilatable, and predispose it to rupture when its coats are diseased.† The tendinous zones are distensible, but to a considerably less extent than the middle coat of the arteries. I am not aware that this account of the manner in which the middle coat of the arteries is attached to the tendinous rings has been previously given. I suspect, however, that Dr. Duncan must have been perfectly aware of it from some parts of his manuscript. The differences between these tendinous festoons and the yellow elastic coat of the arteries, and the manner of their attachment, can easily be made out in the human heart; they are, however, more apparent in the larger animals, as the horse and ox. The different characters of the two tissues are obvious at the first glance after boiling, even in the human heart.

Muscular tissue.‡—The greater part of the heart is composed of muscular fibres arranged in a very intricate manner. These fibres are connected together by cellular tissue,* which, however, exists in much smaller quantity in the heart than in the other muscles of the body. These fibres are attached generally by both extremities to the tendinous rings situated around the orifices of the heart; the fibres of the auricles pass upwards to form the auricles, and those of the ventricles downwards to form the ventricles, so that these tendinous rings must form the fixed points towards which all the contractions of the heart take place. None of the muscular fibres of the auricles are continuous at any part with those of the ventricles, and we will find that while some of them are confined to a single auricle, others belong to both. In the same manner a great part of the fibres of the ventricles are common to both, and are interwoven together, while others again belong exclusively to a single ventricle, or, as Winslow† expressed it, the heart is composed of two muscles enveloped in a third. The intimate arrangement of these muscular fibres, particularly those of the ventricles, is exceedingly complex, as the contraction of the organ is not in one particular direction only, but in all directions, and has long been considered as a kind of Gordian knot in anatomy. Vesalius, Albinus, and Haller‡ confessed their inability to trace them, and more lately De Blainville§ assures us, from his own experience, that we can only arrive at very general conclusions (*des choses très-générales*) on this subject. By adopting the method of long-continued boiling of the organ before commencing to attempt to trace the course and arrangement of its fibres, we will find that after a few trials several of the most important points connected with the distribution of these can be ascertained, and by perseverance they can be unravelled to a great extent. By long boiling the muscular fibres are rendered hard and firm, while the tendinous and cellular tissues are softened or dissolved, and the fat melted. Dr. Duncan, who employed this method to a great extent, states that the essential circumstance is to continue the boiling long enough, and that he has never been able to carry it too far. I have found from eighteen to twenty hours generally sufficient for this purpose. Some have recommended that the heart should be previously put for a short time into a strong solution of salt, and Vaust advises that it should be boiled in a solution of nitre, for the purpose of rendering the fibres firmer. The boiling is infinitely superior to the maceration in vinegar. By stopping the boiling before the tendinous rings are rendered too soft, we can easily see their form and their connexions to the muscular fibres.

The general connexion and distribution of

* So striking is the difference between the middle coat as it fills up the concavity of these festoons, and where it stretches between the projecting extremities in the hedgehog, that at first sight it appears to be deficient at that part.

† According to Valsalva aneurisms are frequently found in this situation: "Atque hic aortæ sinus maximus ille est, in quo sæpe aneurysmata circa præcordia contingunt, ut propria observatione edoctus sum." Valsalvæ Opera. Epist. Anat. ed. Morgagni, tom. i. p. 131. 1740. This greater tendency to aneurismatic dilatation must depend upon two circumstances. The increased calibre of the artery at this part will increase the pressure upon its walls from the well-known hydrostatic law, that "in a quantity of fluid submitted to compression, the whole mass is equally affected, and similarly in all directions," and the diminished thickness of the middle coat will materially favour this distending force.

‡ While I was engaged in examining the arrangement of the muscular fibres of the heart, Dr. Alison had the kindness to procure for me the manuscript of the late Dr. A. Duncan, jun. on this subject. It was well known not only in this country but on the continent that Dr. Duncan had for a very long period attended very particularly to this question, and was in the habit of demonstrating the parts he had ascertained to his pupils. Unfortunately his intentions of publishing on the subject were never carried into execution, and his papers referring to it were left in so confused a state that it is exceedingly difficult and in most parts impossible to make out the description. I have availed myself of those parts that are legible in the following pages, and these I have scrupulously acknowledged. Dr. Duncan's dissections of the heart were taken entirely from the ox and sheep.

* [This however is denied by other observers, and from very recent and careful examinations. See the succeeding article by Mr. Searle.—Ed.]

† Mémoires de l'Academie Royale des Sciences, 1711, p. 197.

‡ El. Phys. tom. i. p. 351.

§ Cours de Physiologie, &c. tom. ii. p. 359.

the muscular fibres of the ventricles may be stated to be as follows. 1st, Most of these fibres are connected by both extremities to the tendinous structure of the heart, a fact well known to Lower,* though overlooked by many subsequent anatomists. 2d, The direction of these fibres is more or less oblique, a comparatively small part of them only being vertical, and that too for a limited part of their course. The degree of obliquity of these spiral turns is different in different portions of the heart: they are more oblique on the surface and less oblique as we proceed to the deeper fibres, more particularly at the base. The deeper fibres approach more to the circular form. 3d, As has been already stated, part of these fibres are common to both ventricles; while part only belong exclusively to a single ventricle, and that principally at the base. 4th, The external fibres are longer than the next in order, and after turning round the apex pass upwards into the interior, below the lower margin of the shorter fibres, and form the inner surface of the ventricles, while the deeper again turn up below the lower margin of the fibres next in succession, so that the longer enclose by their two extremities all the shorter fibres. By this arrangement we can explain how the base and middle part of the ventricles should be much thicker than the apex. This arrangement has been particularly insisted upon by Dr. Duncan and Gerdy, and to illustrate it Gerdy has given an ideal illustration, of which *fig.* 271 is a copy.

Fig. 271.

In examining the course of the fibres of the ventricles we shall not attempt to describe each particular band of fibres, but confine ourselves to their general arrangement.† In examining the surface of the ventricles the superficial fibres of the anterior surface are observed to run in a spiral manner from above downwards and from right to left, while those on the posterior surface, which are in general more vertical, run from left to right. Most of these bands are thin and broad at the upper part, and become narrower and thicker as they approach the apex, where they form a remarkable twisting, which has been termed the vortex, (of which *fig.* 272, taken from the human heart after boiling, is an accurate representation,) and then pass in to assist in forming the inner surface

Fig. 272.

of the left ventricle and the columnæ carneæ. The manner in which the external fibres turn in at the apex to form the inner surface of the ventricles and enclose the deeper fibres was well known to Lower, and he has illustrated it by an engraving, of which *fig.* 273 is a copy.

Fig. 273.

* Tractatus de Corde, p. 34 to 37. Lugd. Batav. 1669.

† Wolff has named and minutely described eight distinct bands of muscular fibres on the surface of the right ventricle: Acta Petropolit. pro anno 1781, tom. viii. p. 251, 1785.

This arrangement of the external fibres was also well known to Winslow* and Lancisi.† Winslow, however, denied that they described the figure of eight, as stated by Lower. More lately Gerdy has given a description of this arrangement, to which he has added an engraving, which approaches more to the appearance of the perfect figure of eight than that given by Lower. I, however, prefer that given by Lower, as it more nearly resembles the arrangement which I have myself seen in tracing these fibres. A small part of the right and posterior side of this vortex is formed by fibres from the posterior surface of the left ventricle, and from that part of the posterior surface of the right ventricle near the septum, and are attached above to the auricular tendinous rings, while the whole of the anterior and left side of the vortex is formed by fibres from the anterior surface and right margin of the ventricles. On tearing these last fibres, which form the principal part of the apex, from the anterior surface of the left ventricle, we find, as we proceed upwards, that a comparatively small part of them cross the anterior fissure upon the right ventricle to reach the right auricular tendinous ring. The greater number dip in at the anterior longitudinal fissure, and we shall afterwards find that they can be traced to the base of the septum of the ventricles. By tearing off these fibres downwards, we open into the apex of the left ventricle. A general notion of the manner in which these fibres, passing from the base of the septum, turn in at the apex, and proceed upwards on the inner surface of the left ventricle, may be obtained from *fig.* 273. To have been quite accurate the inner fibres should have been more scattered, and some of them represented as terminating in the columnæ carneæ. By unravelling the fibres which form the apex, we may open into the interior of the left ventricle without breaking a single muscular fibre. Having thus opened the apex of the heart, although the point is removed, the circular edge is left entire (*fig.* 274, *a*), and is formed of another series

Fig. 274.

of fibres, which, like those taken away, advance spirally from the base to the apex, and turning over the edge (*fig.* 274, *b*) ascend in the opposite direction, continuing their course after being reflected. "Proceeding in the same manner the whole apex of the left ventricle may be removed, and the same principle of arrangement is found throughout the whole heart even to the base. When we get down as far as the apex of the right ventricle, although the principle remains the same, its effects are more complicated, as it applies to two cavities instead of one." I have frequently satisfied myself of the correctness of the description contained in this passage, which I have quoted from the manuscript of Dr. Duncan. This is the same kind of arrangement which, we have already stated, has been insisted upon by Gerdy, but which we believe can be more satisfactorily seen by tracing the fibres in this manner. Gerdy lays it down as a general law, that all the fibres of the heart form loops, the apices of which look towards the apex of the heart (*fig.* 271). I find that Dr. Duncan states that while the apices of those loops which form the lower part of the heart point to the apex, as Gerdy has described, "yet he commits a great error when he asserts that the apices of all the fibres of the heart point in that direction, since the number of tops which point in the opposte direction is not less."* When the superficial fibres of the heart have been removed as represented in *fig.* 274, we will find that if we trace the great mass of fibres occupying the lower and middle part of the left ventricle, they will be seen to run spirally in strong bundles from above downwards and from right to left, to wind round and form the posterior as well as the anterior part of the point of the heart; that the greater mass pass in at the apex of the left ventricle to assist in forming the columnæ carneæ and internal surface, while others pass in at the apex of the right ventricle, and others again, after turning a little upwards, dip into the interior below some of the higher fibres. On tracing them upwards, on the other hand, they dip in at the anterior longitudinal fissure (*fig.* 274, *d*) where they are as it were dovetailed with other fibres from the anterior surface of the right ventricle passing in at the same fissure, and then mount almost vertically upwards to the base of the septum, forming part of the septum of the right ventricle, only separated from its lining membrane by a thin layer of fibres, and are inserted in a strong band in the ox into the bone of the heart, which is placed between the auriculo-ventricular openings and aorta, while in the human heart they are spread

* Mémoires de l'Acad. Roy. 1711. p. 197.

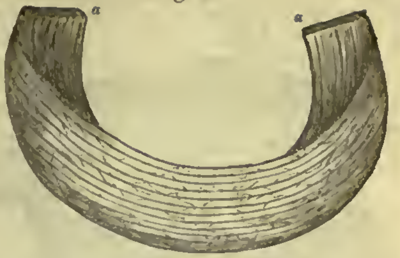
† De Motu Cordis: Opera omnia, tom. iv. p. 96. 1745.

* I could not discover in Dr. Duncan's manuscript any other description or allusion to the fibres here mentioned whose arrangement is opposed to the general law which Gerdy is anxious to establish. There is no doubt, however, that many of these loops at the base are principally directed to the periphery of the organ, and very little downwards, and that a few in the infundibulum are slightly directed upwards.

over a wider surface at this their upper insertion. I have been more particular in describing this part of the heart, as this arrangement of the fibres appears to me to be intimately connected with the production of the tilting motion of the heart. The fibres which occupy the upper part of the anterior surface of the left ventricle, as well as those occupying the upper part of the posterior surface (nearer the base than those bands already described as passing from the anterior surface), partly dip into the interior of the left ventricle as they wind round it, partly pass in at the posterior longitudinal groove to assist in forming the septum, while other strong bands, more particularly near the base, cross this groove and dip into the interior of the right ventricle. In the human heart I have stripped off pretty strong superficial bundles from the upper part of the posterior surface of the left ventricle over the posterior longitudinal groove, and over the surface of the right ventricle as far as the anterior longitudinal fissure, into which they dipped. In stripping off the fibres from the posterior and anterior surface of the right ventricle at this stage of the dissection, part of them disappear in their course around the ventricle, where they dip in to assist in forming the interior; others proceed as far as the anterior groove before they dip inwards; while part of the fibres which arise from the conus arteriosus cross the upper part of the anterior fissure upon the anterior surface of the left ventricle, where they pass into the interior of the left ventricle. These fibres, crossing the anterior surface of the right ventricle, and which dip in at the anterior fissure, form the inner surface of the septum of the right ventricle. On tracing those fibres which dip inwards at so many different points, they are observed to rise upwards to the tendinous rings either directly or indirectly through the medium of the chordæ tendineæ. In following the fibres in this manner we perceive the intimate connexion that exists between the two ventricles, and that their contraction must be simultaneous. We also see that comparatively few fibres cross the anterior longitudinal groove except near the base, while large bundles of fibres cross the posterior groove. When these fibres crossing the two grooves have been torn away, the two ventricles become detached from each other. By this time the apices of both ventricles have been opened.

On examining the deeper fibres (which occupy that part of the heart near the base), they are seen to form a series of curved bands, of one of which *fig.* 275 is a representation. These bands are imbricated, the lower disappearing by its internal extremity below the higher, so as to be inserted by that extremity into the tendinous rings at a point more internal than the corresponding extremity of the higher bands. Some of these bands are common to both ventricles, others belong exclusively to one. The fibres of the right ventricle become very complicated where they form the conus arteriosus and fleshy pons between the

Fig. 275.



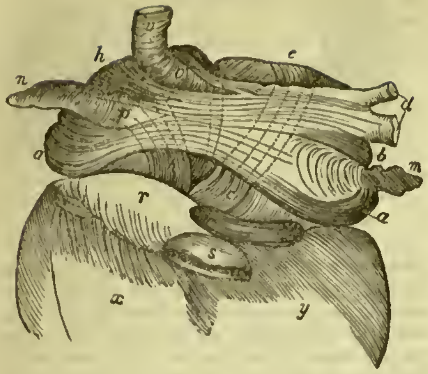
pulmonary artery and right auriculo-ventricular orifice. The fibres of the left ventricle are stronger and coarser than those of the right ventricle, while those of the conus arteriosus are still firmer than those on the lower part of the right ventricle.* "There do not occur in any part of the heart cellular sheaths or tendinous aponeuroses dividing bundles of fibres as separate muscular fasciculi. Although a complex it is not a compound muscle, and does not consist of a number of distinct bellies or heads. The only thing approaching to this structure are the columnæ and a strong muscular stay between the peripheral and septal wall of the pulmonic ventricle, and the reticulated texture on the inside of the ventricles, much more conspicuous in man than in oxen." "Many fibres are attached to each other by agglutination or in a manner not easily understood." "Many fibres bifurcate, and the divided fibres follow different directions: or two fibres from different parts approximate, and at last are united and proceed as one fibre. I am doubtful if this can be considered as a tendinous point of union of all three. These points of union are often arranged in one line so as to give some appearance of a pennated muscle, but the tendinous points, if they exist, do not adhere to form membranes or strings. This bifurcation is very evident in the connection of the septal with the peripheral walls of the heart."†

The auricles are formed by two sets of fibres, a superficial and a deep. The arrangement of these two sets of fibres does not follow the same laws as those of the ventricles. The superficial layer (*fig.* 276, *a a*, *fig.* 277, *a a*), surrounds the base of the auricles, and is of unequal height and thickness. It is broader on the anterior and narrow on the posterior surface, more particularly on the posterior and outer part of the right. It extends upwards towards their superior edge on the anterior surface, and on the posterior surface of the left as far as the inferior pulmonary veins. It is very thin, particularly on the outer and posterior part of the right auricle. In its course round the auricles the fibres diverge to enclose the appendices, and the orifices of the

* Dr. Duncan has given a very minute description of the fibres of this and other parts of the heart, which are much too long for insertion here. He has also given a very accurate and minute description of the bone in the heart of the ox.

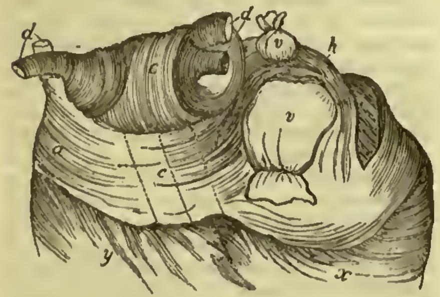
† Dr. Duncan.

Fig. 276.



large veins. These fibres cross transversely between the anterior surface of the two auricles and connect them together. These superficial fibres are also prolonged into the interauricular septum (*fig.* 277, *f*) to assist in forming the

Fig. 277.



circular band of fibres which surrounds the fossa ovalis. Gerdy figures a superficial band of fibres (*fig.* 276, *b*) as belonging exclusively to the left auricle.

The deep fibres belong exclusively to a single auricle. They are superficial at various parts, where the external or circular fibres are deficient. By their inner surface they are connected to the inner membrane of the auricles, and a thin layer of cellular tissue unites their outer surface to the inner surface of the superficial fibres. In the left auricle Gerdy describes, 1st, a left auricular loop (*fig.* 276, *c c*, *fig.* 277, *c c*), which embraces the auricle from its superior edge to its base, which runs a little obliquely to the left, before, above, and then behind the auricle, and is attached by its extremities to the auricular tendinous ring near the septum. It is contracted at that part where it passes between the pulmonary veins. 2d. The pulmonary veins are surrounded by circular fibres (*fig.* 276, *d d*, *fig.* 277, *d d*), which are continued along their course to a variable extent,—sometimes they merely surround the termination of one or more of these veins, at other times I have seen them prolonged outwards as far as the roots of the lungs. These fibres generally form a continuous layer, and of sufficient thickness to render them capable of constricting these vessels considerably. 3d. Some fibres proper to the appendix (*fig.* 276, *m m*), which, by passing between and uniting themselves to the other fibres of the appendix, form that reticulated appearance which it presents in its inner surface. Some of these fibres are circular, others form incomplete circles.

In the right auricle, Gerdy has described, 1st, a right auricular loop (*fig.* 276, *h h*, *fig.* 277, *h*), which is attached anteriorly to the tendinous structure at the base of the auricle; it extends upwards in the anterior edge of the septum auriculorum; it then curves round the fossa ovalis, of which it forms the projecting edge, and at the orifice of the vena cava superior it divides into a right and left band. The first proceeds downwards, becomes engaged with some of the superficial fibres around the cava superior, and forms the angle between them (*tuberculum Loweri*), from which it passes downward to the auricular tendinous ring along the right side of the cava inferior. The left division passes along the left side of the cava inferior, in the posterior edge of the auricular septum, where it intermixes with the fibres which embrace the entrance of the coronary vein. 2d, Some muscular fibres (*fig.* 276, *p*), which pass between the anterior part of the tendinous ring and the appendix. 3d, Some circular fibres, which surround the entrance of the cava superior (*fig.* 276, *o*): these do not extend upwards beyond the orifice of the vein. 4th, The bundles of fibres which arise from the right side of the auricular ring proceed upwards to the posterior part of the appendix, and form the musculi pectinati seen in the interior of the auricle. 5th, A few fibres proper to the auricle (*fig.* 276, *n*), which assume the circular form. The action of all these fibres superficial as well as deep must be to diminish the capacity of their cavities, and draw them towards the auriculo-ventricular openings, and thus favour the passage of their contents through these openings.

Inner membrane of the heart.—Each side of the heart has its own lining membrane, and both of these are closely allied to the serous membranes in structure and appearance. They are continuous with the inner coat of the vessels which open into their different cavities. These have been termed the endocarde by Bouillaud to distinguish them from the serous coat of the pericardium on the outer surface of the heart. If we commence to trace the inner membrane of the right side from the entrance of the two cavæ, we find that it is folded upon itself to form the Eustachian valve at the entrance of the inferior cava; it then passes upon the inner surface of the auricle, and at the opening of the coronary vein it is again folded upon itself to form the valve of the coronary vein. It passes through the auriculo-ventricular opening, adheres to the inner surface of the tendinous ring, and is there folded upon itself to assist in forming the tricuspid valve. It now proceeds upon the inner surface of the ventricle, and at the origin of the pulmonary artery it assists in forming the semilunar valves, and becomes continuous with its inner coat. If we trace the inner membrane of the left side of the heart from the entrance of the pulmonary veins, we find that, after lining the auricle, it is continued through the auriculo-ventricular opening, and is there folded upon itself to assist in forming the mitral valve. In the left ventricle it surrounds the chordæ tendineæ and unattached columnæ carneæ in the same manner as in the right ventricle; and at the origin of the aorta it assists in forming the semilunar valve, and becomes continuous with the inner coat of the artery. These membranes adhere intimately to the inner surface of the heart by close cellular tissue, and have their inner surface perfectly polished and smooth. That of the left auricle is thicker than that of the right. They are thicker in the auricles than in the ventricles. In the ventricles, except near the origin of the large arteries, they are exceedingly thin.

Nerves of the heart.—The heart is supplied with nerves from the sympathetic and par vagum. The sympathetic branches come from the superior, middle, and inferior cervical ganglia, and frequently also from the first dorsal ganglion. The branches from the par vagum come directly from the trunk of the nerve, and indirectly from the recurrent or inferior laryngeal. The course of these on the right side differs from those of the left in some respects, and requires a separate description. These nerves, like most of the other branches of the sympathetic, are very irregular in their size, number, and origin, so that it would be difficult to find two subjects in which they are exactly alike; they are also very irregular in their course before they reach the cardiac plexus, but become more regular when they gain the arteries of the heart, whose branches they accompany. These nerves, after forming different anastomoses and plexuses with each other of the same side, converge at the upper and back part of the arch of the aorta, where they form a free anastomosis with those of the opposite side, and then pass on to the heart. The left cardiac nerves are sometimes much smaller than those on the right side, so as to appear, as in the dissection described by Lobstein,* merely accessory to those on the right. On the other hand the size of those on the left side may preponderate considerably over those on the right. The proportional size of the different nerves of the same side is also very various. When the nerves of one side are small, the deficiency is made up by the greater size of those of the opposite side; and when any particular branch is either unusually small or entirely wanting, its place is supplied by the greater size of the other nerves of the same side, or of those of the opposite side. The branches from the par vagum, particularly those coming from the recurrent, vary also considerably in size. All the sympathetic branches of the cardiac plexuses are of a gray colour, and are generally not so soft as Scarpa has described them.

The right cardiac branches of the sympathetic are generally three in number: 1st, superior cardiac *(supremus et superficialis cordis)* arises from the lower and inner part of the superior cervical ganglion, or from the continuation of the sympathetic between the superior and middle ganglia, or from both these origins. It generally also receives a filament from the par vagum. In its course down the neck it lies behind the sheath of the carotid artery. It anastomoses with the external laryngeal nerve and descendens noni, and sends a twig along the inferior thyroid artery to the thyroid body; and at the lower part of the neck it sometimes divides into two branches as figured by Scarpa,* one of which unites itself to the middle cardiac, the other forms an anastomosis with the recurrent nerve of the same side. At other times it passes into the thorax either in front or behind the subclavian artery, takes the course of the arteria innominata, and reaches the posterior part of the arch of the aorta, where it anastomoses with branches of the middle and inferior cardiac nerves, or with branches of the recurrent. It more rarely appears to pass to the cardiac plexus without any anastomosis with the middle and inferior cardiac branches. It frequently presents a ganglion in its course down the neck.

Middle cardiac nerve.—This nerve arises by several short twigs from the middle cervical ganglion. This is generally the largest of the cardiac nerves, and is named by Scarpa the great or deep cardiac nerve *(n. cardiarus medius, s. profundus, s. magnus).* It proceeds downwards and inwards, crosses the subclavian artery, sometimes in front, at other times it divides into several branches, which surround the artery and again unite. It anastomoses with the branches of the recurrent, in the neighbourhood of which it runs, also with the par vagum, superior and inferior cardiac nerves; and following the course of the arteria innominata it passes behind the arch of the aorta to terminate in the cardiac plexus.

Inferior cardiac nerve (n. cardiacus minor of Scarpa).—This nerve generally arises by filaments from the inferior cervical ganglion, sometimes from the first dorsal ganglion, at other times from both. It proceeds behind the subclavian artery near to the recurrent nerve. It follows the course of the innominata close to the middle cardiac, with which it anastomoses, and proceeds to join the cardiac plexus.

Left cardiac nerves.—Perhaps the differences in the course of the right and left cardiac nerves are principally to be attributed to the known differences between the large arteries of the two sides. The left superficialis cordis is figured by Scarpa† as dividing a little above the arch of the aorta into four branches; two of these pass in front of the aorta to form an anastomosis with a branch of the par vagum and deep cardiac; a third also passes in front of the aorta to unite itself with the middle cardiac; and the remainder of the nerve proceeds behind the arch to unite itself with the cardiac plexus.

* De Nervi Sympathetici humani fabrica, &c. pp. 16 & 18.

* Tab. iii. Tabulæ Neurologicæ, &c.
† Tab. iv. op. cit.

The left middle cardiac nerve is generally smaller than the right, and is frequently partly formed by a branch from the inferior cervical ganglion. It passes behind the arch of the aorta, sometimes in the form of a single trunk, sometimes double, at other times triple, and generally throws itself into the upper and left part of the cardiac plexus.

Cardiac plexus (great cardiac plexus of Haller) is placed behind the arch of the aorta and in front of the lower part of the trachea, extending from the arteria innominata to the right branch of the pulmonary artery, and is formed by the convergence of nearly the whole of the cardiac nerves of both sides, but more particularly of the middle cardiac nerves. There is occasionally a distinct ganglion at the junction of these nerves; more generally there is only a plexiform arrangement. From this plexus a very few branches pass upon the anterior surface of the aorta *(cardiaci superficiales aortæ)*, and anastomose with the right coronary plexus: some twigs also pass backwards to anastomose with the bronchial plexuses. By far the greater part of the cardiac plexus proceeds to the heart in the form of two large divisions to form the right and left coronary plexuses which accompany the coronary arteries. Where the right branch leaves the lower part of the plexus there is a gangliform swelling (ganglion of Wrisberg), which is occasionally, however, very indistinct. This ganglion furnishes the greater part of the superficial plexus of the aorta which we have just described. This great right cardiac branch divides into two parts; the smaller passes between the aorta and pulmonary artery to reach the right side of the origin of the pulmonary artery, where it attaches itself to the right coronary artery to form the principal part of the right coronary plexus; the other and larger portion creeps under the pulmonary artery to the posterior part of the heart, to assist in forming the left coronary plexus. The great left cardiac branch, which principally comes from the upper part of the cardiac plexus, and at first passes from right to left posterior to the ductus arteriosus, after which it is joined by other smaller branches which pass in front of the ductus arteriosus. It also divides into two branches; the smaller passes between the aorta and pulmonary artery, and reaches the origin of the right coronary artery, and throws itself into the right coronary plexus; the larger bends round the posterior surface of the pulmonary artery to reach the left coronary artery, where it forms, with the larger branch of the right, the left coronary plexus. There is thus a free interchange of filaments between the nerves of both sides. The left coronary plexus is considerably larger than the right, in proportion as the left side of the heart is thicker than the right. These coronary plexuses consist of a number of minute filaments which accompany the ramifications of the coronary arteries everywhere, and are distributed upon the surface of the auricles as well as upon the ventricles. They anastomose with each other upon the anterior and posterior surface of the heart. All the nerves of the heart enter into its substance upon the surface of the arteries, and cannot be traced beyond the second or third division of the arteries. The nerves of the heart are generally considered to be small compared to the size of the organ.* Though the nerves of the heart are not equal in size to those of the tongue and eye, yet Scarpa is doubtful if they are not equal to the nerves of the other voluntary muscles, as, for example, the muscles of the arm. It must be remembered that the minute subdivision and diffusion of these nerves over a large extent of surface, by which many of them can only be seen after a minute examination, causes them to appear of less size than what they collectively really are. Soemmerring maintained that very few of the nerves of the heart were distributed to the muscular tissue of the heart, and that they more properly belonged to the arteries: "nervi cardiaci proprie ad arterias, ad aortam et arterias coronarias pertinent, eaque filia subtilia nervorum parum sibi (cordi) constant."† Behrends, the pupil of Soemmerring, affirmed that not a single twig went to the muscular tissue of the heart, but that they were entirely distributed on the coats of the arteries.‡ The announcement of these opinions, bearing so directly as they do upon the Hallerian doctrine of the nature of irritability, so keenly agitated immediately before throughout Europe, could not fail to create considerable sensation at the time, and it is probable that to this we owe the splendid work of Scarpa upon the nerves of the heart, which has entirely set the question concerning the distribution of these nerves at rest. Scarpa has shown that when followed to their minute distribution, the nerves of the other muscles accompany the arteries in the same manner as the nerves of the heart, and that the nerves of the heart only differ from those of voluntary motion in this, that the nerves accompanying the arteries of the voluntary muscles are firmer and thicker than those of the heart.

Bloodvessels of the heart.—The heart is supplied with blood by the two coronary arteries, for a description of which see Aorta. The blood is returned by the coronary veins. The branches of the coronary veins generally accompany those of the arteries. They are divided into the larger coronary vein and smaller coronary veins.

Great coronary vein (vena coronaria maxima cordis).—This vein is formed by several branches, three of which surpass the others considerably in size. One of these lies in the anterior longitudinal groove; another runs along the obtuse or left margin of the heart; and the third, which may be replaced by two or three

* Bichat in his Anatomie Générale says, "that the nervous mass intended for the muscles of organic life is much inferior to that of the voluntary muscles. The heart and deltoid muscle, on being compared together, display in this respect a very considerable difference."

† Corporis humani fabrica, tom. v.

‡ Dissertatio qua demonstratur cor nervis carere. After making this general statement, he admits, in one part of his treatise, that he has traced two twigs of the cardiac nerves into the substance of the heart.

smaller veins, runs along the posterior surface of the left ventricle, between the obtuse margin and posterior longitudinal groove. The first of these is frequently described as the trunk of the vein, and it commences at the apex of the heart, where it anastomoses with the smaller posterior and anterior veins. It runs upwards in the anterior longitudinal groove along with the left coronary artery, gradually increasing in size as it ascends, from the junction of the other veins. When it reaches the base of the ventricles it changes its direction, enters the groove between the left auricle and ventricle, leaves the coronary artery, passes from left to right in the posterior part of the same groove, when it becomes considerably dilated *(sinus of the coronary vein).* It then opens into the right auricle at its lower and back part close upon the posterior edge of the septum auriculorum.

Smaller posterior coronary vein (vena coronaria cordis minor).—It commences at the apex of the heart, runs up in the posterior longitudinal groove, or a little to its right side, and receives its blood principally from the right ventricle. It generally joins the sinus of the coronary vein; at other times it enters the auricle separately immediately by the side of the great coronary vein, so that its aperture is also covered by the coronary valve.

Smaller anterior coronary veins (venæ innominatæ of Vieussens).—These are very small and variable in number, and are placed on the anterior surface of the right ventricle. One of these, larger than the others, (generally the superior,) sometimes receives the name of anterior vein of Galen. They frequently unite to form a single trunk; more generally perhaps they continue separate, pass in front of the right coronary artery as it lies in the auriculo-ventricular groove, and enter the right auricle at its anterior and inferior part. One of the musculi pectinati overlaps their entrance, forming a kind of valve.

Venæ minimæ, or *veins of Thebesius,* are minute veins, which enter the auricle at various points. It was maintained by Vieussens, Thebesius, and Ruysch, that some of the coronary veins opened into the left side of the heart, thus producing a slight intermixture of the dark blood with the arterial. This has been more lately asserted by Abernethy,* and has been supposed to occur more frequently in phthisical cases; the difficulty of transmitting the blood through the lungs causes their enlargement. Such injections are liable to great fallacy, from the great facility with which fine injections, or even coarse injections when forcibly pushed into the vessels, escape into the cavities of organs. Especial care is, therefore, required in conducting them. Notwithstanding that we have the authority of some of the most accurate anatomists in favour of this opinion, it is very doubtful if any of these veins open into the left side of the heart.†

Sinus of the coronary vein.—This is always described as a dilatation of the large coronary vein, but I have found it decidedly muscular in man and in several of the Mammalia, as the dog, horse, ox, and sheep; and it presents the appearance of a muscular reservoir placed at the termination of this vein, similar to the auricles at the termination of the two cavæ. This sinus is placed in the posterior part of the groove between the left auricle and ventricle, adheres intimately to the outer surface of the auricle, and communicates by one extremity with the auricle, and by the other with the large coronary vein. The commencement of the dilatation is generally abrupt, and the first appearance of the muscular fibres well defined. I have seen it vary from two inches to only half an inch in length. These muscular fibres are generally circular; part of them, however, are oblique. Some of them belong exclusively to the vein; a great part appear to be connected with the muscular fibres of the auricle. This muscular sinus must serve to prevent regurgitation along the coronary veins. I have also generally found a distinct valve at the termination of the coronary vein in the sinus. This valve resembles the valves found in the veins of the extremities. It is generally single, sometimes it is double. I have also occasionally found one or more single valves in the course of the vein.* A distinct valve may also occasionally be seen at the termination of the posterior coronary vein in the sinus. Portal† mentions that he has seen the coronary valve situated in the interior of the vein a little from its mouth. Thebesius and Morgagni have observed valves placed in some of the smaller veins where they terminate in the larger. The valves of the coronary veins do not in general prevent the passage of injections contrary to the course of the blood along them.

Lymphatics of the heart.—The lymphatics of the heart are divided into two sets—superficial and deep; the superficial commencing below the external serous membrane, and the deep upon the internal membrane. They follow the course of the coronary vessels. Some of them pass directly into the thoracic duct, and, according to Meckel, sometimes directly into the subclavian or jugular veins. Others pass into the lymphatic glands situated in front of the arch of the aorta, while others pass into the glands situated around the bifurcation of the trachea, and a few also join the lymphatic vessels of the lungs.

Pericardium.—The pericardium is a fibrous

* Philos. Trans. 1798.

† Professor Jeffray (Observations on the Heart, &c. of the Fœtus, p. 2) mentions a case in which the large coronary vein opened into the left auricle. Lecat (Mém. de l'Acad. des Scien. 1738, p. 62) found the coronary veins in a young child unite themselves into a single trunk and enter the left subclavian. It is probable that Soemmerring had this case in view when he states, "Rarissime vena hæc in vena subclavia *dextra* finitur," (de corp. hum. fab. tom. v. p. 340. 1800.) particularly as Haller, (Element. Phys. tom. i. p. 375, 1757), in quoting the case, has inadvertently substituted the word *dextra* for *sinistra.*

* I have seen two or three pair of double valves in the course of the coronary vein in the horse and ass. These animals have no Thebesian valve.

† Anatomie Médicale, tom. iii.

bag surrounding the heart and origin of the large bloodvessels, but without any direct attachment to the heart itself, having its inner surface lined by a serous membrane. It is from this latter circumstance that it is generally termed a fibro-serous membrane. It is placed behind the cartilages of the second, third, fourth, and fifth ribs of the left side and middle part of the sternum. Posteriorly it rests upon the parts contained in the posterior mediastinum; anteriorly it corresponds to the anterior mediastinum, and may be reached by perforating the left side of the sternum, as has been proposed in some cases of hydrops pericardii. The pleuræ adhere to its lateral and part of its anterior surface by pretty close cellular tissue, when the interposed fat is small in quantity. The phrenic nerves with their small accompanying arteries pass down the thorax between the pleuræ and lateral surfaces of the pericardium. Below, the fibrous part of the pericardium adheres intimately to the upper surface of the cordiform tendon of the diaphragm, and is also connected by pretty dense cellular tissue to the upper surface of the muscular fibres running into the anterior part of the left lobe of the tendon. It adheres more firmly to the cordiform tendon at the edges, particularly anteriorly, than at the centre. It is broader below where it adheres to the upper surface of the diaphragm, narrower above where it is attached to the large vessels that pass in and out from the heart. Upon these large vessels the fibrous part of the pericardium is prolonged, forming a kind of sheath, which gradually becomes thinner until it is confounded with the cellular coat of the vessels. From the manner, however, in which the vena cava inferior enters the heart, it can have no fibrous sheath of this kind. At the different points where the fibrous coat becomes applied upon these vessels, and where the cava inferior passes through the cordiform tendon, the serous coat is reflected upon the outer surface of the vessels, and accompanies them back to the heart to cover the outer surface of that organ. In this manner the serous part of the pericardium is a shut sac, the outer surface of which adheres to the inner surface of the fibrous portion, and to the outer surface of the heart. The inner surface, like that of all the other serous membranes, is unadherent, smooth, and shining, and is everywhere in contact with itself, and only contains the small quantity of fluid which serves to lubricate its interior. The serous portion of the pericardium adheres intimately to the inner surface of the fibrous. At that part, however, where the serous leaves the fibrous to pass back upon the surface of the large vessels, there is a small triangular space left between them. The serous membrane is reflected upon and covers the outer surface of the aorta rather more than two inches above its origin; upon the pulmonary artery about the same distance and immediately before its bifurcation; upon the cava superior about an inch above its entrance into the right auricle; upon the cava inferior shortly before it reaches the heart; upon the two right pulmonary veins soon after they have emerged from the right lung; and upon the left pulmonary veins shortly before they enter the auricle. This serous membrane, in passing upon the aorta and pulmonary arteries, covers the anterior surfaces of both before it passes round upon their posterior; it then envelopes both arteries in the same sheath, so that their opposed surfaces are only separated from each other by a little cellular tissue. It leaves part of the posterior surface of the cavæ and pulmonary veins uncovered, occasionally, however, enveloping the whole or nearly the whole, of the left pulmonary veins. It adheres but loosely to the large bloodvessels, and firmly to the outer surface of the auricles and ventricles. The attachment of the fibrous part to the cordiform tendon is very firm at the edges and blended with the tendon, but becomes looser towards the centre. Cloquet* describes the serous membrane as lying in contact with the upper surface of the cordiform tendon; or, in other words, he appears to consider the fibrous part not to be prolonged over the upper surface of the tendon, but to stop at its attached margin. In most cases I have been able to trace the fibrous part of the pericardium over the upper surface of the cordiform tendon, but almost always more or less diminished in thickness. In some cases I was unable to detect anything like a fibrous layer at this part. The fibrous part of the pericardium is comparatively thin, and is composed of tendinous fibres interwoven together. It is not much larger than sufficient to contain the heart when its cavities are distended. This fact taken along with the physical properties of the membrane, not admitting of sudden dilatation, explains how the sudden escape of a small quantity of blood (8 oz. or sometimes less) into the interior of the pericardium is sufficient to arrest the heart's action.

The arteries of the pericardium are small and come from various sources, from the bronchial, œsophageal, phrenic, from the arteries of the thymus gland, internal mammary, coronary arteries, and the aorta itself. Its veins partly terminate in the azygos, and partly accompany the corresponding arteries to terminate in the veins of the same name. Its lymphatics pass to the glands placed around the cava superior. The nerves can be traced into its texture.

Uses of the pericardium.—The pericardium restrains within certain limits the irregular movements of the heart. The inner serous surface of the pericardium must also facilitate its ordinary and healthy movements.

Relative position of the vessels within the pericardium.—The pulmonary artery at its origin overlaps the anterior surface of the aorta as it springs from the left ventricle. (See *fig.* 276, *s*, for the relative position of these vessels at their

* Traité d'Anatomie Descriptive, p. 633, translated by Knox. Cloquet does not state distinctly that the fibrous part of the pericardium is not continued over the cordiform tendon, but this may be inferred from the statement that the serous membrane "is applied below, directly and in a very close manner upon the aponeuroses of the diaphragm."

origin.) It then proceeds into the concavity of the arch of the aorta, and as it is about to pass through the fibrous coat of the pericardium, it divides into its two branches, the right and left. The left branch passes in front of the descending portion of the arch of the aorta to reach the left lung; the right branch passes behind the ascending portion of the arch to reach the right lung. In the fœtus the pulmonary artery divides into three branches, the two we have just mentioned, and a third, the ductus arteriosus, which unites the pulmonary artery to the descending portion of the arch,—in other words, after the aorta has given off the large branches to the head and superior extremities. The descending cava, immediately before it perforates the fibrous coat of the pericardium, crosses the right branches close upon the bifurcation of the trachea; within the pericardium it lies on the right side of the ascending portion of the arch of the aorta. The inferior cava is seen perforating the cordiform tendon of the diaphragm, and almost immediately afterwards it enters the posterior and inferior angle of the right auricle. The pulmonary veins are placed inferior to the two branches of the pulmonary artery. The two right pulmonary veins pass behind the right auricle to reach the left, which they enter near the septum auriculorum.

Peculiarities of the fœtal heart.—(For an account of the developement of the heart and large bloodvessels see Ovum.) The heart of the fœtus before the fourth month is placed vertically, but towards that period the apex begins to turn towards the left side. The auricular part of the heart is considerably larger in proportion than the ventricular. The relative size of the heart to the body at birth differs considerably from that of the fœtus at an earlier period of its developement. According to Meckel the relative size of the heart to the body about the second or third month of uterine life is 1 to 50; at birth and for a few years afterwards as 1 to 120. The greater size of the heart of the fœtus seems to depend principally upon the greater thickness of the walls of its cavities. The great disparity between the thickness of the two sides so very apparent shortly after birth does not exist in the earlier periods of uterine life, though also generally sufficiently well-marked in the fœtus at the full time. This is explained by the circumstance that the two sides of the heart at this period have nearly equal obstacles to overcome in propelling the blood.* In the earlier stages of its developement the infundibuliform portion of the right ventricle is less prominent than at a later period. The left ventricle is at first a little larger than the right; at birth and for a short while after they are equal. The two auricles communicate with each other through the foramen ovale.* This foramen is at its maximum size about the sixth month.

Valve of the foramen ovale.—This valve, which, however, can scarcely be called a valve, as it is a provision for effecting the obliteration of the foramen ovale at the time the child assumes its independent existence, first makes its appearance at the lower part of the foramen about the third month, or, according to Senac and Portal, about the second month. It is formed by the inner membranes of the two sides of the heart, containing some muscular fibres between them, particularly at its lower part. It is of a semilunar form; its convex edge adheres to a greater or less portion of the margins of the valve as its growth is more or less advanced; its concave margin, which is free and loose, looks upwards and forwards. This valve may be said to belong almost exclusively to the left auricle, as it is attached to that margin of the foramen.† Though this valve is of sufficient size at birth to shut the foramen, yet its concave or upper margin is easily depressed so as to leave a considerable interval between it and the upper margin of the foramen. We will find, from the manner in which the valve is attached to the left margin of the foramen, that it is much more easily depressed by a current passing from the right auricle into the left than in the opposite direction. In fact any force of this kind applied in the opposite direction would rather tend to keep the valve applied to the upper edge of the opening; a circumstance which occurs after birth when the blood flows along the pulmonary veins into the left auricle, and which must materially assist in producing complete obliteration of the foramen. The manner in which the blood passes between the auricles through the foramen ovale in the fœtus was the subject of a violent controversy in France at the termination of the seventeenth and the commencement of the eighteenth centuries. It was first commenced between Meri on the one side, who had proposed a new theory of the fœtal circulation by which the blood was made to pass from the left auricle into the right, and by Duverry and Fauvery on the opposite side, who maintained the opinion of Harvey, and which is now universally adopted, that it passes from right to left. Many celebrated anatomists and mathematicians attached themselves to the opposite parties, and at last the controversy extended itself to the neighbouring kingdoms.‡

Eustachian valve.—This valve, the appearance and position of which have been already

* In two fœtuses, however, which I lately examined, and where I had positive evidence that they had not yet reached the sixth month of utero-gestation, the difference between the thickness of the two ventricles of the heart was distinctly marked.

* This opening is frequently termed *trou de Botal* by the French writers though described by Galen.

† This explains how the depression (fossa ovalis), marking in the adult the position of the valve, should be better seen from the right than the left auricle.

‡ Those who may be anxious to acquaint themselves more fully with the nature of this controversy and to examine the arguments adduced on both sides may consult the Mémoires de l'Academie for that period, and Senac's Traité de la Structure du Cœur, tom. i. p. 369, and the Supplement in tom. ii.

pointed out in describing the interior of the right auricle, is also intimately connected with the peculiarities of fœtal life. It was discovered by Eustachius about the middle of the sixteenth century, who contented himself by pointing out its position. Little attention was paid to it until the commencement of the eighteenth century, when it was more particularly brought into notice by Boerhaave and Lancisi, who published a new edition of the works and plates of Eustachius, which had then become very scarce. Lancisi supposed that this valve prevented the blood of the superior cava from falling with too much force upon the column ascending by the cava inferior. Winslow,* finding it only perfect in the fœtal state, and having cause to believe that its diminution kept pace with the increase of the valve of the foramen ovale, was led to adopt the opinion that its presence had a special reference to that state, and believed that it not only served to break the current of the superior cava as stated by Lancisi, but also opposed the regurgitation of the blood of the auricle into the inferior cava. In the absence of this valve he supposed there would arise two inconveniences in the fœtus—the imperfect intermixture of the contained blood, and the regurgitation of the blood of the umbilical vein into the placenta. Senac† believed that the Eustachian valve can have no effect in preventing the blood of the cava superior from falling upon the current ascending by the cava inferior, and that it must direct a part of the blood of the cava inferior through the foramen ovale. Sabatier‡ more particularly pointed out that from the position of this valve passing from the anterior and left part of the vena cava inferior to the left side of the foramen ovale, and from the situation of the foramen ovale at the inferior part of the auricle, the blood of the cava inferior must be directed through the foramen ovale; and further, from the difference in the direction of the two cavæ themselves—the superior looking downwards, forwards, and to the left side, while the inferior, though it is also slightly directed to the left, passes at the same time upwards and backwards, when combined with the upper thick margin of the foramen ovale—it would necessarily happen that the blood of the superior cava must fill the right auricle.

In three injections of the fœtal circulation which I performed, where arrangements were made to imitate, as far as possibly could be done, the manner in which the two currents flow into the heart during the life of the fœtus, results were obtained confirmatory of the opinion of Sabatier.§ This arrangement cannot of course exist in the early months of uterine life from the imperfect developement of the heart itself, and in all probability part only of the blood of the inferior cava is transmitted through the foramen ovale into the left side of the heart for a short time before birth. The pulmonary veins appear to bring very little blood to the left side of the heart until the time approaches that the fœtus must necessarily assume an independent existence. The circulatory apparatus becomes gradually prepared for this change;—the Eustachian valve begins to shrink, the foramen ovale to diminish in size, and a greater quantity of blood is transmitted through the lungs. Billard* has ascertained from the examination of the bodies of a great number of infants who died within a few days after birth, that the foramen ovale and the other circulatory passages peculiar to the fœtus are generally shut about the eighth day after birth. In nineteen infants who had lived only one day the foramen ovale was completely open in fourteen; in two it had commenced to become obliterated, in the remaining two it was completely shut. On the subsequent days the number of those with the foramen shut continued to increase; and in twenty examined, who had died on the eighth day, five only had the foramen open.

Physiology of the heart.

Mode of action of the valves of the heart.—While the blood is rushing through the auriculo-ventricular openings during the contraction of the auricles, the lips of the mitral and tricuspid valves are separated from each other and thrown outwards from the axis of the opening, and the larger lip of both is at this time carried towards the arterial orifices. It has generally been supposed that the mitral and tricuspid valves are, during the systole of the ventricles, passively floated up towards, and obstruct the auriculo-ventricular orifices so as to prevent the free regurgitation of the blood into the auricles; and that the use of the cordæ tendineæ is merely to limit the movements of the valves,—to permit them to be raised sufficiently to close the orifices, but at the same time to provide against the otherwise unavoidably fatal consequences that would result from these unresisting valves being carried through into the auricles by the current of blood. Mayo, Bouillaud, and others have, however, maintained that the lips of these valves are not approximated in the mechanical manner just stated, but by the contraction of the musculi papillares of which the cordæ tendineæ are the proper tendons. As the musculi papillares contract along with the other fibres of the ventricles, the lips of the valves are drawn towards the axis of the opening, and are closely applied to each other, forming a kind of cone, the apex of which projects downwards into the ventricles. It is from the adoption of these views that Bouillaud proposes to call these musculi papillares, the tensor, elevator, or adductor muscles of the valves. That the lips of the

* Mémoires de l'Acad. Roy., année 1717.
† Op. cit. tom. i. p. 228.
‡ Traité complet d'Anatomie, tom. ii. p. 224.
§ Edinburgh Medical and Surgical Journal, 1835. These injections are also confirmatory of one made by Kilian, where the fluid thrown along the aorta passed to the head and superior extremities, and that along the pulmonary artery to the lower part of the body.

* Traité des Maladies des Enfans nouveau-nés, &c., p. 557, 1828.

valves are approximated in this manner appears to me to be the much more probable opinion; for when we examine the uniform position and course of the musculi papillares and chordæ tendineæ, more particularly those of the left ventricle; that the chordæ tendineæ pass from each musculus papillaris to both lips of the mitral valve, occasionally crossing each other; and that the posterior or smaller lip, though it may be drawn inwards so as to meet the larger and more moveable, is so bound down as to be scarcely capable in most cases of being floated up on a level with the orifice; and further, when we also remember that the musculi papillares contract at the same time with the other fibres of the heart, we can scarcely resist coming to this conclusion. Besides, if the lips of the valves were floated up to the orifice, a greater quantity of blood would regurgitate into the auricles during the systole of the ventricle than in all likelihood takes place; for as the lips of the valve must be widely separated from each other when the systole commences, it is evident that a less quantity of blood must have passed through the orifice before the lips are sufficiently approximated to obstruct its further passage when these are assisted by an active force, than when they are merely passively brought together by the current of blood passing in that direction. It has, however, been supposed that the musculi papillares do not contract with the other fibres of the ventricles. Haller states* that on laying open the heart he has seen the muscles of the valves contract during the systole of the heart. It may be objected to this experiment that the unusual stimulus applied to the heart in cutting its fibres across may have deranged the usual order of its contractions. I have repeatedly opened the heart in rabbits and waited until its contractions had ceased, and on renewing its movements by irritating the inner surface at a distance from the cut edges, I have observed that the columnæ carneæ acted simultaneously with the other muscular fibres of the heart.† I was also satisfied that the musculi papillares were proportionally more shortened during their contraction than the heart itself taken as a whole, which is nothing more than what we would expect when we remember that the fibres of the musculi papillares are so far free and run longitudinally, while by far the greater part of the other fibres run in a spiral manner.

Haller, in relating his observations on the contraction of the musculi papillares, makes another statement, which, however, is decidedly adverse to this opinion. The chordæ tendineæ appeared to him to be relaxed during the contraction of the musculi papillares.

It is difficult to make satisfactory observations upon the effects of the contractions of the musculi papillares upon the tension of the chordæ tendineæ. In several animals upon which we attempted to ascertain this, it was only when the heart was acting languidly that we could observe what was likely to be the effect of the contraction of the musculi papillares on the chordæ tendineæ when they were placed as far as possible in their natural relation to each other. We could never observe that they contracted sufficiently to move the valves, but they certainly rendered some of the chordæ tendineæ more tense. When, however, we take into account, that in an experiment of this kind, the valves are not thrown out widely from the orifices of the auriculo-ventricular orifices, the ventricle is not distended with blood, the chordæ tendineæ consequently not put so far on the stretch as occurs at the commencement of the systole, and that the contractions of the musculi papillares are languid, we can easily perceive how, in the natural systole of the heart, these contractions of the musculi papillares should be sufficient to move the valves inwards, though not to such an extent as to apply them closely to each other. The contraction of these musculi papillares apparently sets the valves in motion, and they are subsequently applied to each other by the currents of blood. It may be supposed that if the contraction of these musculi papillares can render the chordæ tendineæ sufficiently tense to move the valves, this would prevent the subsequent elevation of them to obstruct the auriculo-ventricular opening. We believe, however, that it is only at the commencement of the systole that they are sufficiently tense to move the valves, for as the contraction proceeds the capacity of the heart is so much diminished, both in its transverse and longitudinal dimensions, that they become relaxed. Besides, if we could suppose that these musculi papillares are capable of contracting through a sufficient space to draw the valves together, this would be all that is necessary to prevent the regurgitation of the blood through the auriculo-ventricular opening.*

So convinced, indeed, were the older anatomists and physiologists that the chordæ tendineæ are relaxed during the systole of the heart, and of the necessity of an accompanying diminution of the length of the ventricles themselves to effect this, that this argument adduced by Bassuel appears to have been principally instrumental in deciding the once keenly controverted question whether or not the heart was elongated during its contraction.†

* Elementa Physiolog. tom. i. p. 390. Sur le Mouvement du sang, p. 129. Mémoires sur la Nature sensible, tom. i. p. 379.

† [The observations of the London Committee appointed by the British Association to examine into the motions and sounds of the heart confirmed this view of the simultaneity of contraction of the columnæ carneæ and ventricular fibres.—Ed.]

* All these experiments upon the action of the columnæ carneæ were finished and the article forwarded to London about the middle of June, 1836.

† Mr. T. W. King in an elaborate essay (Guy's Hospital Reports, No. iv. April 1837,) has pointed out what he conceives to be a "safety-valve function in the right ventricle of the human heart." This view is founded upon the fact which he believes that he has ascertained, "that the tricuspid valve, naturally weak and imperfect, closes less and less accurately, according to the increasing degrees of the ventricular distention." From this he is "convinced that, in all cases in which the

It may be supposed that the relative size of the auriculo-ventricular orifices to the length of the lips of the valves would not admit of their apices being brought together in the form of a cone as described, but it must be remembered that from the course of the muscular fibres in the immediate neighbourhood of those openings, their areas must be diminished during the systole of the heart. There is at least one thing certain connected with the action of these valves, viz. that the contraction of the musculi papillares can never cause the valves to strike the inner surface of the ventricle and produce a sound as has been supposed.

The manner in which the semilunar valves at the origin of the aorta and pulmonary artery perform their office is entirely mechanical and easily understood. During the systole of the heart they are thrown outwards from the axes of these vessels; but during its diastole, when part of the blood driven into the artery would fall back into the ventricles, these valves are thrown inwards and obstruct completely the whole calibre of the arteries. In all probability the sinuses of Valsalva placed behind these valves contain a certain quantity of blood even during the systole of the heart, and this reacting upon the valves through the agency of the elasticity of the arteries brought into operation at the termination of the systole, materially assists in producing the more rapid and certain action of the valves.

Movements of the heart.—The heart is a muscle of involuntary motion, being, for the wisest of purposes, placed beyond the direct control of volition. The case of Colonel Townshend * is of too obscure a nature to entitle us to found upon it an opposite doctrine, more particularly as it is at direct variance with every other fact or observation.

The movements of the heart, when the body is at rest or in a state of health, proceed without our consciousness. In certain cases of disease they are attended by uneasy feelings, but they are never at any time or under any circumstances dependent upon sensation for their continuance.

It is not so easy a matter as may at first be imagined to ascertain the order of succession in which the different cavities of the heart contract and dilate, and the different circumstances which attend these movements, even by experiments on living animals, more particularly the warm-blooded animals; for if the heart when exposed is acting vigorously and rapidly, every one who has examined for himself must have felt the exceeding difficulty of following and analysing these movements by the eye. If, on the other hand, the animal has become debilitated and the movements of the heart languid, these are apt to deviate from their natural order, and to be performed in an irregular and unnatural manner.* It is in this way that we can account not only for the discrepant statements of the older observers, but also for the very frequent announcement of new views on this subject which appear in the medical periodicals of our own day. As we will find that many of these theories connected with the physiological actions of the heart even in the present day, have been founded upon false notions of the normal anatomy and natural movements of the organ, and only require a reference to these for their full and satisfactory refutation, it will be necessary that we attend particularly to the manner in which these different contractions and relaxations succeed each other, and the visible phenomena by which they are accompanied, as observed by the most accurate experimenters.

When the heart of a living animal is exposed and the organ is acting in a natural manner, the auricles are observed to become distended with blood, then to contract rapidly and simultaneously, and propel part of it into the ventricles; this is accompanied with a corresponding enlargement of the ventricles, which is immediately followed by their simultaneous contraction and the propulsion of their blood along the large arteries: then follows a pause, during which the auricles become gradually distended by the blood flowing along the veins. When the auricles are filled, they again contract, and the same train of phenomena just described occur in uniform succession.

Systole and diastole of the auricles.—The contraction or systole of the auricles is preceded by their relaxation or diastole. During the diastole the auricles become distended with the blood flowing along the veins. The commencement of the diastole occurs during the contraction of the ventricles; the latter part corresponds to the pause in the heart's action, and to the interval between the recurrence of the sounds of the heart, and is more or less long in proportion as the blood flows more or less rapidly along the veins.

The systole of the auricles is performed with great rapidity when the action of the heart is still vigorous, and appears to be effected by the simultaneous contraction of all its fibres. The terminations of the cavæ and pulmonary veins are seen to contract simultaneously with the fibres of the auricles, but sometimes they are seen to contract previous to the auricles, into which they expel their blood. In the cold-blooded animals this contraction of the terminations of the large veins extends over a greater surface, and is visible in the venæ he-

right ventricle is, in any material degree, temporarily distended or permanently dilated, the heart and lungs are relieved by a considerable reflux of the ventricle's contents into the auricle and systemic veins." In experiments upon the lower animals I have repeatedly seen the right ventricle, when gorged with blood and acting feebly, empty itself through an opening in the jugular vein. Edinb. Med. and Surg. Journ. 1836.

* Cheyne's English Malady, p. 307. 1734, London.

* The illustrious Harvey thus describes the difficulties which he experienced in his first attempts to analyse the movements of the heart: "ita ut modo hinc systolem, illinc diastolem, modo e contra, modo varios, modo confusos fieri motus me existimarem cernere."

paticæ.* Judging from the number of muscular fibres which surround the termination of the pulmonary veins in the human species, we would expect these contractions to occur to a greater extent in these veins than in the cavæ. These contractions in the veins must assist the *vis à tergo*, or the force with which the column of blood flows along the veins towards the heart, in limiting the regurgitation along these during the contraction of the auricles. This regurgitation along the veins appears to be to a small extent only when the circulation is proceeding in a natural manner, but becomes considerable where there is any impediment to the free passage of the blood into the ventricles, and when the blood becomes stagnated in the veins. When the actions of the heart are enfeebled, the contractions of the auricles are slower, and may become more or less vermicular, as I have myself occasionally observed. Two or more contractions of the auricle may also now be necessary before the languid ventricle can be excited to contraction. When the action of the heart is still more enfeebled, particular portions only of the auricles continue to contract. According to the observations of Harvey, Lower, Senac, Haller, and others, the contractions of the auricles are performed with considerable force.

Harvey states that he has observed that if the finger is applied to the ventricles in those cases where the action of the auricles continues after the contractions of the ventricles have ceased, a distinct beat is felt in the ventricle at each stroke of the auricle; and Senac, in quoting this, adds (evidently from his own observation) that it is similar to the pulse in the arteries. Senac also states that if an opening be made into the apex of the heart under those circumstances, a jet of blood rushes through it at each stroke of the auricle. He, however, admits that the contraction of the auricles in these cases is not sufficient to dilate sensibly the walls of the ventricles, but, of course, very considerable allowance ought to be made for the enfeebled state of the auricles at this stage of the experiment.† In the experiments of Dr. Hope, Mr. Carlisle, M. Bouillaud, and the Dublin Committee for investigating the cause of the sounds of the heart, the contraction of the auricles appeared to be comparatively trifling, and was most apparent in the appendices. From my own observations upon rabbits and dogs I am convinced that the auricles contract considerably more when the movements of the heart are proceeding in a natural manner, than some of these last experiments would lead us to believe, and that this contraction is not confined to the appendix, but extends over the whole auricle. When the circulation through the lungs becomes impeded, the right ventricle is then unable to empty itself, and the auricle of the same side (and this is the one that is most generally observed in such experiments) is consequently impeded in its movements. The auricles do not certainly exert the force or contract to the extent which some have stated, do not expel the whole of their contents, and their diastole is comparatively feeble; but that none of the muscular fibres of the auricles are passive, but exert a force proportionate to their strength, we have evidence both from experiment and the effects of disease. In some of those cases where an impediment to the passage of the blood from the auricle to the ventricle exists, all the muscular fibres of the auricles become much increased in thickness and in strength. As the left auricle has naturally greater difficulties to overcome in propelling its blood than the right, so we find that the left auricle is considerably more muscular than the right.* The appendix from its being loose, and supplied by a band of longitudinal fibres drawing it backwards, must enjoy a freer motion than the other parts of the auricle.

Systole and diastole of the ventricles.— When the heart is acting vigorously, the contraction of the ventricles succeeds immediately upon that of the auricles, so that they sometimes appear continuous; or, in other words, the sudden distention of the ventricles by the blood propelled into them during the systole of the auricles is rapidly followed by the contraction of the ventricles. The systole of the ventricles must occur during the diastole of the auricles. As we are only sensible of the systole of the ventricles from external examination during life, the expression *systole of the heart* is always employed as synonymous with the systole of the ventricles. When the action of the heart is a little less active, an apparent interval is observable between the completion of the contraction of the auricles and the commencement of the contraction of the ventricles, —the irritability of the ventricles being at this time somewhat impaired, their contraction does not so quickly follow their sudden distention. The ventricles during their systole are diminished in all their dimensions; the apex is drawn upwards to the base and tilted forwards so as to strike the parietes of the thorax between the cartilages of the fifth and sixth ribs.†

* The contractions of the different parts of the heart in cold-blooded animals have been observed to occur in the following order: first, the termination of the large veins, then the auricles, then the ventricles, and, lastly, the bulb of the aorta.

† I have convinced myself of the accuracy of these statements of Harvey and Senac in experiments upon dogs opened soon after they had been deprived of sensation.

* In the case mentioned by Allan Burns, where an ossific deposit covered the whole surface of the ventricles, so as to entirely, or nearly entirely, prevent their action, the auricles must have performed part of their functions for some time before death. In one of the experiments of Dr. Williams, of London, upon asses, he observed the circulation along the arteries continue although the ventricles were quiescent, and the auricles alone contracted.

† "Dr. C. J. B. Williams has, in a lecture lately published in the Medical Gazette (July 28, 1838, p. 692,) pointed out that, during a deep inspiration, the ribs are elevated without raising the heart in the same degree, and the impulse may be felt

The parietes of the ventricles at this time are firm and resisting, and present some rugæ on their outer surface. Haller* states that though the principal movement of the ventricles during their systole is from the apex upwards, yet he has sometimes observed a slight but distinct movement from the base downwards. The contraction of the ventricles is performed with great force, and, when vigorous, appears to be accomplished by the simultaneous action of all its fibres; but at other times, when it has become enfeebled, it has been observed to commence at the apex and extend itself upwards.

The diastole of the ventricles consists of two distinct stages. The first, which immediately follows its systole, is sudden, the apex being pushed downwards and apparently passing deeper into the chest, and is occasioned by the return of the heart to its state of rest. The second is also sudden, and attended by a rapid but not very extensive enlargement of the heart in all its dimensions. The parietes of the heart are soft and flaccid, and their external surface smooth during their diastole. The diastole of the heart is performed with considerable force, so that Pechlin, Perrault, Hamberger, and others long ago maintained that this equally with the systole is the result of a vital action. This opinion was again revived by Bichat, Dumas, and their followers, and is still introduced by some into the discussions upon the movements of the heart. Before we can admit an opinion of this kind, it would be necessary that very strong evidence be adduced in its favour, as it is at perfect variance with all that we know of the arrangement of the fibres of the heart, and of the laws of muscular contractility.†

Oesterreicher‡ has performed the following experiment, which appears nearly decisive on this point. When a body is placed on the heart of a frog heavy enough to press it flat, but sufficiently small to allow the heart to be observed, it will be seen that the body will be lifted during the contraction of the heart, but that during its extension it will remain flat. From this it appears that the extension of the heart after the contraction is not a muscular act. The diastole of the heart depends then upon two circumstances. 1st, Upon the natural elasticity of the organ, which it possesses in common with every other muscle, and by which it instantly resumes its state of rest as soon as its contraction has ceased. This, which is usually termed the relaxation of a muscle in whatever part of the body it occurs, must be expected to be more energetic in the heart than in the muscles of voluntary motion, as from the arrangement of its fibres a great part must be more strongly compressed. This occurs during the first of the two stages into which we divided the diastole. 2d, Upon its sudden distention during the contraction of the auricles, when we have every reason to believe that the ventricles are completely passive. This constitutes the second stage of the diastole. The blood must then pass from the auricles into the ventricles during each diastole at two distinct periods of time, corresponding to these two stages. During the first stage, or the relaxation of the ventricles, it flows from the auricles to fill up the vacuum produced in their interior; while, during the second stage, it is forcibly propelled by the auricles. It would be difficult to estimate the relative proportion of these two quantities of blood. Those who suppose that the contraction of the auricles is feeble must consequently believe that most of the blood passes from the auricles into the ventricles during the first stage.

It has been long disputed whether or not the ventricles empty themselves completely during each systole. It is very difficult to perceive anything like correct data upon this point in the warm-blooded animals with opaque hearts; but reasoning from analogy, from what we see in the cold-blooded animals whose hearts become quite pale during each systole, (not, as Harvey supposed, from the blood being pressed out of its parietes, but from the blood in its cavity, seen through its transparent sides, being almost entirely expelled during its systole,) we would be inclined to believe that little blood remained after each systole in the active state of the organ, while we can easily suppose that a greater or less quantity is left after each contraction when the organ is less vigorous.

It was the subject of a violent dispute at the commencement of the last century between the Montpellier and Parisian anatomists and physiologists, whether or not the heart became shortened or elongated during its contraction. In all the warm-blooded animals at least it undoubtedly becomes shortened.* We may at the same time state that the obliteration of the cavity of the ventricle depends much more upon the approximation of its sides than the drawing up of the apex.

Impulse of the heart.—It has been at various times, and still is by some late and modern experimenters,† maintained that the apex of the heart strikes the parietes of the thorax during

below the sixth rib. On the other hand, when the ribs are depressed, as during a deep expiration, the apex of the heart may be felt beating between the fourth and fifth ribs."

* El. Phys. tom. i. p. 400.

† Scharschmid supposed that certain pretended longitudinal fibres by shortening the heart enlarged its cavities, while the transverse fibres by contracting separately diminish its capacity.

‡ Müller's Handbuch der Physiologie des menschen, Erster Band, p. 163.

* The authority of Harvey has been quoted in favour of the opinion that the heart becomes elongated during its contraction, and certainly in one part of his work it is distinctly stated, that it is so to a certain extent: "Undique contrahi magis vero secundum latera; ita uti minores magnitudinis et *longiusculum*, et collectum appareat."

† Pigeaux, Stokes, Burdach, and Beau. Dr. Corrigan has, much to his credit, publicly renounced his previously published opinions on this question, after more accurate observations had convinced him of his error.

its diastole, and not during its systole. This is in reality what we would *à priori* expect, for it certainly does at first appear somewhat paradoxical that the heart should strike the parietes of the chest when the apex is approximated to the base. The concurrent testimony of the most accurate observers has, however, fully established the correctness of the fact. Harvey observed it in the human body when the heart had been exposed from the effects of disease.* One of the principal arguments adduced in support of this opinion by these authors was drawn from the fact that the pulse at the wrist is not synchronous with the impulse against the chest, an opinion which had been pretty generally maintained since the time of Aristotle. It is difficult to be convinced of this when the pulse is quick; but when it is slow, and in certain cases of disease of the heart, it can generally be satisfactorily ascertained. So far then they are right, but in the next and most important step of the argument they fall into a decided error; for they proceed upon the supposition that the pulse is synchronous in all the arteries of the body at the same time, and consequently the impulse of the heart at the chest cannot be synchronous with the flow of blood along the arteries, or, in other words, with the systole of the heart. In opposition to this opinion, Dr. Young† had previously shown upon the principles of hydraulics that the pulse along the arteries must be progressive, yet in general so rapid as to appear to arrive at the extremities of the body without the intervention of any perceptible interval of time. And when the attention of medical men was turned to this subject, various observers soon ascertained by repeated experiments that the pulse could be felt in favourable cases to pass along the arteries in a progressive manner, — that the pulse in the large arteries at the root of the neck and impulse at the chest are synchronous or nearly so, that both precede that at the wrist, and more distinctly still that of the dorsal artery of the foot.‡

Various attempts have been made to explain in what manner the apex of the heart is made to impinge against the parietes of the chest by those who maintain that it occurs during the systole of the ventricles. Senac supposed that this was principally effected by the curvature of the two large arteries, but principally of the aorta, which arise from the ventricles; for at each stroke of the ventricles when an additional quantity of blood is driven into the large arteries, as they are curved they make an attempt to straighten themselves; and as this takes place to a slight extent, the heart, which is attached to their extremities, ought to be displaced, and its apex, which describes the arc of a circle greater than the other parts of the heart, is thus made to impinge against the walls of the chest. He also believed that the distention of the left auricle with blood during its diastole has also, from its position between the spine and base of the heart, the effect of pushing the heart forwards; and this occurring at the same time with the attempt which the curved arteries make to straighten themselves, it thus acts as a second or subsidiary cause in tilting the heart forwards.* Though this supposed effect of the curvature of the large arteries has been a favourite explanation with many of the impulse of the heart against the chest, yet it really appears to have little, if any, influence in producing this. Shebeare,† and, more lately, Dr. Corrigan,‡ have shown that the direction of the curvature of the large arteries is such, that if any effect of this kind is produced, the heart would not be carried to the left side, but in the direction of the curve, which is exactly in the opposite direction. Besides the tilting forwards of the heart has been observed though no blood was passing along the large vessels at the time, and the same thing takes place after the large vessels have been cut through and the heart removed from the body.§ Haller and others have supposed that the secondary cause assigned by Senac,—viz. the sudden distention with blood of the left sinus venosus which lies impacted between the spine and left ventricle,—is the principal if not the sole cause by which the heart is pushed forwards against the ribs. In confirmation of this opinion Haller states ‖ that if we inflate the left auricle after having opened the chest, we see the point of the heart approach with vivacity the region of the mamma. As we cannot, however, under these circumstances distend the auricle without also distending the corresponding ventricle, this movement of the heart depends more upon the sudden inflation of the ventricle than upon any

* "Simul cordis ipsius motum observavimus, nempe illud in diastole introrsum subduci et retrahi; in systole vero emergere denuo et protrudi fierique in corde systolem quo tempore diastole in carpo percipiebatur: atque proprium cordis motum et functionem esse systolem: denique cor tunc pectus ferique et prominulum esse cum erigitur sursum." As quoted by Shebeare, Pract. of Physic, vol. i. p. 195.

† Phil. Trans. 1809.

‡ It is interesting and curious, as shewing the revolution of opinions, to compare the strict similarity of the arguments adduced by the modern supporters of this doctrine with those maintained by Shebeare in 1755. (Practice of Physic, vol. i. p. 193.) "This, however plausible it may appear, cannot be the true cause of it (impulse of the heart), because then this stroke must be during the systole of the ventricles, which would be synchronous with the diastole of the arteries; whereas the beating of the heart precedes the dilatation of the arteries, and thence this stroke must be made during the diastole of the ventricles: thus the diastole or distention of the heart is the cause of the beating against the ribs."

* Op. cit. tom. i. p. 356. The cause of the tilting motion of the heart was also, at a later period, attributed to the curvature of the aorta and to this exclusively by Dr. W. Hunter. Note in John Hunter's Treatise on Inflammation, p. 146, 1794.

† Op. cit. p. 195.

‡ Dublin Med. Trans. vol. i. p. 154.

§ Dr. Carson (Inquiry into the Causes of the Motion of the Blood, p. 183.) maintains that no proof can be adduced that the curvature of the aorta is rendered more straight during the systole of the heart.

‖ Sur le Mouvement du Sang, p. 124.

distention of the auricle, as any one may easily satisfy himself by repeating the experiment. Besides, the distention of the auricles by the blood flowing along the veins is too gradual for this sudden and rapid impulse of the heart; nay more,—the impulse may be observed when no blood is flowing into the auricles. Sabatier* believed that this impulse depends upon two causes,—1st, principally upon the distention of the auricles, more particularly the left; and, 2dly, upon the curvature of the large arteries. Apparently, however, perceiving the necessity of there being a sudden distention of the auricles to produce this, he supposed that this was effected by the auriculo-ventricular valves. He argued that, as these valves during the diastole of the heart form a cone stretching from the base towards the point of the ventricle, which is full of blood when the systole commences, when the valves are carried upwards to obstruct the auriculo-ventricular orifices, this blood is pushed before them into the auricles, producing a reflux into the auricles, which, with the blood flowing along the cavæ and pulmonary veins, causes a sudden distention of the auricles, which pushes the ventricle forwards.† Meckel appears to have adopted the opinions of Sabatier. We need not repeat our objections to this explanation. Dr. Alison, perceiving the insufficiency of all these explanations, has for a considerable time past suggested in his lectures, that this might be explained by the arrangement of the fibres, "more particularly by the irregular cone which they form, being *flattened posteriorly*, and by the consequent greater mass of fibres on the anterior surface." More lately Mr. Carlisle ‡ has also attempted to explain this by the greater length of the anterior fibres of the heart than of the posterior. As the shape of the ventricles is an oblique cone, and as they have their longest sides in front, he argues, "that it is a law of muscular contraction that fibres are shortened during their contraction in proportion to their length when relaxed. For instance, if a fibre one inch long lose by contraction one-fourth of its length, or one quarter of an inch, a fibre two inches in length will lose one inch by contractions of equal intensity. The apex then does not approach the base in the line of the axis of the ventricles, but is drawn more to the side of the longer fibres, that is, towards the front, thus producing the tilting forwards." We believe that it may be proved on mechanical principles, that though the anterior and left surfaces of the ventricles are considerably longer than those on the posterior and right, yet during their contraction, when they are drawn towards their fixed attachments, if the fibres are of equal thickness, the apex will be drawn up nearly in the diagonal of the two forces, and that if any tilting upwards of the apex take place, this will be only to a small extent, and be quite insufficient to account for the impulse felt at the chest. We must therefore look to some other circumstances besides a mere difference in length of the two surfaces to account for this. Mr. Alderson* has ingeniously attempted to apply the law of action and reaction between bodies,—one of considerable importance in mechanical philosophy, and upon which Barker's centrifugal mill has been constructed. Unfortunately, however, for this explanation, the axes of the large arteries and the direction in which the apex is tilted do not by any means accord. Dr. Hope's supposition that "the retropulsion of the auricular valves" may assist in producing this impulse, "as these act on a column of blood which offers a greater resistance than the weight of the heart, the action is reflected on the organ itself and impels it forwards," is, on the other hand, completely opposed to the law that action and reaction are the same. As well may a man attempt to propel a boat by standing in the stern, and push with an oar against the prow. Dr. Filhos attributed the impulse to the spiral turns of the fibres at the apex of the heart attempting to straighten themselves during their contraction, and so raise themselves suddenly and throw themselves forwards. The objections to this explanation are so palpable that they must occur to every one. Since the tilting of the apex of the heart forwards is observed after the blood has ceased to flow through its cavities, it is obvious that we must look for the cause of this in the arrangement of the muscular fibres themselves, though it may be difficult to point out that particular arrangement. It appears to me that the distribution of some of the strong bands of fibres, the course of which I have already described when treating of the muscular tissue of the heart, may satisfactorily account for it. We there pointed out that several strong bands of fibres arise from the base of the septum between the ventricles, pass downwards and form part of the septum, then emerge from the anterior longitudinal groove (*fig.* 274, *d*), and wind round in a spiral manner to form both the anterior and posterior part of the lower portion of the heart. On entering the apices of the ventricles, (principally the left,) the fibres are scattered over their inner surfaces, and while a great number of them go directly to be inserted into the tendinous rings, others form part of the columnæ carneæ. We have thus strong bands of fibres attached by one extremity (their septal extremity) to the base of the ventricles at a point pretty far posterior, while at the other extremity many of the fibres are loose, or at least only attached to the tendinous rings through the media of the chordæ tendineæ and valves, which must admit of a certain degree of contraction of these fibres before they become tense. At each systole of the heart when these fibres act, it is evident that the tendinous rings must form the fixed points towards which all these fibres contract; and since they are by one extremity all closely and directly connected to a

* Traité complet d'Anatomie, tom. ii. p. 230.

† Dr. Bostock has failed of his usual accuracy in detailing the opinion of Sabatier on this question.

‡ Transactions of British Scientific Association, vol. iii. Dublin Journal of Medical Science, vol. iv.

* Quarterly Journal of Science, &c. vol. xviii. p. 223.

fixed attachment, viz. the tendinous rings, while by their other extremity part only are directly attached to the tendinous rings, the other part being loose, or at least only connected to the tendinous rings through the lax chordæ tendineæ and valves, it must follow that the force with which the contraction takes place towards the septal extremity must preponderate over the other. If these bands of fibres had been as closely connected to the tendinous rings at the one extremity as at the other, then the force of the contraction towards both would have been equal; but since this is not the case, the apex must be carried forwards at the same time that it is drawn upwards towards the base. This forward motion may also probably be assisted by another arrangement of the same fibres which we have been describing; for some of these muscular bands are attached by their inner extremity to the anterior part of the left auriculo-tendinous ring, so as to form loops, the greater part of which lie more in front than behind the axis of the heart, and may have a tendency, when in a state of contraction, to draw the apex forwards and upwards. Now when we remember that by this elevation of the apex forwards, the heart, before placed obliquely, now becomes more horizontal, and consequently more approximated to the walls of the chest,—the more particularly as the transverse diameter of the chest diminishes rapidly as we proceed from below upwards, we believe that we have here sufficient to account for this impulse against the chest. As the proximity of the apex of the heart to the chest is affected by the position of the body, as we have already pointed out, this circumstance ought to be attended to in judging of the strength of the impulse of the heart.

What parts of the heart most irritable.—The inner surface of the heart is considerably more irritable than the outer. In experiments, when the heart has become quiescent, and refuses to obey a stimulus applied to the outer surface, it frequently contracts readily for a short time after this when air is introduced into its cavities, or when any other stimulant is applied to its inner surface. After death the different cavities of the heart generally lose their contractility in the following order, the left ventricle, the right ventricle, the left auricle, and last of all the right auricle.* And as the heart is generally the part of the body which shews the latest evidences of contractility, the right auricle has long received the name of *ultimum moriens.* Haller supposed that the greater persistence of contractility in the right side of the heart over the left might depend on the circumstance that the right side of the heart generally contains a greater or less quantity of blood after death, while the left side is generally empty. In this manner the inner surface of the right side of the heart is subject after death to the presence of a stimulant from which the left side is comparatively free. He put this opinion to the test by performing repeatedly the following experiment.* He emptied the right side of the heart by the section of the pulmonary artery and venæ cavæ, having previously retained the blood of the left side by passing a ligature around the aorta. The experiment succeeded many times: the right auricle remained perfectly immoveable, and the only motion which the right side retained arose from the connexion of its fibres with those of the left ventricle. The left auricle retained its movements for a certain time, the ventricles during a longer period, sometimes even for two hours. He adds, we thus transfer from the right auricle to the left ventricle the property of being the last living part in the body, in preserving for it during a longer period the irritation produced by the contact of blood. These experiments of Haller certainly shew that the left side of the heart will continue to contract longer than the right where it is subjected to a stimulant of which the other is deprived; but they do not entitle us to conclude that the persistence of their contractility is the same when placed under similar circumstances. We have every reason for believing that the right auricle is the part of the heart which last loses its contractility. Indeed Haller himself confesses, that if any part of the heart remains longer contractile than another, it is the right auricle. Nysten,† who performed a number of experiments upon the comparative persistence of the irritability in the different contractile parts of the body in the human species, after decapitation by the guillotine, and when the heart was consequently emptied of its blood, obtained the following results upon the order in which the different parts of the heart lose their contractility:—1st, the left ventricle, the contractility of which is annihilated much more quickly than that of the other organs; 2d, the right ventricle, the movements of which generally continue more than an hour after death; 3d, the two auricles, the right being of all the parts of the heart that which preserves for the longest time its contractile power.

The stimulant used in these experiments was galvanism. The greater persistence of the contractility in the right auricle over the other parts of the heart has been observed by other experimenters, after it had been cut from the body, and consequently without any contained blood. The particular part of the auricle which last loses its contractility varies in different cases. Sometimes the appendix is found contracting when the rest of the auricle is quiescent; at other times, and perhaps more frequently, those parts of the auricle around the entrance of the venæ cavæ retain their contractility longest.

* There is occasionally considerable variety observed in the order in which the different cavities lose their contractility after death. The left ventricle has been seen to contract after the right auricle; and Haller has observed in experiments upon cats the irritability of the left auricle first cease. In experiments upon dogs I have seen the ventricles contract after the auricles had ceased to do so.

* Sur le mouvement du sang, p. 172. Similar experiments were performed by Walther with the same results: Experimenta de vivis animalibus, p. 11, as quoted by Burdach.

† Recherches de Physiologie, &c. p. 321.

Harvey and some of the older anatomists observed the movements of the venæ cavæ to continue in some of the lower animals after the auricles had ceased to move. The apex of the ventricles frequently remains longer contractile than the rest of the ventricle. Haller suggested that this might depend on the remaining blood gravitating to the apex, and there acting as a stimulant.

Duration of contractility after death.—In the cold-blooded animals the heart may be made to contract fourteen, twenty, thirty-four hours, or even longer after death. In warm-blooded animals the heart remains contractile for a much shorter period after death than in cold-blooded animals. Haller found the heart contractile in a warm-blooded animal in one case four hours after death, and in another seven hours. He sometimes observed it to cease before the vermicular motion of the intestines. Wepfer found it irritable in a dog six hours after death. Nysten, who attended particularly to this subject, found in one of his experiments on the human subject, that the ventricles refused to contract upon the application of galvanism one hour after decapitation, while the auricles continued contractile for seven hours five minutes after death.* In another case the right auricle was still contractile eight hours after death;† and in a subsequent case which he relates, it remained contractile in the neighbourhood of the entrance of the superior cava sixteen hours and a half after death.‡ In the Mammifera, Nysten found that the left ventricle often refused to contract thirty minutes after death; that the right ventricle retained its contractility two hours, and sometimes longer, while the right auricle was not quiescent upon the application of the galvanism until eight hours after death.

He found it to vary in birds according to the degree of muscular activity which they enjoyed during life. In those of high flight, and which exercise great muscular contractility during life, and have a rapid circulation, as the sparrow-hawk, the irritability of the heart and other muscles becomes much more speedily exhausted than in those the movements of which are comparatively slow and feeble, as in most domestic fowls.§ Nysten supposes that the explanation of the greater persistence of contractility of the right ventricle over the left lies in the circumstance that the left acts with greater vigour during life, thus referring it to the important general law which he has established by his experiments upon the comparative excitability of the muscular tissue in the various classes of animals, that the duration of the contractility after death is in the inverse ratio of the muscular energy developed during life.|| Before we could admit this explanation, it would be necessary to show, what we believe it will be found impossible to do, that the left ventricle, apart from its greater quantity of muscular fibre, exerts greater strength or exhibits more energetic contractions during life than the right ventricle. In young animals, immediately after birth, the contractility of the heart continues longer after death than in the adult animal. We would expect this to be most apparent in those which are born with their eyes shut, as puppies and kittens, and in those birds which are hatched without feathers, since these animals at that period of life approach in their physiological conditions to the cold-blooded animals. There is a curious circumstance stated by Mangili, and confirmed by Dr. Marshall Hall, connected with the hybernation of animals, that if those mammalia which hybernate are killed while under a state of lethargy, the heart and other muscles remain contractile for a longer period than when they are killed in a state of activity, thus resembling, when under the influence of this lethargy, in this as in many other respects, the physiological condition of the cold-blooded animals. The contractions of the heart may frequently be renewed by the application of warmth after they have apparently ceased. I have repeatedly observed the fact which has been stated by Haller and Nysten, that when any of the cavities of the heart become congested with blood, their contractility becomes arrested, and, in their opinion, extinguished.* I have also found that unloading the right side of the heart soon after the congestion has taken place, which can be done in many cases by opening the external jugular vein, acts as a valuable adjuvant under certain circumstances in renewing the heart's action. These it would be out of place to discuss here; but I may state that it appears to me to be principally useful in certain cases of poisoning, in asphyxia, and after the accidental entrance of air into the veins. Since the introduction of a considerable quantity of air into the veins produces death by mechanically arresting the movements of the right side of the heart, we believe that circumstances may occur in which the surgeon may be justified in introducing a tube into one of the large veins passing into the upper part of the chest, and suck-

* Op. cit. p. 316.

† Page 318.

‡ In these experiments all the other parts of the body lost their contractility before the right auricle.

§ Op. cit. p. 349.

|| Dr. Marshall Hall (Phil. Trans. 1832) has more lately laid it down as a general law that the irritability of the heart and other muscles is in the inverse ratio of the oxygen consumed in respiration. Various experimenters distinctly show that as we descend in the scale of animals the quantity of oxygen consumed diminishes, and that Birds consume more than Mammalia. Dr. Edwards has also shown that the young of the Mammalia deteriorate the atmospheric air less rapidly than the adult animals; and the experiments of Mangili and Prinella prove that hybernating animals, when in a state of lethargy, consume exceedingly little oxygen, so that there is evidently some relation between irritability and the quantity of oxygen consumed in respiration; but for the proof that the irritability is exactly in the inverse ratio of the respiration, we must wait for Dr. Marshall Hall's promised experiments.

* Haller supposed that this was effected, as must be if allowed to continue for any length of time, by the too great distension of the muscular fibres, in the same manner as distension of the bladder produces paralysis of its fibres.

ing the frothy blood from the right side of the heart. It is also necessary to remember this circumstance in experimenting upon the length of time during which the heart remains contractile after death, as the division or non-division of the large veins at the root of the neck in laying open the thorax may considerably modify the results.*

For the probable force exerted by the heart, the share which the heart has in carrying on the circulation, and the probable quantity of blood expelled at each contraction, see the article CIRCULATION.

Frequency of the heart's action.—The frequency of the heart's action is considerably modified by age, condition of the other functions of the body at the time, by mental emotions, and by the original constitution of the individual. Its movements are influenced by very slight muscular exertion, and the extent of this appears to vary at different times of the day. In the fœtus its movements are rapid, being about 140 in the minute. At birth it is from 130 to 140; at one year 115 to 130; second year 100 to 115; third 90 to 100; seventh 85 to 90; fourteenth 80 to 85; middle age 70 to 75; in very old age 50 to 65. The heart's action generally sympathises powerfully with the other organs of the body, and this has always been regarded as a most important and necessary guide in the detection and cure of diseases.

It becomes strong and rapid in some cases of inflammation, while in others it becomes rapid and feeble. It becomes quicker after eating and slower during sleep. It is much increased in frequency during bodily exertion. In cases of great general debility it becomes very quick and feeble. It becomes more rapid and weaker during inspiration, slower and stronger during expiration.

It is an important fact that when the contractility of the heart is much enfeebled by extensive injuries of the central organs of the nervous system or of the other parts of the body, (as when a limb is extensively crushed,) its contractions are not only much weaker, but are also greatly increased in frequency. It is also worthy of remark that such injuries do not produce convulsive movements in this organ. The effect which severe injuries and certain inflammatory affections have in greatly debilitating or even destroying the contractility of the heart is a fact of great practical importance, as it not only explains the cause of the most alarming symptoms in such cases, but also points out the most appropriate remedies to avoid the chief tendency to death. To this cause, for example, we are to attribute the rapid and feeble pulse, in concussion of the brain, in extensive mechanical injuries, the shock after operations, extensive burns, peritonitis, &c. It is very fortunate that the contractions of the heart become more frequent when its contractility becomes enfeebled. If the heart under these circumstances had required, as we would *à priori* expect, the presence of a greater quantity of blood to stimulate it to contraction, instead of a smaller quantity, as is actually the case, what would have been the consequence? It is evident that since the resistance, under ordinary circumstances, which the heart has to overcome in contracting, is, according to a well-known hydrostatic law, in proportion to the extent of the area of the inner surface of the cavities of the heart at the commencement of their contraction, (each square inch of surface, according to the experiments of Hales, having a pressure upon it nearly equal to four pounds,) the more frequent contractions, where there is a smaller quantity of blood present in the heart at the commencement of each contraction, will not demand the same degree of muscular force for their performance, as if these had been less frequent. If, when the contractility of the heart became debilitated, the presence of a greater quantity of blood than usual in its interior had been necessary to stimulate it to contraction, and if the area of the inner surface of the cavities of the heart be in proportion to the quantity of blood contained there, it is apparent that the movements of the heart would have been much more rapidly and frequently arrested when its contractility became enfeebled, than they are under the actual arrangement.

The influence of mental emotions upon the movements of the heart requires no illustration, for this is so universally experienced that in common language the heart is considered to be the seat of the affections and passions, and this has had a powerful influence upon the phraseology of all languages.

In sanguine temperaments the heart generally contracts more frequently than in phlegmatic temperaments. In women it is also generally a little quicker than in men.

It varies very much in different classes of animals.

Burdach* has given the following table collected from numerous sources, as an approximative valuation of the frequency of the heart's action in various animals.

Number of pulsations in a minute.†

In the Shark	7
Mussel	15
Carp	20
Eel	24
Snake	34
Horse	36
Caterpillar	36
Bullock	38

* Edinburgh Medical and Surgical Journal, 1836. When I performed these experiments, I was not aware that I had been anticipated to a certain extent by Mr. Coleman. (Wilson on the Blood, &c. p. 131.) It is very possible that the sinuses upon the inferior cava and hepatic veins in the seal may, besides answering other purposes, have the effect of preventing this mechanical distension of the right side of the heart.

* Physiologie, vol. iv. p. 251.

† We cannot consider the number of pulsations of the heart in a minute given in the above table as by any means quite satisfactory. The number of pulsations in the ox and horse is given on the authority of Vetel in Froriep, Notizen, t. xxiv. p. 112. Other observers state the number of pulsations in a minute at from 38 to 52 in the horse, and from 64 to 70 in the ox.

Ass	50
Crab	50
Butterfly	60
Goat	74
Sheep	75
Hedgehog	75
Frog	77
Marmot	90
Locust	90
Ape	90
Dormouse	105
Cat	110
Duck	110
Rabbit	120
Menoculus Caster	120
Pigeon	130
Guinea-pig	140
Hen	140
Bremus terrestris	140
Heron	200
Menoculus pulex	200

For the effects of the respiration upon the contractions of the heart, and the influence of the circulation of dark blood upon its irritability, see ASPHYXIA.

The cause of the motion of the heart.—The motion of the heart, and the constancy and regularity of its movements, are circumstances so remarkable that they could not fail early to excite a deep interest among medical philosophers when they had once turned their attention to the explanation of vital phenomena. When we contemplate the heart commencing its movements at an early period of fœtal existence, and never resting from its apparently unceasing toil until the latest moments of life, and when we remember the uniform and regular manner in which all its actions are accomplished—all conspiring for the proper performance of the deeply important functions assigned to it, we are at first impressed with the idea that it is regulated by laws different from similar textures of the body, and altogether peculiar to itself. It must have been under the influence of similar impressions that the older medical philosophers approached this subject, and it is in this manner only that we can account for many of the strange speculations on the heart's action which they have left recorded.

We find one sect attempting to explain it by a peculiar innate fire. Sylvius, the head of the chemical sect, had recourse for its explanation to an effervescence excited by the intermixture of the old and alkaline blood with the acid chyle and acid pancreatic lymph.* Descartes supposed that a constant succession of explosions occurred in the heart from steam generated there, which propelled the blood through the body. Stahl got at once out of the difficulty by affirming that the heart was more particularly under the guidance of the anima or soul. But we cannot here dwell longer on these obsolete and to us in the present time almost incredible opinions, and the only use to which they are now applicable is to serve as beacons to keep us, in all our inquiries into the phenomena of living bodies, within the strict path of facts and observation, and to forcibly impress upon us into what strange and fatal errors even the brightest intellects may fall, when they leave the inductive method of investigation, and wander into the alluring but dangerous regions of hypothesis. And the effects of these errors are only the more to be dreaded as they are often clothed in the most seductive ingenuity. It ought also still more forcibly to inculcate upon us the important truth, which, though generally in our mouths, is not unfrequently forgotten in practice,—that as the material world and all which it contains have been placed by the Author of Nature under arbitrary and fixed laws, it is impossible to extend our knowledge of these by theorizing in the closet, and that this can only be effected by the patient interrogation of Nature herself.

It was not until the time of Senac and Haller that accurate notions began to be entertained on the nature of the heart's action.

The cause of the movements of the heart is distinctly referable to the same laws which regulate muscular contractility in other parts of the body, only modified to adapt it for the performance of its appropriate functions. Like all the other muscles it is endowed with irritability, which enables it to contract upon the application of a stimulus. The ordinary and natural stimulus of the heart is the blood, which is constantly flowing into its cavities. The greater irritability of the inner surface over the outer is evidently connected with the manner in which the stimulus is habitually applied. When the blood is forced on more rapidly towards the heart, as in exercise, its contractions become proportionally more frequent; and when the current moves on more slowly, as in a state of rest, its frequency becomes proportionally diminished. If the contractions of the heart were not dependent upon the blood, and their number regulated by the quantity flowing into its cavities, very serious and inevitably fatal disturbances in the circulation would soon take place.

As the heart continues to contract often for a very considerable time after the venæ cavæ have been tied, and after the blood has ceased to pass through its cavities, or after it has been removed from the body, this has been supposed by some to indicate that there is something in the heart's structure or in its vital properties which enables its movements to proceed independent of all other circumstances. But in all these cases a stimulus has been applied in some form or other to the heart. If the heart has been allowed to remain in its place, though the circulation of the blood may have come to a stand, part of it may yet remain in the different cavities of the organ; or if the pericardium has been opened, the impression of the external atmosphere may act as a stimulus. The experiments of Walther and Haller formerly mentioned upon the comparative irritability of the

* In the same manner Borelli says, "Constat ex dictis immediatam causam motivam cordis esse ebullitionem fermativam tartarei succi sanguinei excitatam à commistione succi spirituosi à nervis instillati." De Mutu Animalium, p. 97.

two sides of the heart, and the different results obtained when the one side of the heart was emptied of blood, and when it was retained in the other, are sufficient to shew the effect which the presence of blood in the cavities of this organ has upon the continuance of its action after the circulation has ceased. If the heart has been removed from the body and emptied of its blood, it must naturally follow that its different cavities will be filled with atmospheric air; and it has been well ascertained that this acts as a very powerful stimulant upon the inner surface of the heart.* Every circumstance connected with these experiments is in exact conformity with the opinion that the movements of the heart are only called into action by the application of a stimulant. Thus, when the irritability of the heart becomes more languid, and when the blood or the atmospheric air in its cavities becomes insufficient to raise it to contraction, strong and energetic movements may still generally be excited by having recourse to a more powerful stimulant, such as the prick of a scalpel or the application of galvanism. Since the heart is highly endowed with irritability, various other mild fluids besides the blood are capable of exciting it to contraction. As every organ, however, has its irritability adapted for the function which it is destined to perform, so we find that the heart, the central organ of the circulation, is most fitly called into action by the blood, its appropriate and natural stimulant.

In examining the nature of the irritability of the heart, and contrasting it with that of the voluntary muscles, we must not compare its contractions with those excited by volition in the muscles of voluntary motion, for these last are evidently modified by the nervous influence for an obvious purpose; but let us observe both when placed under similar circumstances, and irritated by the application of the same stimulant applied to the muscles themselves, and we will find that they only differ in this,—that in the voluntary muscles each successive application of the stimulant is generally followed by a single contraction, while in the heart it is followed, except when the contractility is much impaired, by several consecutive contractions alternated with relaxations. This tendency to successive contractions is also observed, though not to the same extent, in the muscular coat of the intestines.

We must admit, however, that the contractions of the heart proceed under circumstances where it is difficult to point out the presence of any sufficient stimulus, and where, to account for their continuance, we are almost obliged to have recourse to the supposition, that there is some innate moving power in the heart itself. It has been stated, for example, that the movements of the heart will proceed under the exhausted receiver of an air-pump. I have repeatedly placed under the bell-glass of an air-pump the heart of a frog when removed from the body and emptied of its blood, and I could never satisfy myself that the frequency or strength of its contractions was at all affected by the withdrawal or renewal of the air; and though it might be urged that the air is only rarefied, not entirely removed, in the best exhausted receiver of an air-pump, and that consequently in such experiments a stimulant still existed in the presence of the rarefied air, yet I would not consider this explanation of the continuance of its contractions by any means satisfactory. In these experiments there is another source of stimulation present which ought to be taken into account, for, as I shall afterwards shew, the slightest movement of the heart, such as that caused by its contraction, upon the surface upon which it is placed when removed from the body, is sufficient, from the great irritability of the organ, to act as a stimulant upon it. If these external stimuli appear to be insufficient to account for the persistence of the contractions of the heart under the circumstances we have mentioned, we may have recourse to another explanation drawn from the mechanical structure of the organ; for it is possible, as has been suggested by Dr. Alison, that from the peculiarly convoluted arrangement of the fibres, the outer may, during the contraction of the organ, pinch or stimulate the inner, and so cause this tendency to repeated contractions from one application of a stimulant. We do not, however, consider that we have succeeded perfectly in accounting for the continuance of the contractions of the heart under all circumstances, but we are unwilling to admit the existence of any peculiar innate and unknown agency in the production of any phenomenon, until it is satisfactorily established that it cannot be accounted for on the known laws which regulate similar phenomena in the same texture in other parts of the body. And it must also be remembered that these movements of the heart have only been observed when its contractility was still comparatively vigorous, and where sources of stimulation were still present. We ought, besides, to be the more cautious in admitting the existence of this innate moving power, since it is in opposition to a well-known law in the animal economy,—that though the various tissues of an organized body are endowed with certain vital properties, yet the application of certain external and internal stimuli is necessary to produce their manifestations of activity. In fact it is from the action and reaction of these tissues and excitants upon each other, that the phenomena of life result.*

* Peyer, Brunner, and Haller have seen the contractions of the heart renewed by blowing air into the cava ascendens. Wepfer and Steno produced the same effect by inflation of the thoracic duct. Enman states that he once observed the renewal of the heart's action in the human subject by blowing air into the thoracic duct. Vide Senac, tom. i. p. 326.

* The remarks which we have made above, illustrating the great length of time which the heart will continue to contract after being removed from the body, and when all communication between the nerves ramified in its substance and the sympathetic ganglia and the central organs of the nervous system have been cut off, when taken along with the equally well ascertained fact, that its contractions

Upon what does this irritability of the heart depend?—This has been one of the most keenly agitated questions in physiology, as a great part of the experiments, and much of the reasoning upon the nature of *muscular irritability*, have been furnished by this organ. As, however, the general doctrines entertained on this subject have already been fully discussed under the article CONTRACTILITY, we shall here confine ourselves to a few of the leading facts connected with it which have a special reference to the heart. The two principal questions on this point since the time of Haller have been, whether does it depend upon nervous influence? or is it a property of the muscular fibre itself independent of the nerves?

We have seen that the nerves distributed upon the heart are the par vagum and sympathetic. Numerous experimenters have removed portions of the par vagum on both sides of the neck without the slightest diminution of the strength of the contractions of the heart. These experiments we have frequently performed with the same results. There can now be no doubt that the sudden death which occasionally follows this operation is not to be attributed to the cessation of the heart's action, as some of the older experimenters believed, but, as Legallois has shewn, it depends upon an arrestment of the movements of the muscles attached to the arytenoid cartilages. Portions of the sympathetic have also been destroyed in the middle of the neck without any effect upon the contraction of the heart, except what could be sufficiently accounted for by the pain of the incisions and the terror of the animal. A portion of both of the sympathetic and pneumogastric nerves may be removed in the neck with the same results; in fact we cannot, in the dog and most quadrupeds, cut the par vagum in the middle of the neck without also dividing the sympathetic. Magendie affirms that all the sympathetic ganglia of the neck, along with the first dorsal, may be removed without any sensible derangement of the parts to which their nerves are distributed. Brachet* supposes that the reason why the excision of the sympathetic ganglia in the neck does not always arrest the heart's action, is because there is another source of nervous influence for the cardiac nerves placed below this in the cardiac plexus or ganglion. He accordingly put this opinion to the test of experiment, and he assures us that the total destruction of the cardiac plexus was followed by the sudden and permanent arrestment of the heart's action. Now when we consider the nature of such an experiment as this, with the chest of the animal laid open, the respiration arrested, and the heart exposed during the time the experimenter is searching and tearing for the plexus placed deep behind the aorta and pulmonary artery, and which would require a considerable time to display even in the dead body when unembarrassed by the movements of the heart, we must be more astonished that the action of the heart had not completely ceased before the experiment was finished, than that it should have continued so long. Besides, even allowing that this experiment could be relied upon, we have sufficient evidence, from the facts stated above, to entitle us to conclude that the heart is not dependent for its movement upon any influence constantly transmitted along its nerves from the central organs of the nervous system,—the brain and spinal marrow. Brachet is himself obliged to admit, from other experiments which he performed, that the division of the sympathetic at the lower part of the neck is not sufficient to arrest the heart's action, so that this experiment is intended to shew that its irritability depends upon the ganglia of the sympathetic itself. The independence of the irritability of the heart upon the brain and spinal marrow can be very satisfactorily proved in another manner. The occurrence of acephalous monsters,* and the experiments of Wilson Philip,† Clift,‡ and Brachet§ demonstrate that the brain or spinal marrow may be naturally wanting; that one or both of them may be removed entirely, or destroyed in small portions at a time, without arresting the heart's action. We may here observe that the experiments of Legallois,‖ Wilson Philip, Wedemeyer,¶ Brachet, and many others, in which the action of the heart was arrested by crushing large portions of the brain or spinal marrow, though they do not prove the dependence of the irritability of the heart upon the brain and spinal cord, at least shew, what the effects of mental emotions upon the movements of the heart had already pointed out, that it can be influenced to a great and most important extent through these organs. The advocates for the dependence of the irritability of the heart upon the nerves appear to have pretty generally abandoned the opinion that this is derived from the central organs of the nervous system, and now maintain the doctrine, which was more prominently developed by Bichat, that this is derived from the sympathetic, the ganglia of which, according to him, are independent sources of nervous influence. From the manner in which the sympathetic is distributed upon the heart, it is

may be readily increased or renewed under those circumstances, by mild excitants applied to its inner surface, are completely opposed to the supposition that the heart is called into contraction in a manner similar to those sympathetic movements more lately described under the term excito-motary. Though this mode of explanation may be considered quite legitimate when applied to those sympathetic movements which do not require the intervention of the brain for their performance, such as deglutition, respiration, &c., it is certainly pushing the doctrine far beyond its proper limits to apply it to the explanation of the movements of the heart.

* Du système nerveux ganglionaire, p. 120.

* The heart is generally though not always absent in acephalous monsters.

† Experimental Inquiry into the vital functions.

‡ Phil. Trans. 1815.

§ Système nerveux ganglionaire.

‖ Legallois performed these experiments on the spinal cord alone, and supposed he had proved that the movements of the heart were dependent upon that portion of the nervous system.

¶ Physiol. Untersuchungen über das Nervensystem, &c. p. 235.

perfectly impossible to insulate that organ from the nerve and experiment upon it; but we think we are justified in concluding from observations and experiments derived from other sources, that in all probability the contractility of the heart depends upon a property possessed by the muscular fibre itself without any necessary intervention of its nerves. The possibility of exciting or increasing the action of the heart by stimuli applied to its nerves has been mixed up with this question. Though it must be admitted that mechanical and chemical stimulants applied to a considerable surface of the central organs of the nervous system quicken the heart's action, yet experimenters have generally acknowledged that these stimulants applied to the nerves of the heart produce no effect upon its movements. Burdach,* however, maintains that he has quickened the heart of a rabbit deprived of sensation by applying caustic potass to the trunk of the sympathetic, or its inferior cervical ganglion. That the heart can be excited to contraction by the application of galvanism has had many supporters, and many celebrated names are arranged both on the affirmative and negative sides of the question. That the movements of the heart may be increased or renewed by the application of galvanism as the experiment is usually performed, there can be no reasonable doubt; for if one wire is placed upon the nerve and the other upon the heart, the moist nerve will act as a conductor to the electricity, and the effect produced will be the same as if the stimulant had been applied to the substance of the heart itself. Nysten admits that movements of the heart were excited by the galvanism when one of the wires was applied to one of the large arteries from which all the visible filaments of the nerves had been dissected off. Dr. C. Holland,† in a number of experiments, satisfied himself that the tissues of the body conduct galvanism with so much facility, that the heart's action could readily be excited, when one wire was placed upon the heart and the other in the nose, mouth, and even among the moist food in the stomach. I have performed similar experiments with the same results. Humboldt and Brachet assert that they have quickened the movements of the heart by applying both wires to one of the cardiac nerves. If these and the experiments of Burdach could be relied upon, they would be sufficient to prove that the heart could be occasionally stimulated through the cardiac nerves, but the negative experiments on the other side are so numerous, and the sources of fallacy in judging in this manner of the relative quickness of the heart's action between one time and another so obvious, that we must be allowed to distrust them unless they should be confirmed by other accurate observers.

Constancy of the heart's action.—The constancy of the heart's action is more apparent than real. After each contraction a state of relaxation follows. The relative duration of the contraction of the auricles and ventricles, according to Laennec, appears to be as follows:—a third at most, or a fourth or a little less by the systole of the auricles; a fourth or a little less by the state of quiescence; and the half or nearly so by the systole of the ventricles. From this he calculates that the ventricles, when the heart is acting with its usual frequency, rest twelve hours out of the twenty-four, and that in those individuals in whom the pulse is naturally below 50, it must be in a state of relaxation sixteen hours out of the twenty-four.* Now this is a degree of contraction of which many muscles of the body are probably susceptible, such as the muscles which support the trunk when we sit or walk, and which some, as the diaphragm and intercostals, generally perform.

Regularity of the heart's movements.—The regularity of the heart's movements, so essential to the welfare of the animal, has appeared, even to many modern physiologists, to be intimately connected with some peculiarity in its structure. We are inclined, however, to agree with Haller, that this is perfectly explicable on the known laws of muscular contractility in other parts of the body. The regularity of the heart's action was another fertile subject of hypothesis to the older physiologists; and even in the present day we find the term "*organic instinct*" employed to designate it.

The contractions of the heart take place in the order in which the blood flows into its different cavities; and if the blood be the habitual stimulant upon which its movements depend, this is exactly what we would expect.† The blood forced in greater quantity into the auricles by the contraction of the termination of the cavæ and pulmonary veins, stimulates the auricles to contract and propel an additional quantity into the ventricles; and this, acting as a stimulant upon the ventricles, excites them to contract and drive the blood into the arteries, when the same series of phenomena is renewed and repeated in the same succession.

The continuance of the heart's action after the circulation has ceased, we have already attempted to explain; and if these contractions depend upon the presence of a stimulus, they must evidently be in the same order as in the natural state of the organ, as these have not been interrupted. The continuance of the regular order of the contractions of the heart after its removal from the body can in general, we think, be satisfactorily accounted for by the substitution of a new stimulant for that of the blood; the cavities are then occupied with air instead of blood, and each

* Traité de Physiologie, tom. vii. p. 74, traduit par Jourdan.

† Experimental Inquiry, &c. p. 275.

* We have not here given Laennec's calculations of the relative duration of the contraction and relaxation of the auricles, as they must be founded on false data—on the supposition that the second sound of the heart marked the duration of the contraction of the auricles.

† This was also the doctrine maintained by Senac, op. cit. tom. i. p. 325. Senac, however, was opposed to the doctrine of Haller, that the contractility of the heart was a property inherent in the muscular fibre, and independent of the nerves, Tom. i. p. 451.

contraction of the auricle must force an additional quantity into the ventricle, and this, though small in quantity, may be quite sufficient to excite the ventricles to contraction, when the irritability is not too much impaired.* It is only in this manner, taken along with the greater irritability of the internal surface over the external, that we can explain the observation made by Dr. Knox in the course of his experiments upon the irritability of the heart in fishes, where, when the irritability was nearly exhausted, contractions excited in the auricle were sometimes followed by contractions of the ventricle, when irritation of the outer surface of the ventricle itself produced no effect.† Certainly, under ordinary circumstances, this regularity of the heart, so necessary for the proper performance of its functions, is a marked feature in its action; but that it is not either necessarily connected with its structure or vital properties, but depends solely on the manner in which its stimulant, the blood, is applied, is proved by various facts. 1st. The movements of the auricles and ventricles generally cease at different times after death; and though the auricles much more frequently continue to contract after the ventricles, yet several accurate experimenters have observed the left auricle become quiescent before its corresponding ventricle.‡ 2dly. When the movements of the ventricle have ceased, while the auricles continue to contract, the ventricle may generally be excited to vigorous contractions by the application of a powerful stimulus. 3dly. When the irritability of the heart becomes somewhat languid, two, three, or sometimes six or seven contractions of the auricle may take place before the ventricles are roused to contraction; the evident deduction from which is, that the contractions of the ventricles do not necessarily follow those of the auricles, unless the contractions of the auricles occasion the application of a stimulant to the inner surface of the ventricles sufficient to excite them to contraction. 4thly. The movements of the ventricles and auricles will go on in the same manner, though detached from each other by the knife. 5thly. If we were allowed to argue from final causes in negative cases, we could easily shew that a peculiar endowment, such as we are contending against, would not be of the slightest advantage in securing the regularity and constancy of the heart's movements. It appears, then, quite unphilosophical to call in the agency of some unknown and indefinite principle for the production of these periodic movements, as they have been called, of the different chambers of the heart, when they can be satisfactorily referred to the laws which regulate muscular contractility in other parts of the body. We have here a beautiful example of the manner in which nature produces adaptation of means to an end, not by the creation of new properties, which we, in our ignorance, sometimes erroneously attribute to her, but by the employment of those already in use in the performance of other functions, only modified to accommodate them to the circumstances under which they are placed.

Sounds of the heart.—On applying the ear over the region of the heart, two distinct sounds are heard accompanying its contraction. Though the existence of such sounds seems to have been known to Harvey,* who compares them to the noise made by the passage of fluids along the œsophagus of a horse when drinking, yet, as is well known, it is to Laennec that we owe the first accurate description of the character of these sounds, the order of their succession, and the manner in which they may hereafter be made available for the important purposes of the diagnosis of the diseases of the heart.

The first of these sounds is dull and prolonged; the second, which follows closely upon the first, is sharp and quick, and is likened by Laennec to the flapping of a valve, or the lapping of a dog. After the second sound a pause ensues, at the end of which the sounds are again heard. These three—the first sound, the second sound, and the pause—occur in the same uniform order, and when included along with the movements of the heart, to which they owe their origin, have received the term *rhythm of the heart*. As the dull prolonged sound is synchronous with the impulse of the heart, and consequently with the contraction of its ventricles, Laennec attributed this sound to the contraction of the ventricles. The second sound, which is synchronous with the diastole of the ventricles, he supposed must depend upon the systole of the auricles; and to this he was naturally led by the supposition that their contraction must also produce some sound. From the weight of Laennec's authority, this opinion

* When the heart has ceased to contract, it may frequently be called into pretty vigorous action by opening one of the large veins, and blowing some air into its cavities.

† I have repeatedly attempted to ascertain if the circumstances here described as sometimes occurring in the cold-blooded animals could be observed in the warm-blooded animals, but without success. In one experiment upon the heart of a rabbit, after all the movements of the ventricles had ceased, but *where they could still be readily excited by the application of a stimulant*, we were convinced that contraction of the auricle, when excited by stimulation applied to itself alone, was sometimes followed by contaction of the ventricle even after the ventricle had been *slit open*. But in subsequent experiments upon dogs, we ascertained a source of fallacy which we had overlooked in the other experiment, for we found that a slight movement of the heart on the surface upon which it rests, such as that caused by a very gentle pull at the large arteries, and not exceeding the effects produced by the contraction of the auricle, was, in some of these cases, sufficient to excite contractions of the ventricles.

‡ In one experiment upon a cat, I distinctly observed the right ventricle occasionally pulsate twice for each pulsation of the auricle. In another experiment, I distinctly observed the contractions of the ventricles precede those of the auricles, when the contractility of the heart had become enfeebled. In this case, the pause in the heart's action occurred after the contraction of the auricles.

* Op. cit. cap. v.

seems to have been almost implicitly adopted until the appearance of a paper by the late Professor Turner, in 1829. Professor Turner there recalled to the attention of medical men the observations of Harvey, Lancisi, Senac, and Haller, upon the order of succession in which the cavities of the heart contract, which appear to have been forgotten amidst admiration at the brilliancy of Laennec's progress. He also pointed out from their experiments that if the second sound was dependent upon the contraction of the auricles, it ought to precede instead of following the first sound, and that the pause ought to occur after the first sound, and not after the second. He also adduced, in farther proof of Laennec's error, observations drawn from the effects of disease, when, from some impediment to the passage of the blood from the right auricle into the ventricle, a distinct regurgitation takes place into the large veins at the root of the neck, and showed that in these cases the regurgitation marking the contraction of the auricles occurs without any accompanying sound; that immediately afterwards the impulse is felt attended by the first sound, and that the second sound takes place during the diastole of the ventricles and the passive condition of the auricles. He suggested that the second sound might be accounted for by the falling back of the heart into the pericardium during its diastole, to which "the elasticity of the ventricles at the commencement of the diastole, attracting the fluid by suction from their corresponding auricles, may perhaps contribute." Soon after the appearance of Mr. Turner's paper, Laennec's explanation of the cause of the second sound appears to have been pretty generally abandoned; and numerous attempts, both in this country and in France, have since that time been made to solve this difficulty. Some of these explanations appear to be mere guesses, occasionally at total variance with the anatomical structure of the organ, and at times presenting even as wide a departure from its normal action as that given by Laennec himself. Others, again, have entered upon an experimental investigation of the subject with enlightened views of its anatomy and physiology, have furnished us with much additional information, and lead us to indulge in the pleasing prospect that in a short time the matter will be completely set at rest.

The result of the experiments of Hope and Williams, attested as they have been by various gentlemen well qualified to judge of their accuracy,—also those of Mr. Carlisle, Magendie, Bouillaud, and the Dublin Committee, have satisfactorily determined that the account of the order of the contractions of the heart, and their isochronism to the sounds as stated by Mr. Turner, are perfectly correct. As, however, so many different circumstances attend each movement of the heart, any one of which may be capable of producing these sounds, it became a much more difficult matter, and one requiring great perseverance and accuracy of investigation, to determine upon what particular one or more of these, each sound depends. For accompanying, and synchronous with the first sound, we have the contraction of the ventricles, the collision of the different currents of blood contained there thus set in motion, the approximating of the auriculo-ventricular valves, the impulse of the heart against the chest, and the propulsion of the blood along the large arteries; while attending the second sound, we have the diastole of the ventricles, and the rush of a certain quantity of blood from the auricles into the ventricles, the sudden separation of the auriculo-ventricular valves towards the walls of the ventricles, and the regurgitation of part of the blood in the arteries upon the semilunar valves, throwing them inwards towards the axes of the vessels; so we will find that each of these in its turn has been thought capable of producing the sound which it accompanies, and still has, or until lately had, its advocates and supporters. As the subject is one surrounded with numerous and unusual difficulties, and is of comparatively recent investigation, it has followed, as was to be anticipated, that as new facts and observations are collected, many of the opinions first promulgated on this question have required to be modified or changed; and the scientific candour displayed by several of these authors in renouncing former published opinions is deserving of the highest praise.

Several of the explanations of the cause of the sounds of the heart proceed, however, upon the supposition that the relation of these sounds to the movements of the organ is different from what has been here represented. We shall merely state these without alluding to the arguments adduced in support of them, as we believe that they are founded upon inaccurate observation. Sir D. Barry believed that the first sound was synchronous with the diastole of the auricles, and the second sound with the diastole of the ventricles. Mr. Pigeaux, Dr. Corrigan also until lately, Dr. Stokes, Mr. Hart, and Mr. Beau, have maintained that the first sound is synchronous with the diastole, and not with the systole of the ventricles. According to Mr. Pigeaux, when the auricles contract they project the blood against the walls of the ventricle, and a dull sound (first sound) is produced; on the other hand, whilst the ventricles contract, they project the blood against the thin walls of the great vessels which spring from them, and a clear sound (second sound) is the result. Dr. Corrigan supposed that the first sound was produced by the rush of blood from the auricles into the dilating ventricles, and that the second sound owed its origin to the striking together of the internal surfaces of the ventricles during their contraction, after they had expelled all their blood. Mr. Beau believes with M. Magendie that the first sound arises from the impulse of the heart against the inner surface of the chest, but differs from him in maintaining that this occurs during its diastole, and not during its systole. The second sound he believes to depend upon the dilatation of the auricles. M. Piorry has revived the obsolete and perfectly untenable opinion of Nicholl, that the two ventricles contract at different times, and attributes the dull sound to the contraction of the left ventricle, and the clear sound to the contraction of the right ventricle. Dr. David Williams, while he believes that the first sound depends upon the rush of blood into the large arteries during the systole of the ventricles, attributes the second sound to the musculi papillares, which he considers as forming part of the valvular apparatus, causing the valves to strike against the walls of the ventricles. These musculi papillares do not, in his opinion, contract during the systole of the ventricles, but immediately afterwards, for the purpose of throwing open the auriculo-ventricular valves. In a former part of this article several circumstances are stated adverse to this opinion.

We shall now proceed to the explanation of the cause of these sounds given by those who maintain the views of the rhythm of the heart which we have here adopted, as resting upon the concurrent testimony of numerous accurate observers. These may be divided into those who attribute both sounds *to causes intrinsic to the organ*, or, in other words, to circumstances occurring within the organ itself, and into those who place them *external to the organ*, and depending upon extraneous objects. The only supporters of the latter opinion are Magendie and his followers. Magendie maintains that "in contracting, and for causes long since known, the ventricles throw the apex of the heart against the left lateral part of the thorax, and thus produce the first sound, *i. e.*, the dull sound. In dilating, in a great measure under the influence of the rapid influx of the blood, the heart gives a shock to the anterior paries on the right of the thorax, and thus produces the second sound, the clear sound." In proof of this, he states that on removing the sternum of a swan (an animal selected expressly for the experiment, as it interfered less with the natural action of the heart than in the Mammalia), he found that the movements of the heart produced no sound, while, on replacing the sternum, and allowing the heart to impinge upon its posterior surface as in the natural state, both sounds were again distinctly heard. He adduces several arguments drawn from the action of the heart both in its healthy and diseased state in favour of his opinion; and he ingeniously attempts to get rid of the objection which must instantly suggest itself, that in many cases, such as frequently occur in hypertrophy of the organ, the loudness of the sounds is diminished, while the force of the impulse is increased, by arguing that in these cases this increased impulse depends rather upon a heaving of the chest produced by the heart, which from its increased size is brought close to its inner surface, than upon a distinct impingement upon it, such as takes place in the healthy state. Dr. Hope, M. Bouillaud, Dr. C. J. B. Williams, and the Dublin and London Heart Committees have, however, distinctly heard both sounds of the heart, after that portion of the chest against which it impinges had been removed. It may, nevertheless, be objected to these experiments, that as the stethoscope was used in many of them, the impulse of the heart against the extremity may have produced an effect similar to its impulse against the parietes of the thorax. M. Bouillaud, having apparently this objection in view, states that the rubbing of the heart during its movements against the extremity of the stethoscope, is easily distinguished from the sounds of the heart; and that he has distinctly heard both sounds, though feebler than through a stethoscope, as was to be expected when nothing but a cloth was interposed between his naked ear and the surface of the heart. Dr. C. J. B. Williams, in his experiments, heard both sounds when the stethoscope was placed over the origin of the large arteries, and where no external impulse could take place; and this observation was repeated by the Dublin Committee. The Dublin Committee heard both sounds through the stethoscope, though feebler after the pericardium had been injected with tepid water; and in another experiment they were also heard when the ear was simply approximated to the organ. From all these experiments, I think there can be little doubt that the movements of the heart, independent of all extraneous circumstances, are attended by a double sound. As the impulse of the heart against the chest must produce some sound, as any one may convince himself by making the experiment in the dead body, and as this occurs during the systole of the heart, or, in other words, during the first sound, it may increase the intensity of that sound. Dr. R. Spittal,* after relating several experiments in which a sound similar to that of the first sound of the heart was heard by tapping gently with the apex of the heart or the point of the finger against the chest, both when empty and when filled with water, and after pointing out several sources of fallacy which he supposes were not sufficiently guarded against in the experiments which we have adduced above as subversive of this view, and which deserve the attention of future experimenters, comes to the conclusion that "it is highly probable that the percussion of the heart against the thoracic parietes during the contraction of the ventricles assists materially in the production of the first sound." He is also inclined to believe "that the act of the separation of the heart from the thorax after its approach, which was found in his experiment to produce a sharp, short sound, somewhat resembling the ordinary sound, may in certain circumstances be an assistant cause to the second sound."† Magendie's explanation of the second sound is completely untenable.

Among those who maintain that these sounds depend upon causes intrinsic to the heart, *the first sound* is referred by Rouanet, Billing, Bryan, and Bouillaud to the rapid approximation of the auriculo-ventricular valves during the systole of the ventricles, to which Bouillaud

* Edin. Med. and Surg. Journal, July 1836.

† Though Dr. Spittal is inclined to believe that the impulse of the heart against the chest has considerable share in the production of the first sound, he does not concur with Majendie in the explanation of the second sound.

adds the sudden separation of the semilunar valves when the blood is forced into the large arteries; by Mr. Carlisle to the rushing of the blood along the inner surface of the large arteries during the systole of the ventricles.* Dr. Hope, in the appendix to the second edition of his work, describes it as consisting, 1st, possibly of a degree of valvular sound; 2d, of a loud smart sound produced by the abstract act of a sudden jerking extension of the muscular walls, in the same manner that such a sound is produced by similar extension of the leather of a pair of bellows; to avoid circumlocution, he calls it the *sound of extension*; 3d, a prolongation and possibly an augmentation of this sound by the sonorous vibrations peculiar to muscular fibre." Dr. C. J. B. Williams has very justly objected to the correctness of the second cause here adduced as aiding in the production of the first sound, as the phrase "sound of extension" is obviously contradictory when applied to a contracting muscle.† Dr. C. J. B. Williams maintains "that the first sound is produced by the muscular contraction itself," the clearness of which is increased by the quantity of blood in the heart "affording an object around which the fibres effectually tighten, whilst the auricular valve, by preventing the reflux of the blood, increases its resistance, and thus adds to the tension necessary for its expulsion." He was first led to the adoption of this opinion by the observations of Erman and Wollaston upon the existence of a sound accompanying every rapid muscular contraction. This opinion he afterwards put to the test of experiment, the results of which we give in his own words. "Experiment 1st, observation 8th; I pushed my finger through the mitral orifice into the left ventricle and pressed on the right so as to prevent the influx of blood into either ventricle; the ventricles continued to contract strongly (especially when irritated by the nail of the finger on the left), and the first sound was still distinct, but not so clear as when the ventricles contracted on their blood. Observation 9th. The same phenomena were observed when both the arteries were severed from the heart." He also found in other observations that the first sound was louder over the surface of the ventricles than over the origin of the large arteries, which is in direct opposition to the opinion of those who believe that this is produced by the rush of blood along the great arteries. That the first sound is not dependent upon the closing of the auriculo-ventricular valves, he also ascertained from observations, in which the closure of these valves was partially or completely prevented, and yet the first sound was still heard. Besides, this sound continues during the whole of the ventricular systole, while the shutting of the valves must take place and be completed at the commencement of the systole." That the collision of the particles of fluid in the ventricles does not produce this sound he was convinced from observations, in which it continued although there was no blood in the ventricles.

Though we must admit that these experiments of Dr Williams prove that part at least of the first sound is caused by the muscular contraction of the ventricles, yet we must consider it still problematical, until we obtain further observations, whether it produces the whole of that sound, for it is very possible that some of the other circumstances attending the systole of the heart may increase its intensity. M. Marc d'Espine has maintained that both sounds depend on muscular movements; the first sound upon the systole, and the second upon the diastole of the ventricles. The Dublin Committee have in the meantime concluded that the first sound is produced either by the rapid passage of the blood over the irregular internal surface of the ventricles on its way towards the mouths of the arteries, or by the *bruit musculaire* of the ventricles, or probably by both these causes. We must wait for further experiments before this question can be fairly settled.*

Second sound.—Later experimenters appear to be more nearly agreed about the cause of the second sound than that of the first sound. M. Rouanet appears to have been the first who publicly maintained the opinion that the second sound was dependent upon the shock of blood against the semilunar valves at the origin of the aorta and pulmonary artery. M. Rouanet himself acknowledges that he owed the suggestion to Dr. Carswell, at that time studying in Paris, who came to that conclusion by a beautiful process of reasoning upon the phenomena which presented themselves in a case of aneurism of the aorta. The same opinion has been supported by Billing, Bryan, Carlisle, and Bouillaud.† It is, however, to Dr. C. J. B.

* As Mr. Carlisle is a member of the Dublin Heart Committee, we must now consider him as concurring with the report of that Committee.

† Medical Gazette, Sept. 1835.

* The London Committee, in their report given in at the meeting of the British Scientific Association for 1836, have adduced some additional experiments in favour of the opinion that the first sound of the heart depends upon muscular contraction. It appeared to them that the sound produced by the contraction of the abdominal muscles as heard through a flexible tube resembles the systolic sound. They, however, admit that though "the impulse is not the principal cause of the first sound, it is an auxiliary and occasional cause, nearly null in quietude and in the supine posture, but increasing very considerably the sound of the systole in opposite circumstances." From the great care with which these experiments appear to have been performed, we believe that we are now fully justified in adopting this explanation of the cause of the first sound. The Dublin Committee, in their report given in at the same time, also detail some experiments which they believe to be confirmatory of their former conclusions. See Sixth Report of British Scientific Association.

† In justice to Dr. Elliott, of Carlisle, I must state that I find, on consulting his Thesis De Corde Humano, published in Edinburgh in 1831, that he states (p. 51) that he believes that the second sound of the heart is dependent upon the rush of blood from the auricles into the ventricles during their diastole, and also upon the sudden flapping inward of the sigmoid valves at the origin of the large arteries by the refluent blood.

Williams that we owe the first direct experiments in support of it. In one experiment he ascertained that the second sound was louder over the origin of the large arteries than over the surface of the ventricles, while it was the reverse with the first sound; that pressure upon the origin of the aorta and pulmonary artery suspended the second sound; and that the second sound disappeared after the auricles had been laid open, although the first continued. In a second experiment* we find the following observations stated:—"Observation 6. A common dissecting hook was passed into the pulmonary artery, and was made to draw back and thus prevent the closure of the semilunar valves; the second sound was evidently weakened and a hissing murmur accompanied it. A shoemaker's curved awl was then passed into the aorta so as to act in the same way on the aortic valves. The *second sound now entirely ceased and was replaced by a hissing.* Observation 7. The hook and the awl were withdrawn; *the second sound returned and the hissing ceased.* Observation 8. The experiment 6th was repeated with the same result, and whilst Dr. Hope listened I withdrew the awl from the aorta. He immediately said, 'Now I hear the second sound.' I then removed the hook from the pulmonary artery; Dr. Hope said, 'Now the second sound is stronger and the murmur has ceased.'" The Dublin Committee have repeated and confirmed these experiments of Dr. Williams. In their experiments one of the valves in each artery was transfixed and confined to the side of the vessel by a needle, and the second sound disappeared; on withdrawing the needles they re-appeared.

As the second sound thus appears to be produced by the *shock of the blood upon the semilunar valves*, its intensity must, in a great measure, depend upon the diastole of the ventricle drawing part of the blood back upon them, but perhaps more particularly upon the elasticity of the large arteries returning suddenly upon their contents during the diastole of the ventricles, when the distending force of the ventricles has been withdrawn. We would therefore expect that the second sound should be louder in those whose aorta retains its elasticity, than in those (a circumstance sufficiently common in old age) in whom, from a morbid alteration of the structure of its coats, the elasticity is either lost or greatly diminished. This is an observation which, as far as I know, has not yet been verified; but my friend Dr. W. Henderson informs me that he is positive from numerous observations that the second sound is louder in young than in older persons; but whether this is in the exact ratio of the change upon the elasticity of the coats of the large vessels he is not at present prepared to say.

* These experiments were performed upon asses, in which the sensation was first suspended by a dose of wourara poison and then maintaining artificial respiration. In this manner the heart continued to act upwards of an hour after the commencement of the artificial respiration.

BIBLIOGRAPHY.—As a complete bibliography of the Anatomy and Physiology of the Heart would include all the systematic works on Anatomy and Physiology, we shall here confine ourselves to the enumeration of those works and memoirs which treat exclusively or in a prominent manner of the normal anatomy or functions of that organ.

Harvey, De motu cordis, Rot. 1661. *Lower (Richard)*, Tractus de corde, &c. Lond. 1669. *Pechlinus (John Nicol)*, Dissertat. de fabrica et usu cordis, Ricl. 1676. *Bartholin (Casp.)*, Dissert. de cordis structura et usu, Hafniæ, 1678. *Charleton (Walter)*, The organic structure of the heart, Lond. 1683. *Morton (C.)*, Dissert. do corde, Lugd. Batav. 1683. *Bellini (Laurent.)*, Opuscula aliquot de urinis, de motu cordis, &c. Lugd. Bat. 1696. 4to. *Chirac (Peter)*, De motu cordis adversaria analytica, Montp. 1698. *Vieussens*, Nouvelles Decouvertes sur le cœur, Montp. 1706. Traité nouveau de la structure du cœur, &c. Toulouse, 1715. *Thebesius*, De circulo sanguinis in corde, Leipsick, 1708. *Ibid.* De circulo sanguinis per cor, Leipsick, 1759. *Borelli (J. A.)*, De motu animalium, Lugd. Bat. 1710. *Winslow*, Sur les fibres du cœur et sur ses valves, Mém. de l'Acad. Roy. de Paris, 1711. *Morgagni (Jo. Bapt.)*, Adversaria Anatomica, Lugd. Bat. 1723. *Santorinus*, Observ. Anatomicæ, Venise, 1724, cap. viii. *Ruysch*, Epist. Anat. problemata decima de auricularum cordis earumque fibrarum metriciam structura, Amsterdam, 1725. *Lancisi (Jo. Mar.)*, De motu cordis, &c. Rom. 1728. fol. Op. Om. tom. iv. 1745. 4to. *Walther*, De structura cordis auricularum, Leipsick, 1738, reprinted in Haller's Disput. Anat. tom. ii. 1747. *Stuart (Alex.)* De motu et structura musculari, Lond. 1738. Examen de la question si le cœur se raccourcit ou s'alonge lorsqu'il se contracte, Mém. de l'Acad. de Paris, vol. i. p. 114. 1743. *Senac*, Traité de la structure du cœur, de son action, &c. Paris, 1749. tom. i. and Appendix to tom. ii. *Lieutaud*, Observ. Anatom. sur le cœur, dans Mémoires de l'Acad. de Paris, 1752-54. *Haller (Albertus)*, Mémoires sur la nature sensible et irritable des parties du corps animal, Laus. 1756. tom. i. *Ibid.* Elementa Physiologiæ, tom. i 1757. This last work, and the Traité de la Structure du Cœur, &c. of Senac, contain a most accurate and detailed account of all that was known upon the Anatomy and Physiology of the Heart before and at the time they were written. *Wolff (C. F.)*, Dissertationes de ordino fibrarum muscularum cordis, in Acta Acad. Petropolit. 1780-1792. *Abernethy (John)*, Observations on the Foramina Thebesii of the Heart, Phil. Trans. 1798. *Legallois*, Dictionnaire des Sc. Méd. tom. v. 1813. *Gerdy (P. N.)*, Journal Compl. du Diction. des Sc. Méd. tom. x. 1821. Recherches, Discussions, et Propositions d'Anatomie, Physiologie, &c. 1823. The plates given by Gerdy in the latter work have been copied by M. Jules-Cloquet in his Planches d'Anat. de l'Homme, &c. tom. iv. *Vaust (J. F.)*, Recherches sur la structure et les mouvemens du cœur, Liege, 1821.

Memoirs exclusively on the relative size of the several cavities of the heart.—*Helvetius*, Sur l'inégalité de capacité qui se trouve entre les organs destinés à la circulation du sang dans le corps de l'homme, &c. Mém. de l'Acad. de Paris, 1718. *Weiss*, De dextro cordis ventriculo post mortem ampliore, Altdorf, 1745. *Avrivillius*, De cavit. cordis inæquali amplitudine, &c. *Haller*, Disp. Anat. Sel. vol. viii. pars ii. p. 257. 1751. *Sabatier*, Mém. de l'Acad. de Paris, 1774.

Treatises exclusively on the nerves of the heart.—*Neubauer (J. E.)*, Descriptio nervorum cardiacarum, Frankfort et Leipsick, 1772. *Andersch*, Descript. nerv. cord. in tom. ii. Ludwig Script. Neurol. 1792. *Behrends (Jo. B. O.)*, Dissertatio quâ demonstratur cor nervis carere, Mayence, 1792; reprinted in tom. iii. Ludwig Script. Neurol. tom. iii. 1793. *Zerenner*, An cor nervis careat iisque carere possit? Erford, 1794; reprinted in tom. iv. Ludwig. Script. Neurol. 1795. *Scarpa,* Tabulæ Neurologicæ, &c. Ticin. 17:4.

Memoirs on the peculiarities of the fœtal heart.—Memoirs upon the Foramen Ovale by Duverney, Mery, Bussiere, and Littré in Mém. de l'Acad. 1699 to 1703. *Winslow,* Sur une nouvelle valvula de la venæ cavæ inferior, qui peut avoir rapport à la circulation du sang dans le fœtus: Mém. de l'Acad. 1717. Eclaircissement sur un Mém. de 1717. Ibid. 1725. *Haller (Albert),* De Valvula Eustachii, Götting. 1737, et in Disp. Anat. tom. ii. 1747. *Brendelius,* De valvula venæ cavæ, Wittemberg, 1738; reprinted in Opusc. Math. et Med. Pars i. *Lobstein (J. F.),* De Valvula Eustachii, Strasbourgh, 1771. *Sabatier,* in Mém. de l'Acad. 1774. *Wolff,* De foramine ovali, &c. in Nova Comment. Petropol. t. xx. *Kilian,* Kreislauf im Kinde, &c. Karlsruhe, 1826. *Biel (Guil.),* Do foraminis ovalis et ductus arteriosi mutationibus, 1827. Berlin. *Jeffray.* Peculiarities of the fœtal circulation, Glasgow, 1834. Edinb. Med. and Surg. Journ. 1835.

On the sounds of the heart.—*Laennec,* Traité de l'Auscultation Médiate, &c. Paris, 1819. Forbes's translation, 4th edit. 1834. *Turner (John W.),* 3 vol. Med.-Chirurg. Trans. Edinb. 1828. *Williams (Dr. David),* Edinb. Med. and Surg. Journ. vol. xxxii. 1829. *Corrigan,* Dublin Med. Transact. vol. i. 1830. *Stokes and Hart,* Edin. Med. and Surg. Journ. 1830. *Spittol (Dr. R.),* Treatise on Auscultation, Edinb. 1830 *Rouanet,* Journal Hebdom. No. 97. *Pigeaux,* Journal Hebdom. tom. iii. p. 239, et tom. v. p. 187, for 1831, et Archiv. Gén. de Méd. Juillet et Novembre, 1832. *Billing,* Lancet, May, 1832. *Hope,* A Treatise on Diseases of the Heart and great Bloodvessels, 1st edit. 1832. Appendix to 2d edit. 1835. *Bryan,* Lancet, Sept. 1833. *Piorry,* Archiv. Gén. de Méd. Juin, 1834. *Newbigging (Dr. P. S. K.),* Inaugural Dissertation on the impulse and sounds of the heart, Edin. 1834. *Carlile,* Dublin Journal of Medical Science, vol. iv. 1834, and Transact. of British Scient. Assoc. vol. iii. 1834. *Magendie,* Lancet, Feb. 1835. Medical Gazette, vol. xiv. *Bouillaud,* Traité clinique des maladies du cœur, tom. i. 1835. *Williams (Dr. C. J. B.),* The Pathology and Diagnosis of Diseases of the Chest, 3d edit. 1835, and Medical Gazette, Sept. 1835. Report of Dublin Committee for investigating the sounds of the Heart, Dublin Journal of Medical and Chemical Science, Sept. 1835, and Transactions of British Scient. Assoc. vol. v. *Beau,* Lancet, Feb. 1836. *Spittal (Dr. R.),* Edin. Med and Surg. Journal, July, 1836. Reports of the London and Dublin Committees for investigating the sounds of the heart. Transactions of British Scientific Association, vol. vi. 1837.

(John Reid.)

ON THE ARRANGEMENT OF THE FIBRES OF THE HEART.—[The Editor hopes that the following detailed account of the researches of Mr. Searle on this difficult point of minute anatomy will not be deemed unacceptable. Any reference to the labours of other anatomists has been rendered unnecessary in consequence of that part of the preceding article which bears upon this subject.]

Preliminary remarks.—In order to unravel the fibres composing the ventricles of the heart, considerable preparation is necessary. The auricles, fat, coronary vessels, and external proper membrane should be cleanly dissected off; the heart should then be boiled thoroughly, but not too much, so as to give its fibres the requisite degree of firmness without rendering them fragile. For example: sheep's hearts should be boiled ten or fifteen minutes; calves' twenty or thirty, and bullocks' forty or fifty minutes; immediately afterwards they should be immersed in cold water; for if they be exposed to the air while hot, their superficial fibres become dark, dry, and brittle. As the process of unravelling occupies many hours, and as the heart requires to be preserved in a good condition, it should be immersed during the intervals in weak spirit and water. The heart of the calf is preferable to that of any other animal, it being on a scale which affords distinct views, while the fibres of young are more easily separated than those of older animals. The conformation is the same in all quadrupeds, and bears a complete resemblance to that of the human heart. When the coronary vessels are dissected off, a depressed line or track is left on the anterior and posterior surfaces of the heart. Since this line corresponds externally to the entire edge of the septum, and to the boundary of the right ventricle, it may be usefully employed in reference to these parts. It is therefore denominated the anterior or posterior coronary track, accordingly as it pertains to the anterior or posterior surface of the heart.

The fibres of the heart are not connected together by cellular tissue as are those of other muscles, but by an interlacement which in some parts is very intricate, and in others scarcely perceptible. At the entire boundary of the right ventricle they decussate, and become greatly intermixed; at the apex and base of the left ventricle they twist sharply round each other, and so become strongly embraced; but in general the interlacement is so slight that they appear to run in parallel lines. Whether a mere fasciculus or a considerable mass of this last description of fibres be split in the direction of the fibres, a number of delicate parallel fibres will present themselves, some being stretched across the bottom of the fissure perfectly clean and free from any connecting medium whatever; and although some must necessarily be broken, yet these are so few that they do not attract attention unless sought for. In this process of separation very little resistance is offered; and none that is appreciable when a single fibril is taken hold of by the forceps, and stripped off, and which could not be done if bound down by cellular membrane.

If a piece of common muscle be afterwards split, it will be found to offer great resistance, and to be attended with so much laceration of the fibres, that instead of a beautiful series of fine muscular threads arranged in parallel lines, a ragged mass of mutilated fibres appears; and during the process of separation, the cellular substance is seen not only to connect the fibres, but to afford the resistance which is experienced.

This comparison obtains in the undressed state of the specimens; but when cooked, other distinctions are met with. For example: in whatever direction a roasted heart be sliced, its cut surface is uniformly smooth, not grained like other muscles when dressed; and it eats short, not offering that elastic resistance which other muscles do during mastication.

The absence of cellular substance as a con-

Fig. 278.

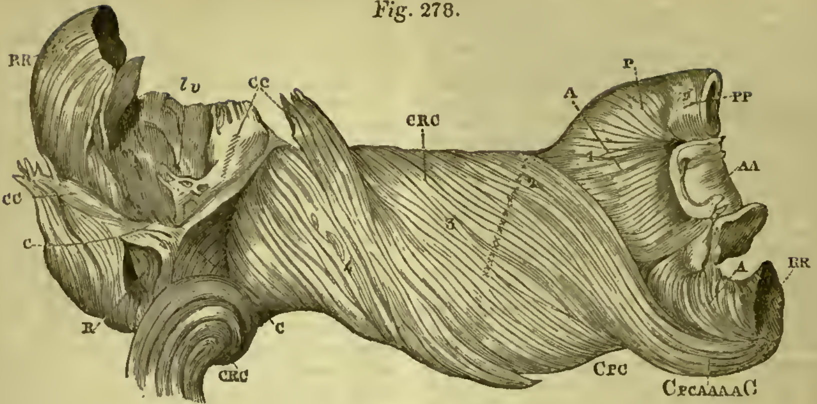


Fig. 279.

Fig. 280.

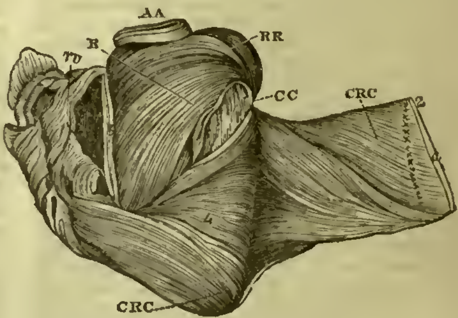


Fig. 281.

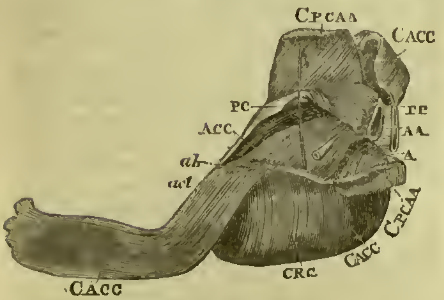
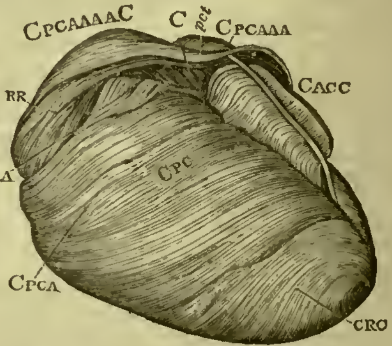


Fig. 282.



necting medium among the fibres in question is not only proved by the absence of its physical characters, but by its not being discovered through the medium of the microscope. Neither Mr. Kiernan nor Mr. Goadby, who examined the fibres with me, could detect its existence.

Since the chief utility of cellular membrane in investing and connecting together the fibres of a muscle is, most probably, that of retaining them within their proper spheres of action, and since the fibres of the heart are devoid of this agent, the question arises as to what other retaining power these possess. On this head no difficulty presents itself; for the fibres, in winding round and round the cavity of the left ventricle, become arranged in concentric layers; and in taking a larger sweep, in surrounding the right ventricle, the same arrangement is preserved, so that during the systole of the heart the whole mass of the fibres firmly compress each other, which necessarily retains them all within their proper spheres of action, excepting the superficial fibres, of which those towards the base, and especially those upon the right ventricle, where there is great latitude of motion, do not preserve a parallelism with their subjacent fibres, but lie nearly at right angles with them. It is on this account, most probably, that the superficial fibres have attracted notice, and have been viewed as a distinct layer.

The disposition of the fibres varies in different parts of the heart, forming parallel lines, angles, decussations, flat and spiral twists. The fibres are arranged in fasciculi, bands, layers, and a rope, which are so entwined together as to form the two chambers called the right and left ventricles. These are lined with their internal proper membrane.

The fasciculi are connected with the aorta, pulmonary artery, and carneæ columnæ, and contribute to the formation of the bands.

The bands.—By tracing the fibres in bands, we are enabled to develop the formation of the ventricles in a progressive and systematic manner. The bands spring from a mass of fibres which forms the apicial part of the left ventricle, and which, in winding round just above the apex of the heart, separates into two bands to form the right ventricle.

It will render the demonstration more intelligible if a preliminary and cursory view be taken of the general course of these bands (*fig.* 283, *p.* 626,) by referring to the diagram. The bands, as there given, form a mere skeleton of the heart, merely indicating the several courses they take. The average width of the bands is not less than a third of the extent between the apex and base of the left ventricle. In the diagram, CRC indicates the winding of a considerable mass of fibres just above the apex; at the septum, S, it splits into two bands. The shorter, CACC, encircles spirally both ventricles, one half round the right, the other round the left ventricle. The longer band describes two circles: it first passes through the septum, round the left ventricle marked CPCA; it secondly passes round the base, and includes both ventricles in its circuit, marked progressively CPCAA, CPCAAA, CPCAAAAC, and RR.

After employing so many letters, it is requisite to explain that as the bands are frequently receiving fresh accessions of fibres, it is desirable to characterise those increments individually by the initials of the names of the respective sources from which they are derived; and in order to make a distinction between the indications of the fibres and of their respective origins, the latter are characterised by double, and the former by single initials. Accordingly, the aorta, the pulmonary artery, the rope, and the carneæ columnæ are designated AA, PP, RR, and CC, while their fibres are marked A, P, R, and C. This plan is modified in one instance only, viz., the fibres of the main bulk of the heart, being derived from the rope and the two carneæ columnæ of the left ventricle, are designated in the first instance by their proper initials CRC; but as numerous increments of fibres are being made, in succession, to these three original sets, it is convenient to make an abbreviation in the lettering; thus, CRC is indicated by C large, when combined with other initials; accordingly, CRCA is contracted to CA, and CRCPCA to CPCA, and so with the rest.

The layers.—Although the heart admits of being split into a number of layers, yet there being no material division formed by fasciæ or condensed cellular membrane, such separations are strictly arbitrary. It is, however, found convenient to separate the fibres into certain layers, in order to give a methodical demonstration of the formation of this organ. The same remarks obtain regarding the bands.

It is generally supposed that the superficial fibres properly constitute a distinct layer, forming a common sac, which encloses the two ventricles. This is not strictly the case, for it has the same origins and terminations as have the fibres immediately subjacent to it. Nevertheless, the superficial fibres are, in the following description, considered as a separate layer, to show the peculiar construction of the apex.

The rope.—It has already been stated that the longer of the two bands terminates at the base in the rope. The fibres of this band, in forming the brim of the left ventricle, make a sharp twist like those of a rope, by which means they become the inner fibres of this chamber, and expand into a layer which enters largely into the formation of the mass which divides into the two bands. So the principal band, although it receives several increments of fibres, has no complete beginning nor ending, a considerable portion of it originating and terminating in itself, which circumstance renders it necessary to fix upon the most convenient part of its course for the commencement of the demonstration.

Although the system here adopted of unravelling the fibres of the heart be strictly arbitrary, as every other must be, yet it will, most probably, be found the only method by which all the various courses, and several connexions made by the fibres in forming the heart, could be displayed.

The demonstration.—It is requisite to pursue two methods of demonstration;—one, describing the *dissection*, or unfolding, which consists in unravelling and separating the fibres, and tracing, from the circumference to the centre of the heart, their various courses, in the form of bands, by which they become in order unwound, and by which a general view of the formation of the two ventricles is at the same time presented. The other, describing the *formation*, or winding up of the fibres, comprehends the retracing of the fibres from the centre to the circumference, showing their respective origins, associations, courses, connexions, and terminations, also the manner in which they are wound up to form the two ventricles into one compact conical body.

The dissection.—The first stage consists in separating the superficial fibres from the two ventricles, which, perhaps, cannot be accomplished in a more simple manner than by raising them in the forms of two wings and a tail, as represented in *fig.* 279, which is to be done by commencing at the anterior coronary track, cutting through the superficial fibres and detaching them by means of a blunt scalpel in their natural direction, so far as their insertions at the base; this will be found to divest the right ventricle, and, from their obliquity, a part of the left. (See the left wing, Cacc.) Then recommencing at the anterior coronary track, the fibres should be separated in the contrary direction, over the left ventricle towards the apex. These fibres take a very spiral course, and as they approach the apex converge, but on reaching it they twist sharply round upon themselves, like the fibres of a thick cord, and entering at the apex become the internal fibres of this chamber. The remaining part of the superficial fibres, extending from the apex to the base, pertains exclusively to the left ventricle; these should be divided an inch or two above the apex, and the apicial portion detached, which will complete the tail, Crc. Its fibres are represented, as they appear after separation, untwisted. The basial portion of these fibres should now be detached so far as the annulus arteriosus, and reflected like the right wing, Crc. These, as do most other fibres which approach the base, take a more longitudinal course, and in general they become so separated as they diverge to encompass the basial part of the heart, that they cannot be raised in an entire layer unless some of the subjacent fibres be taken with them.

The second stage of the dissection comprises the disconnecting the bands which compose the outer or proper wall of the *right ventricle.* The superficial layer of fibres having been removed, there remain two other layers pertaining to this wall of the ventricle, viz. the middle and the internal. The *middle* is separable into two bands, the upper or basial, and the lower or apicial. It is better to detach the *apicial* band first, which makes one spiral circle round the heart. Its outer extremity being attached to the root of the aorta at its anterior face, and sometimes to the pulmonary artery also, an incision should be made extending from the upper part of the anterior coronary track obliquely towards the annulus arteriosus, which incision should, in a calf's heart, be a little more than an inch in length and a tenth of an inch in depth. The band should then be detached agreeably to its spiral course from the base and middle third of the left, and from the lower half of the right ventricle, as far as the anterior coronary track, the line from which the separation commenced. It here receives on its posterior surface a considerable accession of fibres from the right surface of the septum, by the junction of which this part of the boundary of the ventricle is formed, but the further separation of the band prevented. In *fig.* 281, in the first or basial part of its course it is indistinctly seen, marked Cacc. In *fig.* 282 its middle course may be traced, although the half circle of the band which wound round the left ventricle has been cut off. In the preparation exhibited in this figure the separation of this band could not be effected under the posterior coronary track, on account of the separation having been conducted too deeply, where the fibres decussate to form the posterior boundary of the right ventricle. In *fig.* 281, which exhibits a dissection of the right ventricle of a bullock's heart, the whole of the band, Cacc, is separated as far as the anterior boundary of this cavity, and lies extended; and the accession of fibres it receives from the right surface of the septum are seen prolonged into it.

The *basial* band crosses the upper half of this ventricle. It cannot be raised from its situation on account of the numerous lateral connexions it forms in its progress with the margins of the orifices of the aorta, pulmonary artery, and annulus venosus. In order to detach it as far as it will admit, an incision about half an inch on the right side of and parallel with the anterior coronary track, should be made, extending from its lower edge to the base, and an eighth of an inch in depth, or as deep as will expose the fibres from the pulmonary artery, which in general pass at an angle with those of the band. Although this band cannot be disconnected from the base, it can in general be detached from the fibres of the subjacent layer, so far as the posterior coronary track; sometimes, however, they are too interwoven to admit of any separation. The first part of this band is represented in *fig.* 281, marked Cpcaa; it was divided more than half an inch from the anterior coronary track. Its continuation may be seen in *fig.* 282, lettered Cpcaaa, where it is evidently not disconnected from, but merely raised towards the base, and if replaced would overlap the fibres taking the middle course round the heart. The depression at the line of the posterior coronary track, *pct*, is occasioned by the band being bound down at the base and at its under surface also, by which means the upper half of the posterior boundary of this ventricle is formed. As the further pursuit of this band pertains to the third stage, it will be made hereafter.

The *internal* layer. By the separation of the two former bands the internal layer is exposed. It is composed of fibres from the pulmonary artery and from one of the carneæ columnæ. In *fig.* 281 the fibres, pc, are seen arising from the root of the pulmonary artery at its entire circumference, first forming a channel and then expanding into a layer, which, in proceeding obliquely across the cavity, obtains an accession of fibres from one of the carneæ columnæ, which is not brought into view, and which, on reaching the line of the posterior coronary track, joins a band emerging from the septum, and thus forms the apicial half of the posterior boundary of this ventricle. It is raised from its situation, but when replaced its edge, which is everted by the probe, applies itself to the anterior boundary of this cavity. This layer cannot often be so extensively disconnected from its superjacent bands as this figure represents.

The third stage of the dissection.—Having separated the layers composing the right or proper wall of the right ventricle, the next proceeding consists in detaching and unwinding the band and layers composing the left ventricle. First, the detachment of the basial band. As this band has already been detached over the right ventricle in the second stage of the dissection, it is necessary to resume its separation at the posterior coronary track. But as the further separation is somewhat difficult, it will be rendered less so if the remaining portion of this band be first examined in *fig.* 282, wherein it is represented detached. When in its natural situation it forms the uppermost third of this, the left ventricle, and its lower fibres overlap a part of those which occupy the middle third. The fibres which overlap the others in taking an oblique course towards the base reach the brim of the ventricle and pass over it, while the under fibres of this band are appearing in succession, and taking a similar spiral course until the whole bundle of fibres is twisted in the form of a rope. In order, therefore, to trace out and detach this band as it becomes transformed into a rope, it is requisite to commence near the posterior coronary track *(pct)*, in a continuous line with the lower edge of its former portion, introducing the handle of a scalpel obliquely upwards so as to detach the fibres which overlap those of the middle third, and to carry the separation so far up as will reach those marked A, coming obliquely down from the aorta. In conducting this separation from left to right it is soon found that the fibres of this bundle, instead of overlapping others, become themselves by twisting overlapped, rendering it necessary, therefore, to turn gradually the handle of the scalpel obliquely downwards, tracing the rope according to its windings. Two scalpels will be required in conducting the further separation.

The next step should be preceded by viewing the fibres of the rope in *fig.* 280, descending and radiating into a layer which sweeps round the cavity of this ventricle. The heart should now be placed in a small cup or jar of a size that will support it with its base upwards, and then, with the scalpels employed vertically, the separation should be proceeded with, and in passing through the septum a vertical section should be made through the aorta in the line of separation, which should be pursued round and round, and progressively deeper until the handles of the scalpels perforate the external fibres, which, if they have been rightly inclined, they will do a little above the apex of the left ventricle, just after they have completed the division through the layers of the septum. The band of fibres occupying the middle third of the heart, and which now pass over the scalpels, should be divided; the incision being made along the side of the posterior edge of the septum. A section should be made through the rope also, which allows the right ventricle to be raised from the left, and the heart to be unwound as far as the separation has been carried. There yet remains a mass of fibres around the cavity of the left ventricle to be detached. This last process of separation should be conducted in a contrary direction to that which has hitherto been adopted, viz. from right to left, until the internal membranous lining is exposed, and which should be torn in order to lay open this chamber.

The heart can now be unwound and extended as in *fig.* 278, placing the left ventricle, *lv*, at one end and the right at the other, removing that section of the aorta, AA, connected to the right ventricle from its counterpart which exclusively pertains to the left, and which is hidden by the rope, RR; removing also the two portions of the bisected rope to the two most distant diagonal points in this view. The niche, CPC, indicates the part occupied by the divided band which passed along the middle third of the heart.

The second method of demonstration.—The formation, or winding up of the fibres, of the heart. This description comprehends the retracing of the fibres from the centre to the circumference, showing their respective origins, associations, courses, connexions, and terminations, also the manner in which they are wound up to form the two ventricles into one compact conical body.

The first stage consists in retracing the superficial layer from its origins to its terminations. It is necessary to commence at the very centre of the heart—the interior of the left ventricle, whence spring the fibres composing its main bulk. *Fig.* 278, at its right extremity, exhibits the left ventricle, *lv*, laid open, exposing the two carneæ columnæ, CC and CC, one of which is placed out of its situation, in order to show the interior of the chamber. The fibres of the two carneæ columnæ, CC and CC, expand in a fan-like manner; those of the rope, RR, expand in a similar manner; the radiated fibres of each of these three bodies wind round the axis of this ventricle forming its parietes; and as they wind so as to form an inverted cone, it is clear that the inmost fibres alone can reach the apex. Accordingly, a fasciculus of the inmost fibres from each of these three bodies, marked C, R, and C *respectively*, pass down to the apex associated together, and in their course make a gentle twist from left to right, gradually contracting the cavity to a point and closing it; they then twist sharply round upon each other and complete the apex marked CRC *conjointly*, so that by means of this twisting the internal fibres are rendered external. These excluded fibres now enter into the formation of the superficial layer, and form the tail of *fig.* 279. They take a very spiral course near the apicial part, and over the anterior surface of the left ventricle as far as the anterior coronary track; but as they approach the base, pass more longitudinally. It is evident that these few fibres would be inadequate to form a complete layer, unless in their prolongation they pursued an uniformly spiral course. They are more than enough to cover the apicial part as they twist over each other; but in consequence of the conical form of the heart they soon become singly arranged, and as they diverge, separate and leave interspaces, some of which are occupied by fibres which apparently arise abruptly at the surface. The fibres which pass longitudinally to the base of the left ventricle are inserted into the tendinous margin of the annulus arteriosus, and into the posterior part of the root of the aorta, forming the right wing, CRC. The spiral fibres have been stated to arrive at the anterior coronary track along its whole length. The majority of them terminate at the coronary vessels; others are merely intersected by them, while others pass under these vessels and become superficial again: those which maintain their course over the right ventricle vary in different hearts from a small to a considerable number. Along the whole length of this track accessory fibres from the interior of the right ventricle are emerging to associate with these in their way over this ventricle. They take a longitudinal course to the base, and therefore start at an angle with the spiral fibres which are on the left side of the coronary track. In *fig.* 281 these accessory fibres from the aorta, AA, and from two of the carneæ columnæ, are seen passing together obliquely down the right surface of the septum, marked ACC, to enter into the formation of the extended band. These accessory fibres perforate it along the anterior boundary, *ab*, and become superficial. This layer is, accordingly, in *fig.* 279, marked CACC; its fibres pass at nearly right angles with the subjacent fibres, and when raised form the left wing; its insertions are the anterior part of the root of the aorta, the tendinous margin of the annulus venosus, and again the right part of the root of the aorta. Sometimes festoons are formed at the base by communications of fibres between the pulmonary artery and the aorta, at its right and posterior aspects.

It occasionally happens that the accessory fibres which arise from the interior of the right ventricle are not very numerous; in such cases a greater number of fibres arise abruptly from its surface.

The superficial layer has three sets of origins: one, primitive, from the interior of the left ventricle; the others, accessory, from the interior of the right ventricle, and from the outer surface of both. It cannot with propriety be considered as one common investment, since each ventricle for the most part gives birth to its own superficial fibres. It is necessary to raise it as a distinct layer for two reasons: first, that the superficial fibres of the right ventricle in general pass nearly at right angles with their subjacent fibres, and therefore require to be removed in order to proceed with the next stage of separation: secondly, that it developes the peculiar mode of closing the left ventricle, and of forming the apex; and probably no other method than that of the twisting of the fibres could have been so secure, especially as the parietes at the apex of the ventricle do not generally, even in a bullock's heart, exceed a tenth of an inch in thickness.

The second stage —The external layer having been traced from its origins to its insertions, we may now trace the deep-seated layers; and as these have, for the most part, the same origins, courses, and insertions as the superficial layer, we may commence the description at the same points.

It has been already stated that the fibres of the rope and of the two carneæ columnæ expand in a fan-like manner, that their inmost fibres pass through the apex and become external, but that the chief of them wind round the axis of the left ventricle above the apex, as exemplified in *fig.* 279, CRC. The respective sets of fibres pertaining to these three bodies continue separate during their radiation only, after which they become plaited together by folding one over the others. Their mode of association is shown in the extended portion of the split layer, CRC in *fig.* 280, also in its counterpart, CRC, winding round the apicial part of the ventricle. Again, in *fig.* 278, it may be seen that the fibres at the bases of these columns turn under and pass up in conjunction with those of the rope forming the middle mass, CRC, at the upper of which they fold over making flat twists upon themselves, which have, however, become exaggerated in appearance by the unwinding of the heart, as in rolling it up again some of the angles are converted into spires, preserving a considerable degree of parallelism.

Having shown the origins, and the method adopted in the association, of the fibres forming the middle mass in *fig.* 278, we proceed by tracing the divisions and prolongations of its fibres, and the plan of building up the two chambers of the heart. First, the formation of the *left ventricle*. If the right carnea columna, CC, be replaced in contact with its fellow, and if the rope, RR, be brought round the upper part of this cavity so as to embrace them, and if portion 4 be split from the middle mass, CRC, and be wound, in association with the apicial fibres, CRC, round the lower part of this cavity, that division of the heart, comprising the left ventricle and the middle mass, will bear a near resemblance to that represented in *fig.* 280; in which figure the rope, RR, in embracing the heads of the carneæ columnæ, CC, brings into view its fan-like fibres, R, sweeping round the upper part of the axis of this ventricle; in which the fibres of portion 4, in winding round the lower half of the axis, embrace the bodies of the carneæ columnæ, CC, and associate with the apicial fibres, CRC, and in which the extended layer, CRC, represents the middle mass minus the portion 4, which is split from it. Thus much pertains exclusively to the description of the formation of the left ventricle. That of the right is more complicated, and constitutes—

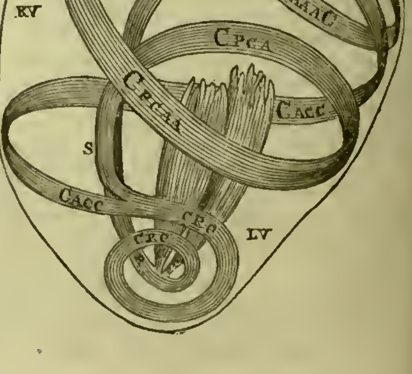
The third stage. In pursuing the mass of blended fibres, CRC, occupying the middle of *fig.* 278, it is found that, after having formed the left, it splits under the line marked by stars into two bands, which embrace and contribute to form the right ventricle. These separated bands were stated in the preliminary remarks to be of unequal lengths, the longer making two and the shorter making but one spiral circle round the heart. The longer, in the first place, assumes the character of a layer and forms the middle layer of the septum. It requires to be described in three portions. Portion 1, being attached to the valve of the other section of the aorta, was stripped off in unwinding the heart; in the wound-up state it passes over the pulmonary channel of fibres, P, along the part marked 1, in its way to the aorta, AA; its absence, however, opens to view the fibres coming from the base and forming the right layer of the septum. Portion 2 proceeds from the starred line across to enter into the formation of the rope, RR, and will be noticed hereafter. Portion 3 is the longer band; it is not entirely seen, being overlapped by some of the fibres of portion 4; it passes across to the niche, CPC, where it was divided in unwinding the heart, in order to liberate the two ventricles which were encircled together by this band. Previously to pursuing this band further, it is better to trace it as the middle layer of the septum in its natural situation—the wound-up state of the heart. In *fig.* 280 it forms the extended layer, CRC, in association with portion 2, and split from portion 4, which does not belong to the septum; on being replaced, its cut edge, *a*, applies to the cut edge, *b*, in passing as the middle layer between the right and left layers of the septum. The middle layer is seen in *fig.* 282 emerging at the posterior edge of the septum, where portion 2 disconnects itself to join at the under surface the band above, but in this figure is marked C large, indicating that it is derived from this layer, which has hitherto been lettered CRC. This layer, being now deprived of all its other portions, will hereafter be considered as a band, and it has already been explained why it should be denominated the longer band. This band in emerging at the posterior edge of the septum is joined by another band of fibres, which is seen in *fig.* 281, forming part of the internal layer of the proper wall of the right ventricle; its fibres, PC, arise from the pulmonary artery, PP, and from one of the carneæ columnæ not in sight; they cross obliquely over this cavity to the posterior edge of the septum to join the band in question. By the intimate blending of the fibres of these two bands the apicial half of the posterior boundary of this ventricle is constructed. The longer band, now augmented, is lettered accordingly in *fig.* 282, CPC, and in proceeding soon receives at its inner surface an accession of fibres, A, coming down from the aorta. This band, CPCA, in winding spirally from left to right round the left ventricle along its middle third, gradually approaches both the base and the surface: for when it arrives at the anterior edge of the septum it becomes the basial band, and having been traced round the left *under* the right ventricle, in making its second circle it passes *over* that cavity. In *fig.* 281 the commencement of its second course is exhibited. It is bisected, one portion, CPCAA, being held up by a probe; the other, at the anterior coronary track, *a c t*, receives at its inner surface a fasciculus of fibres, A, from the aorta, AA, and is also lettered CPCAA. This fasciculus and portion of the band form together a groove, by winding over the pulmonary channel when brought down into its place, and which together form the basial part of the anterior boundary of this cavity. This band in its progress round this ventricle constitutes the basial band of the middle layer of its proper wall, and forms so many connexions with the base, that to trace them all would be found a very complicated piece of dissection; it is, therefore, deemed better to give a general description of them. For instance, the aorta presents three different aspects under which this band is connected to it: the first, at the termination of the anterior coronary track; the second, between the pulmonary artery and the annulus venosus; and the third, between the annulus venosus and the annulus arteriosus, or at the extremity of the posterior coronary track. The aorta receives at each of these parts an insertion of fibres from the outer surface of the band; and the band receives on its inner surface a fasciculus from the aorta. These reciprocal communications occasion the band to be very firmly bound down to the base, and to be arranged, to a certain extent, into festoons. For each of these accessions from the aorta, an additional A is added to the lettering of the band, which is, accordingly, designated CPCAAAA. As the band passes the annulus venosus, its outer fibres by a gentle obliquity in their course successively arrive at its tendinous margin, into which they become inserted immediately below those of the superficial layer, and some proceeding still more deeply pass under the tendinous margin into the ventricle, and form the musculi pectinati. In order to avoid repetition it may be here remarked, that this part of the description applies to the annulus arteriosus also. The last two accessions of fibres this band receives should be traced, since they assist in the construction of the posterior boundary of the right ventricle. In *fig.* 282 this band is seen in the latter part of its course round the right ventricle, marked CPCAAA; on reaching the posterior coronary track, *pct*, it is joined on its inner surface by two fasciculi which bind it down to the base, but on each side of this track it is separated and raised. One of these fasciculi, the last derived from the aorta, is not seen in this figure; the other appears emerging from under this ventricle, being portion 2 of the middle layer of the septum, which disconnected itself from this band, CPC, in its first circle round the left ventricle; it is marked C large, being derived from the middle mass of fibres, CRC, in *fig.* 278, in which portion 2 is seen crossing over to join the band CPCAAAAC, just before it becomes the rope; the fasciculus of fibres A from the aorta A A is also seen joining this band at its inner surface nearer the base. By the union of these two fasciculi with the band in question, the basial half of the posterior boundary of the right ventricle is formed. By pursuing, in *fig.* 282, this band or combination of fibres, lettered CPCAAAAC, it is seen to form, while it is gradually twisting upon itself, the brim of the left ventricle, and then to make a sharp twist of its fibres into the rope R R, by which means they are rendered the internal fibres of the left ventricle; in *fig.* 280 they may be traced expanding again into a layer, pursuing the same spiral sweep from left to right, but from the base towards the apex, and inwardly instead of outwardly. Thus the demonstration brings us back to our starting-point.

We have yet to trace the shorter of the two bands which originate in the splitting of the middle mass of fibres, CRC, in *fig.* 278, to embrace the right ventricle. This view exhibits only the inner fibres of this mass as they are prolonged into the inner or longer of the two bands; but *fig.* 281 affords an outer view of this mass of fibres as they are prolonged into the outer or shorter band. They are seen winding spirally up from the apex marked CRC, and at the anterior coronary track, *act*, they split, in the form of a band, from the general mass to pass over the lower half of the cavity of the right ventricle. In this figure this band is separated and left extended, in order that the accessions of fibres it receives from the right surface of the septum may be seen, which are the fibres A from the aorta AA, and the fibres C and C form two of the carneæ columnæ (not in view) passing obliquely down from right to left to the anterior edge of the septum, from which they extend into the band which is lettered CACC, and unite intimately with its fibres. When the band is replaced in its course over the ventricle, its accessory fibres are made to reflect at an acute angle upon themselves, and thus form the apicial part of its anterior boundary. This band describes one spiral circle round the heart, arriving again at the anterior coronary track at its basial extremity; it is inserted into the aorta, and if the fibres make a very oblique approach to the base, they will be also inserted into the tendinous margin of the annulus arteriosus. The continuation of this band round the posterior side of the heart can be traced in *fig.* 279. Its width is equal to about a third of the heart's axis; it is seen marked CACC in its spiral ascent from left to right, passing, first, a little below the middle third of the heart; at the posterior coronary track, *pct*, becoming the middle third, and afterwards approaching gradually the base in its way to its points of insertion before-mentioned.

As the tracing the fibres from the circumference to the centre, and from the centre to the circumference, is a matter of much difficulty, and as the description has been attended with much detail, it is desirable that a more general and concise view by means of a diagram should be afforded of the courses which the fibres take in constructing this organ.

RECAPITULATION. (Vid. the diagram *fig.* 283.) We commence tracing the fibres of the heart from its very centre. The fibres, CC, from the two carneæ columnæ of the left ventricle, LV, are joined by the fibres, R, from the rope RR, after those fibres of the rope have expanded and formed the internal layer of the septum S; in winding round the axis of this cavity they blend together as the initial letters CRC indicate. The inmost of these fibres descend as far as the apex, where they twist sharply round and close the cavity, by which means they construct the apex, and become the superficial fibres of the heart. But the chief bulk of this mass of blended fibres makes a spiral sweep from left to right round the axis above the apex; and when it has described two circles, CRC, it splits at the anterior edge of the septum into two bands, one being considerably longer than the other. The longer first makes one circle round the left ventricle, then another, enclosing both ventricles. In making the first circle it passes through the septum forming its middle layer, and on reaching its posterior edge it receives from the pulmonary artery accessory fibres, which have crossed over the cavity of the right ventricle, forming the inmost layer of its right or proper wall, and fibres from one of the carneæ columnæ of this ventricle, and from the aorta, being marked CPCA. The accessory fibres are not represented, as they would have rendered the diagram complicated and unintelligible; but they are indicated by their initials being added in the lettering of the bands. This band in question may now be traced round the middle third of the left ventricle advancing towards both the base and the outer surface of the heart; on completing its first

Fig. 283.



circle it arrives again at the anterior edge of the septum, receives another fasciculus of fibres from the aorta, and is marked Cpcaa. It is then seen to take its course round the base and in front of the right ventricle. As it passes by the right aspect of the aorta, it again receives from it a fasciculus of fibres, and is lettered Cpcaaa; on reaching the posterior edge of the septum, it is further augmented by two accessions of fibres, one from the aorta at its posterior aspect, and the other from the middle layer of the septum. This combination of fibres from various sources is indicated by the combination of their initial letters, CpcaaaaC. It should be borne in mind that C large is the synalepha of crc—the initials of the primitive mass of blended fibres. This band, in passing along the base of the left ventricle, makes at first a gentle twist of its fibres forming the brim of this chamber; it afterwards makes a sharp twist and assumes the form of a rope, by which means its fibres are transferred to the interior of the ventricle. In descending this chamber, they expand again into a layer, and wind spirally round its cavity, first forming the internal layer, a, of the septum, and then associating with the expanded fibres of the two carneæ columnæ, and thus arrive at the points from which we commenced tracing them. We now return to the anterior edge of the septum, S, in order to trace the shorter band. At this part the primitive mass of blended fibres splits into two bands: the longer passes behind the right ventricle through the septum as already described; the shorter passes in front. The shorter first receives a considerable accession of fibres from the right surface of the septum, which pass down from the aorta, and from the two carneæ columnæ springing from this surface: it is lettered Cacc; it describes one spiral circle round both ventricles. It first passes over the lower half of the right ventricle, forming the apicial band of the middle layer of its proper wall, and then round the left ventricle in an oblique direction to the base, and terminates at the aorta near the anterior coronary track, having completed its spiral circle round the heart.

As the demonstration has, in reference to the construction of the septum and of the right ventricle, been unavoidably disconnected, it is requisite to give a more systematic and comprehensive description of their particular formation.

The *septum* is composed of three layers: a left, a middle, and a right layer. The two former properly belong to the left ventricle; and the last or right layer exclusively pertains to the right ventricle. The two former are composed of the primitive mass of fibres derived from the rope and the carneæ columnæ of the left ventricle; the left layer being formed of the expanded fibres, a, of the rope, rr, *fig.* 280, in their first sweep round the cavity; and the middle layer of the continued fibres of the rope in its second sweep, blended with the expanded fibres of the two carneæ columnæ. These blended fibres form the extended layer cac; its cut edge *a* applies itself to the cut edge *b*, evidently forming the middle layer of the septum. The last or right layer of the septum has not the same origins as the two former have. Its fibres arise from the root and lower margin of the valve of that section of the aorta which pertains to the right ventricle, from that part of the root of the pulmonary artery contiguous to the aorta, and from the carneæ columnæ of the right surface of the septum. The fibres attached to the aorta and pulmonary artery may be seen in *fig.* 278, lettered a and a respectively, and in *fig.* 280 the fibres from the aorta blended with those of the carneæ columnæ are exhibited marked acc, forming the right layer of the septum.

The right ventricle.—Although the right layer of the septum belongs anatomically to the right ventricle, yet when functionally considered it pertains, as well as the other layers, entirely to the left. For the concavity of this layer is, like that of the other layers of the septum, towards the cavity of the left ventricle, and therefore during the systole approaches the axis of this cavity, while it recedes from that of the right ventricle; thereby assisting in the propulsion of the blood from the former, and to a limited extent counteracting the propulsive effort of the latter ventricle.

The right ventricle has, therefore, but one proper wall, which is connected to the left ventricle in a manner to be described hereafter. The right chamber should be divided into three channels: the *auricular*, the *pulmonary or ventricular*, and the *apicial*. The auricular is that which receives the blood directly from the right auricle; the pulmonary is that formed by the fibres which arise from the root of the pulmonary artery at its entire circumference: in *fig.* 278, the pulmonary artery, pp, and the fibres, p, are seen turned a little upon their axis, by which means the fibres are rendered oblique, and the channel the more complete; and the apicial channel is that which forms the channel of communication between the other two, and which extends to the apex. The proper wall is considered as having three layers, the superficial, middle, and internal, although they cannot always be detached from each other. The *superficial* is composed of the mere superficial fibres of this wall, having the same origins and terminations as have its subjacent fibres; it forms the left wing Cacc of *fig.* 279, and may be seen in *fig.* 281, raised from the right ventricle and reflected over the base marked Cacc. The *middle* layer is composed of two bands, the apicial and the basial. The apicial is formed of the first semicircular portion of the shorter band of the heart, and passes over the lower half or apicial channel of this chamber; it lies separated and extended over the apex of *fig.* 281, marked Cacc. The basial band of this layer is formed of the first semicircular portion of the longer band as it makes its second circle round the heart. It is bisected and separated as seen at Cpcaa, of *fig.* 281; in its natural situation it passes over the pulmonary and auricular channels of this ventricle, and is closely connected to the base. The *internal* layer arises chiefly from the pulmonary artery, PP; it first forms the pulmonary channel, P, and then expands into a layer which crosses obliquely over the apicial channel, associated with fibres derived from one of the carneæ columnæ. The basial portion of this layer which crosses over the auricular channel, cannot often be separated from the fibres of its superjacent band, the fibres of the musculi pectinati being intricately interwoven with them. When this layer is replaced, its lower loose edge applies itself to the anterior boundary, *a b*, of this cavity, and is lined with its internal proper membrane. Of the three layers composing the proper wall of this ventricle, two, the middle and inner layers, are confined at the edge of the septum, forming thereby the lateral boundary of this cavity.

The boundary of the right ventricle.—It is true that every part of the internal surface of this chamber contributes in forming its boundary. But, as this cavity is formed chiefly by the splitting of the mass of fibres into layers and by their re-union, it is clear that unless the layers so separated were well secured at their points of junction, their separation would progressively increase, and the cavity enlarge to a fatal extent by the repeated dilatations to which it is subjected. The mode of union which secures this lateral boundary merits therefore particular notice. As the lateral boundary corresponds to the edge of the septum, it admits of the same division into *anterior* and *posterior*. The *anterior* boundary being formed by the splitting of the layers, and the posterior by their re-union, their respective modes of construction are not precisely similar. The anterior boundary is principally formed by a certain set of fibres winding and reflecting upon themselves, as shewn in *fig.* 281. The basial part of this boundary, *a b*, is formed of fibres A, from the aorta A A, winding over the pulmonary channel of fibres P, in contributing to form the band CPCAA. The fibres of this channel also contribute to form this part of the boundary, as is represented in *fig.* 278. The apicial part of this boundary is obviously constructed by the fibres ACC which form the right layer of the septum being prolonged into the extended band, which on being replaced occasions them to be doubled upon themselves in passing over the apicial channel in association with the fibres of this band.

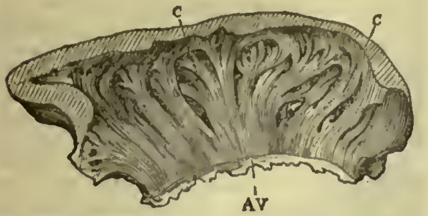
The *posterior* boundary is constructed by the re-union of the fibres which pass in front of the cavity with others which pass behind it, and by the attachment of some of the fibres at the base to the aorta. The basial half of this boundary being formed by the conjunction of the under fibres of the basial band CPCAAA, *fig.* 282, with a fasciculus of fibres, c, emerging from the middle layer of the septum, and with another fasciculus of fibres, A, *fig.* 278, arising from the aorta, AA. That part of the boundary contiguous to the base is greatly strengthened by the outer fibres of the basial band being attached to the aorta at its posterior aspect. And the apicial half of the posterior boundary being formed by the conjunction of the principal part of the internal layers of fibres which cross obliquely the cavity of the right ventricle with the chief part of the fibres of the middle layer of the septum as they emerge at its posterior edge, where they freely decussate. In *fig.* 281 the internal layer of fibres, PC, is seen crossing the cavity obliquely towards the apicial part of the posterior boundary, and in *fig.* 282 their conjunction with the fibres which emerge from the septum is seen forming a firm union. But the lateral boundary is rendered doubly secure by the curious circumstance of the coronary vessels, deeply penetrating the substance of the heart along the entire edge of the septum, stitching down, as it were, just on the outside of the boundary, all the fibres which form it.

The conical form of the heart.—The only point now remaining for consideration is the conical form of the heart. This form admits of the following explanation. Along the central cavity of the left ventricle are placed the two carneæ columnæ, the length of which is equal to the lower three-fourths of the length of the axis of this cavity. The fibres of these two bodies radiate, as represented in *fig.* 278; and the radiated fibres wind round the axis closely upon them, as is seen in *fig.* 280. By this radiation, instead of all the fibres passing longitudinally, which would have preserved these bodies in a state of equal thickness throughout their length, they are progressively parting with their fibres, retaining but a few, which, by their longitudinal course, reach the apex; consequently these columns gradually diminish, becoming pyramidal, and forming together an inverted cone; and as the fibres in well-formed hearts wind closely round these columns, the entire ventricle gently assumes the form of a cone. And although the right ventricle is, as it were, appended to the left, yet it is not so connected to it as to destroy the conical form, but, on the contrary, in such a manner as to form a concave parabolic section of a cone which adapts itself to the gentle cone of the left ventricle. The two ventricles thus united assume the form of the more rapid cone of the heart.

Construction of the auricles.—For the purpose of ascertaining the mode in which the fibres form the auricles, large hearts, as those of bullocks and horses, should be selected. Notwithstanding the muscularity of the auricles is very much greater in large than in small hearts, yet the plan is the same in both, although less developed in the latter.

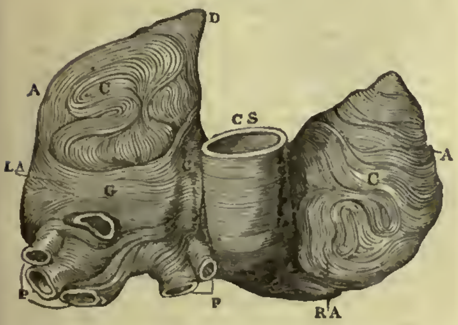
The fibres of the auricles arise chiefly from the tendinous margins of the annulus venosus and annulus arteriosus; they ascend interiorly, and arrange themselves into several columns, which give off branches. Some of the branches form a simple communication between two of the trunk-columns, but most of them subramify, by which means the interstices are filled in. In small hearts the columns are not only more slender, but more numerous and interlaced; in these, the interstices in many places are not filled in, the internal and external proper membranes being in contact, and thus completing the wall. *Fig.* 284 affords an interior view of a section of the right auricle, in which,

Fig. 284.



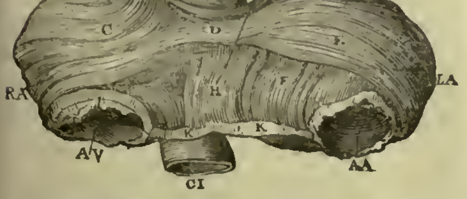
the lining membrane being removed, the fibres are seen arising from the tendinous margin of the annulus venosus AV, forming the internal part of the wall of this auricle, and in their progress up arranged into columns, C, the branches of which are entwined together so as to construct the appendix. These convoluted columns at the posterior aspect of the appendices are flattened, as shown in *fig.* 285, C, where their fibres are associating together, and

Fig. 285.



in passing round the edges to the anterior surface become evenly arranged again, as seen in the appendix A of the right auricle, RA, of *fig.* 286. Thus far the construction of the two auricles

Fig. 286.



agrees, the fibres of each arising from its respective annulus, forming first the inner part of the wall of the auricle, and then being arranged into columns which entwine together, forming the whole of the appendix. The fibres of the right auricle, after having formed the wall of this cavity, are prolonged to form the outer part of the wall of the left auricle. As may be seen in *fig.* 286, the fibres which extend from the convoluted fibres of the posterior surface of the right auricle, RA, wind evenly arranged, some over the apex, and others round the auricle, marked C, completing the outer part of the wall of the entire auricle: they then meet at the septum S, across which they pass associated together, marked D, and on reaching the left auricle divide into an upper portion and an anterior and posterior band. The *upper portion* is composed of the continued fibres D, which proceed up the appendix and encircle its apex. The *anterior band* E winds round the left auricle LA, and on reaching the root of the aorta K, its fibres become more or less attached to it in different hearts; in its course upwards, marked F, when it has completed a circle it passes behind the fibres which form the first part of the circle to enter into the formation of the fleshy columns of the appendix. The *posterior band* passes over the left auricle between the appendix A and the vena cava superior CS; and in *fig.* 285 it can be traced, coming over, marked G, and passing along the posterior surface of this auricle LA, including in its course the posterior edge of the appendix A; the fibres which pass along the posterior edge of the appendix, on arriving at the anterior edge, separate from the band G to pursue their course round the edge of the appendix,—now along the anterior edge,—and join the fibres D, which cap the apex. This division of the band which encircles the appendix is constant, and evidently affords particular strength to its edge. The band itself G winds down towards the base, expanding and surrounding the orifices of the pulmonary veins P; some of its fibres become lost on the surface of the auricle, and the others may be traced to the root of the aorta.

This band cannot be completely detached in consequence of some of its fibres being interwoven with its subjacent fibres.

The left auricle, without the addition of these bands, would nearly balance in substance and strength the right; their addition gives, therefore, to the left a considerable preponderance in these respects over the right auricle.

The septum S is, in *fig.* 286, shown to be composed, superiorly, of the transverse band of fibres D, which passes from the right to the left auricle; in its middle part, of the ascending fibres H, which arise from the root of the aorta K, and pass up behind the band D, some joining this band, the others proceeding to the vena cava superior CS; and lastly, at the inferior and posterior part, of a slender fasciculus of fibres which crosses the septum transversely between the root of the aorta K and the vena cava inferior CI, extending from the annulus venosus to the left auricle, but which cannot be seen in this figure.

In concluding these remarks on the construction of the auricles, it may be mentioned that in the hearts of large animals a great difference exists in the structure of the two venæ cavæ, the superior being particularly fleshy, and the inferior apparently devoid of muscularity.

(H. Searle.)

HEART, ABNORMAL CONDITIONS OF.—There is no organ in the body in which the various deviations from the normal state have been more diligently or more carefully explored than the heart; nor ought it to be otherwise, when we take into account the important part which the heart performs in the organism, and the serious nature of the derangements which its diseases in general produce,—how many organs and how many functions are involved in the break-up which too often follows the occurrence of morbid alterations of the heart. The great frequency* of diseases of this organ, and the manifest and tangible shape which these diseases assume, as well as the little liability of its component structures to those appearances which have been denominated pseudo-morbid, these circumstances render it comparatively easy to detect and observe its abnormal conditions. To one who has made the natural condition of the whole organ, as well as of its several parts, the subject of careful study, there is no field of investigation in morbid anatomy which presents fewer difficulties.

The records of anatomy are not without instances of total absence of the central organ of circulation *(acardia)*; and it may well be supposed that such cases would also afford examples of the defective development of other not less important organs. In short, it is in acephalous and anencephalous fœtuses that the heart is most frequently wanting, although its absence is not, as some observers suppose, a constant characteristic of these forms of monstrosity; nor on the other hand does acardia necessarily imply acephalia or anencephalia. Thus in the case recorded by Marrigues†, and quoted at length in Breschet's Memoir *Sur l'Ectopie du Cœur*,‡ the brain was present, while all the usual contents of the thorax were wanting, their place having been supplied by a large bladder full of clear water which occupied the whole thoracic cavity. The details of another case were communicated many years ago to the Royal Society by Sir Benjamin Brodie, and are published in the volume of their Transactions for 1809. The fœtus was one of twins, as is most frequently the case when the heart is absent. The brain was "nearly the natural size, and nothing unusual was observed in it." The heart, thymus gland, and pleura were absent, and the lungs most imperfectly developed. The aorta, however, was tolerably perfectly developed, but as a continuation of the umbilical artery extending from the left groin upwards on the fore-part of the spine to the upper part of the thorax, where it gave off the two subclavian, and afterwards divided into the two carotid arteries without forming an arch. The external and internal iliac arteries of the left side came from this artery in the left groin immediately after it left the umbilicus, and the common iliac of the right was given off from it in the lumbar region after it had gained the situation of the aorta.

We shall first examine the congenital deviations from the normal state in this organ, and secondly its morbid alterations.

I. *Congenital abnormal conditions.*—These are observed under three heads. 1. Congenital aberrations of position, or ectopiæ of the heart. 2. Malformations by defect in developement. 3. Malformations by excess of developement.

1. *Congenital aberrations of position.*—The simplest form of malposition is that in which the heart retains the vertical position which it occupies during the early periods of intra-uterine life; but of this the authentic instances are rare.* Better known is that deviation in which the heart is directed downwards, forwards, and to the right side. This malposition generally occurs as a part of a universal transposition of the abdominal and thoracic viscera, of which many well-marked examples are now on record; however, it sometimes, although more rarely, exists alone without ectopia of any other organ. Breschet† records four cases of this latter kind. Otto‡ has met with three instances, and many other examples are scattered among the records of anatomists.§ In this form of transposition of the heart, the aorta sometimes passes down along the right side of the spine, and at other times down its left side. In the latter case the transposition is not so complete, the ventricles retaining their natural position with reference to the anterior and posterior aspects of the body. Again the heart may be pushed too much to the left side, as a mechanical result of congenital diaphragmatic hernia of the right side; and it has been found laid across in the chest from one side to the other, the apex being at one time directed to the right side, and at another to the left, or turned upside down, the base toward the abdomen, or in that cavity, the apex upwards still remaining in the thorax.

In such cases as have been just detailed, the heart still retains its title to be considered as a thoracic viscus; but other and more remarkable malpositions of it have been found, where it is excluded from that cavity. These are, in fact, congenital thoracic herniæ in various directions, of which Breschet, whose memoir already referred to contains the most complete account of this subject, enumerates three principal varieties, according to the situation in which the heart is found, viz. the superior or cervical displacement, the abdominal or inferior, and the thoracic or anterior.

Thus Breschet details a case in which the heart, lungs, and thymus gland were all contained in the anterior part of the neck, forming a large tumour under the lower jaw. The point of the heart was attached to the base of the tongue, and placed between two branches of the lower jaw. The thorax was occupied

* Out of 520 post-mortem inspections recorded by Dr. Clendinning, 170 were cases of diseased heart, or about 33 per cent.—Vide his Croonian Lectures for 1838, Med. Gazette, vol. xvi. p. 657.

† Mém. de Mathem. prés. à l'Acad. des Sc. t. iv.

‡ Rép. Gén. d'Anat. et de Physiol. t. ii.

* Sandifort, Obs. Anat. Path.

† Op. cit.

‡ Selt. Beobacht. part i, p. 95, and part ii. p. 47.

§ Reuss' Repertorium, vol. x. p. 90-91.

by the abdominal viscera, which had passed up through a fissure in the diaphragm. In a second instance of this high displacement the apex of the heart adhered to the palate; but in this case the malposition appears to have been owing to a morbid adhesion of the umbilical cord to the head, by which all the viscera were drawn out of their natural positions. A less degree of cervical displacement is where the heart is found immediately above the thorax, in the front of the neck, which, however, is very rare.

When the malposited heart is found in the abdomen, the diaphragm is generally deficient to a greater or less extent.

In a case narrated by Mr. Wilson,* the heart was in a fissure on the convex surface of the liver—the infant lived seven days! Ramel also gives an instance of the heart being placed in the region of the stomach, and the individual in whom he observed it was ten years of age. And in the extraordinary case related by Deschamps, the heart occupied the place of the left kidney! Not the least marvellous circumstance about this case is, that the individual was an old soldier, who had served several campaigns, and enjoyed excellent health, with the exception of nephritic pains, which ultimately procured him his discharge from the service. The right kidney alone existed, and was found in a state of suppuration.† The vessels emanating from the heart passed through an opening in the diaphragm into the thorax.

Dr. Paget mentions some instances of varieties of position which parts of the heart may assume with respect to each other. In a case recorded in the first volume of the Edinburgh Medico-Chirurgical Transactions by Dr. Holmes of Canada, the right auricle, enlarged to the capacity of a pint, was found to open into the left ventricle in place of the right, into which, however, the blood afterwards found its way through a small perforation in the septum of the ventricles.

The aorta and pulmonary artery may arise from one ventricle alone, either right or left, and instances of each præternatural origin are preserved in the museum of the Edinburgh College of Surgeons.

When the anterior wall of the thorax is deficient, the heart may be found protruding through the opening, as in fissure of the sternum, or a defect in its inferior portion as well as in some of the ribs; nor does this malposition necessarily destroy life. Where the deficiency is not confined to the wall of the thorax, but also extends to the abdomen, the stomach, liver, and spleen, with the heart, are found occupying a large hernial sac in front of the opening, which is sometimes contained in the sheath of the umbilical cord, or covered by an extension of the common integument. In the case of simple fissure of the sternum, it has occurred that the heart had not protruded, but occupied its natural position, being simply exposed to view by the abnormal opening in the chest.*

* Phil. Trans. 1798.

† Quoted by Breschet from the Journ. Gén. de Méd. t. xxvi.

2. *Malformations by defect in developement.*—Our limits compel us to restrict the present account to little more than an enumeration of the congenital malformations which may be placed in this class. In these malformations we find a diminution in the normal number of the heart's cavities, either from a very early arrest in the developement of the whole organ, or from a total non-developement of the septum, or from its imperfect developement. A few rare instances, many of which have occurred in the lower quadrupeds, of an extremely imperfect state of the heart, are quoted by Otto, in which that organ seemed to consist of nothing but a fleshy enlargement at the commencement of the aorta, described as "a mere fleshy mass without any cavity," or "a longish solid mass from which the vessels arise," "or a mere expanded vascular trunk."

The *dicœlious* heart of Hunter, or that with two cavities, exists at a very early period of the developement of the Mammiferous embryo: it is described and figured by Baer in the embryo of a dog, of three weeks, only four lines in length, as consisting of a single auricle and a single ventricle.† The permanence of this state of the heart, similar to the natural condition of that organ in fishes, constitutes one of the simplest but rarest malformations in the human subject. From the ventricle a single vessel arises which subdivides into the aorta and pulmonary artery. A very perfect example of this malformation is described by Mr. Wilson in the Philosophical Transactions for 1798; it is the same case which has been already alluded to as affording an instance of malposition. In this case the blood was returned from the lungs by two veins which joined the superior vena cava, and entered the auricle along with it, the inferior cava being formed in the usual way. Other examples are recorded by Mr. Standert,‡ Dr. Farre,§ Professor Mayer,‖ and Dr. Ramsbotham.¶

The heart with three cavities (tricoilia of Hunter), that is, containing two auricles and one ventricle, or that form of the heart which belongs to the Batrachian reptiles, must be very rare, if indeed it ever occurs.

A case is related by Breschet,** in which a

* The reader who desires farther information on the congenital ectopia of the heart, may consult Breschet's memoir already referred to; Dr. Paget's Inaugural Dissertation on Malformations of the Heart, Ed. 1831; the article on Displacement of the Heart, by my valued friend Dr. Townsend, in the Cyclopædia of Practical Medicine, vol. ii.; Fleischman de vitiis congen. circa thoracem et abdomen, Erlang. 1810; Weese de Ectopia Cordis, Berol. 1819; and Haan de Ectopia Cordis, Bonn. 1825.

† De ovi Mammel. et Hominis Genesi; also in Forbes' Journal another case by Baer, vol. i. plate 2, fig. 9, human embryo about the fifth week.

‡ Phil. Trans. 1805.

§ On the Malformations of the Human Heart.

‖ Arch. Gén. de Méd. tom. xvii.

¶ Lond. Med. and Phys. Journal.

** Rép. Gén. d'Anat. tom. ii.

single ventricle and two auricles existed, but along with an imperfect inter-auricular septum. The two auricles, therefore, virtually formed one cavity. A similar case is recorded by Wolff,* and is remarkable from the fact that the individual in whom it was observed lived to the age of twenty-two. These hearts then do not exactly correspond to the tripartite heart of Batrachia, inasmuch as the two auricles communicate. A similar case, shewn by Mr. Lawrence to Dr. Farre,† explains more particularly the true nature of the malformation. It was a deficiency of the septa, both auricular and ventricular, the latter having been altogether wanting; the former consisting only of a small muscular band, which left a large foramen ovale without a valve, but the venæ cavæ and pulmonary veins opened into their respective auricles, which externally appeared to be quite separate. The ventricle communicated with the two auricles by a single ostium ventriculi, and the aorta and pulmonary artery, the entrance of the latter being somewhat contracted, arose side by side from the left part of the ventricle.

Most of the other defective malformations of the heart consist in præternatural communication between the right and left cavities, resulting from various causes. 1. The communication is direct, either from an open foramen ovale, or from an imperfection in the septum of the auricles or of the ventricles, or from the co-existence of all three or any two of them. 2. The communication is indirect, the septa being perfect, but the ductus arteriosus remaining pervious.

The open foramen ovale is by far the most common of all the malformations of the heart; numerous examples of it are now on record, as found in persons of all ages. The opening of communication varies considerably as to size, apparently according to the period of developement at which the arrest took place; the diameter of the opening ranges between two and twelve lines. We know that the size of this orifice is inversely as the size of the fœtus during intra-uterine life, whence we may infer that the larger the opening is, the earlier must have been the period at which further developement ceased. In many instances the valve-like portions which bound this opening have acquired their full developement, and the only defect seems to be the non-adhesion of their margins, so as to close the cavity; this non-adhesion again may involve the whole extent of the margins of the valves, or only a very small portion, thus leaving a large or small opening of communication between the two auricles. Such a condition of the inter-auricular septum does not necessarily occasion that intermixture of the blood which so commonly accompanies the communication between the right and left cavities; and where the opening is small, of course this intermixture is the less likely to occur. Thus every anatomist must be aware that it is not an unfrequent occurrence to find an opening large enough to introduce a goose-quill in the hearts of adults who during life exhibited no derangement of the circulation, and who died of diseases totally unconnected with the heart. On the other hand we are often surprised at the amazing size of the opening in the hearts of persons who have lived many years, and have shewn less disturbance of functions than the freedom of the communications between the auricles would warrant us to expect. In many of these cases the absence or mildness of symptoms may be accounted for by the obliquity of the passage of communication, and the overlapping of the margins of the valves, so that at times they completely oppose the flow of the blood from one side of the heart to the other, whilst at other times the passage is left more or less free. In a heart which I lately saw in the Museum of Guy's Hospital, the circumference of the open foramen ovale was equal to that of a halfpenny, (i. e. about an inch in diameter,) and yet the patient had lived to the adult period; and in a case quoted by Dr. Farre from Corvisart, the foramen ovale was "more than one inch in diameter." Such cases strongly favour the opinion that the foramen undergoes considerable enlargement when once all impediment to the passage of the current of blood from one side to the other has been removed.* More rarely we find the fossa ovalis cribriform, and thus several small openings of communication exist between the auricles, and sometimes in addition to the unclosed foramen ovale, we have a true imperfection in the septum, as in the case related by Walter,† and another by Otto.‡

Imperfection in the septum ventriculorum is a much less frequent cause of the communication between the right and left hearts than the open foramen ovale. The opening, varying in diameter from two lines to about an inch, is situated towards the base of the septum, so that the ventricles communicate at their bases; a fact which evidently indicates that the opening results from the progress of the developement of the septum being arrested near its completion, since the base of the septum is the last portion formed. The orifice of communication generally opens upwards towards the orifices of both arteries, and is bounded inferiorly by the rounded smooth edge of the ventricular septum. In these cases the aorta opens into both ventricles and appears to arise from both; and frequently the orifice of the pulmonary artery is contracted and more rarely obliterated, either from non-developement or from previous morbid action; moreover, ap-

* In Kreysig's die Krankeit, Herz. B. iii.

† Loc. cit. p. 30.

* It is not, perhaps, correct to suppose every case of open foramen ovale congenital; at least it is certain that many patients date their symptoms from a fall or blow; and even without any evidence of the occurrence of such violence many cases have been observed which can be explained only by supposing that the foramen ovale had been morbidly re-opened. See Abernethy in Phil. Trans. 1798; Otto, Selt. Beobachtungen; and Pasqualini, Memorie sulla frequente apertura del foramine ovale rinvenuta nei cadaveri dei tisici. Rom. 1827.

† Observat. Anatom.

‡ Pathol. Anat. by South.

parently as a consequence of this contracted state of the arterial outlet of the right ventricle the ductus arteriosus often remains open, which, by its communication with the aorta, conveys some blood into the pulmonary arteries from that vessel; and, as a further complication, the right ventricle is very small and appears merely as an appendage to the left; sometimes also the left auricle is very small, while the right is much dilated.

Where so much complication exists, as that just detailed, one is only surprised that vitality can be at all supported after extra-uterine life has commenced; yet we find that children with hearts so malformed live three, four, or five days, and even as many weeks or months; but where the perforation of the septum is not accompanied with the contracted state of the pulmonary artery, life may be prolonged to a considerable period. Thus, Louis quotes one case of a general officer (age not stated), whose death was occasioned by the active part he took in the American war. Along with ossified valves of the right auriculo-ventricular orifice, there existed a perforation of the septum ventriculorum large enough to admit the extremity of the little finger. In another case, quoted from Richerand, the patient aged 40, the perforation of the septum was half an inch in diameter.

We say that the two sides of the heart communicate indirectly when the ductus arteriosus continues, as in its fœtal state, to convey the blood of the right heart into the aorta descendens, where it becomes intermixed with the blood of the left heart. But it is very rare to find this condition existing alone, and when it does so exist, the canal of communication is generally very narrow. More frequently it is complicated with a contracted state of the pulmonary artery, the place of which it seems to supply. In a case related by Mr. Howship,* this vessel constituted, in fact, the trunk of the pulmonary artery. The pulmonary artery proper arose in its usual situation, but was quite impervious at its root, though far beyond, and terminated in a cul-de-sac beside the heart. Similar cases are recorded by Dr. Farre. At other times the ductus arteriosus is employed to supply the place of the aorta descendens; the aorta is perfect only as far as the termination of its arch, where it contracts, and its continuation is formed by the ductus arteriosus, through which the descending aorta receives its whole supply of blood.†

A very perfect case of this kind is quoted by Dr. Paget‡ from Steidele. The aorta and pulmonary artery arose as usual; the aorta was entirely distributed to the head and upper extremities, while the pulmonary artery, after giving off two branches to the lungs, continued as the *aorta descendens* without any communication with the *aorta ascendens*.

Malformations of the valves.—A not unimportant class of defective malformations in the heart consists of imperfections in the number or structure of the valves. The aorta may have two valves only, one of which may retain its natural form and size, while the other presents the appearance of having been formed by the fusion of two valves; it may therefore present one or more openings in it, so as to appear somewhat cribriform. A similar condition is met with in the pulmonary artery, when sometimes the three valves seem as it were united to form one membrane, which like a diaphragm stretches across the mouth of the artery, and is perforated in the centre by an opening through which the blood finds its way into the artery. This narrowing of the orifice of the pulmonary artery is the most frequent of the congenital malformations of the valves: we have already described it as a frequent concomitant of imperfect septum of the ventricles. Congenital imperfections of the mitral and tricuspid valves are of very rare occurrence. The perforated or cribriform condition which is frequently seen affecting these valves, the Eustachian and Thebesian valves, and more rarely the semilunar valves, is probably the result of a morbid atrophy.

Congenital absence of the pericardium.—Connected with the malformations by defect of developement we may mention the congenital absence of the pericardium, which, although very rare, rests on too strong evidence to admit any further doubt of the possibility of its occurrence. Most of the cases related by the older authors were in connexion with displacement of the heart, and from the liability of mistaking universal adhesion of the pericardium for this congenital absence, many anatomists, among whom was Haller, denied that such a defect had ever existed.

Dr. Baillie* was the first of modern anatomists who accurately described a case of this kind. "Upon opening," he says, "into the cavity of the chest, in a man about forty years of age, in order to explain at lecture the situation of the thoracic viscera, I was exceedingly surprised to see the naked heart lying on the left side of the chest, and could scarcely at first believe what I saw, but the circumstances were too strong to keep me long in doubt. The heart was as bare and distinct as it commonly appears in opening into the cavity of the pericardium, and every collateral circumstance confirmed the fact. . . . . The heart lay loose in the left cavity of the chest, unconnected in any way except by its vessels; was of a large size, elongated in its shape, and had its apex opposite to the eighth rib. The right auricle was obviously in view in the same manner as when the pericardium has been opened, and the vena cava superior and inferior were clearly observed entering into it. The appendage of the left auricle was as clearly in view; and when the heart was inverted, so as to have its apex turned upwards, the extent of its cavity was seen with the two pulmonary

* Edin. Med. and Surg. Journ. vol. ix.

† See Sir A. Cooper's cases in Farre, loc. cit.

‡ Loc. cit.

* On the want of a pericardium in the human body, in Transactions of a Society for the Improvement of Med. and Chir. Knowledge, vol. i. p. 91, with a plate of the appearances.

veins of the left side entering behind the appendage. The right and left ventricles were distinct, with the coronary vessels running upon them; and the aorta and pulmonary artery were seen clearly emerging from them." There is nothing in Dr. Baillie's description to indicate positively whether the visceral layer of the serous pericardium was absent or not, although we may infer its absence; what he says bearing upon this subject is as follows: "The heart was involved in the reflection of the pleura, belonging to the left side of the chest, which became its immediate covering, and upon making the slightest incision into the substance of the heart, its muscular structure was laid bare, as in any common heart deprived of its pericardium."

Breschet* has put on record a case in which the pericardium was absent, not altogether, but in greatest part. The subject of it was a young man of twenty-eight years of age, who died in the Hôtel Dieu of an inflammatory affection of the intestines. The heart lay free under the left lung without any external fibro-serous envelope. The mediastinum was formed only by a simple serous lamina belonging to the right pleura, and upon the left of this lay a rudimentary fibrous capsule, attached above to the origin of the great vessels. The serous membrane was altogether absent, but the heart was immediately inverted by a serous lamella, which was prolonged from the left pleura. In both this case and that of Baillie, the left phrenic nerve was displaced and brought towards the mesial line of the body, and not covered by the serous membrane,—an anatomical character, which, as Breschet suggests, may serve to distinguish congenital absence of the pericardium from the simple adhesion of that membrane to the heart.†

II. *Malformations of the heart by excess of developement.*— Plurality of the heart itself may be obviously regarded as coming under this head; but I am not aware of any instance in which a double heart has been found in a perfect single fœtus, nor can the possibility of such an occurrence be deemed admissible. It is in monsters formed by the junction of two that this double form of the heart has been met with. Thus, in one case referred to in Bouillaud's work, all the upper parts of the fœtus were double, while the inferior were simple. There were two heads, two necks, quite separate and of the ordinary size. The necks terminated in a single very wide thorax, to the upper part of which and between the insertion of the two necks an arm was attached in the vertical direction, one perfectly formed arm being placed on each side of the thorax. There were four lungs, each having a distinct pleura, but only one diaphragm: there were also two hearts and two pericardia, each of which had two venæ cavæ and a pulmonary artery, four pulmonary veins and an aorta. The two aortæ united at the lower part of the dorsal region of the spine, and formed the artery by which the abdominal viscera and lower extremities were supplied.

The evidence respecting the occurrence of an increase in the number of the parts of the heart is very unsatisfactory. The often quoted case of Kerkring,* with a double right ventricle; one by Vetter,† with four auricles and four ventricles, quoted by Otto; a third by Chemineau,‡ with three ventricles, are, if genuine, the most remarkable instances on record, besides various instances in the lower animals, especially birds. Andral states that he has seen a heart with three auricles, and another with four ventricles: it is much to be regretted that he has given no description of these singular malformations.§

Supernumerary cavities, or septa dividing the primitive cavities of the heart, are the most common instances of excessive developement. Adopting the arrangement of Andral,|| we find—1, a supernumerary cavity forming a sort of accidental appendage to one of the auricles or ventricles, and communicating with the cavity of the part to which it is attached: 2, a supernumerary septum, forming an imperfect division of one of the natural cavities; 3, a second cavity, completely partitioned off by one of these septa, and giving off supernumerary vessels, which communicate with the regular vessels of the heart. It appears to me, however, to be very questionable that all cases of supernumerary cavities are the result of excessive development, but that, on the contrary, they are sometimes mechanically consequent upon defective formation in other parts. At least it is in this way that I account for the condition of the heart of a boy, aged ten years, which I examined several years ago, and which has been described by my respected friend, Dr. John Crampton, in the Transactions of the Dublin College of Physicians for 1830. In this heart there were three instances of defective developement—absence of the valves of the pulmonary artery, an open foramen, and an imperfect septum ventriculorum. Attached to the right ventricle there was a supernumerary cavity with which the pulmonary artery communicated. This cavity communicated also with the right ventricle, by an opening large enough to admit the little finger, and formed under the columnæ carneæ of the ventricle. The pulmonary artery was not only destitute of valves, but at the usual situation of the valves its lining membrane was puckered, by which its orifice was manifestly contracted. The supernumerary cavity, in this instance, was in all probability occasioned by a partial dilatation of the infundibular portion of the right ventricle, in consequence of the obstruction at the pulmonary orifice.

Increase in the number of the valves of the large arteries may be counted among the ab-

* Mém. sur un vice de conformation congenitale des enveloppes du cœur: Rép. Gén. d'Anat. t. i. p. 212.

† See references to other cases in Otto's Path. Anat. by South, p. 254.

* Spicit Anat. obs. 69, p. 139.

† Aphorism. aus der Pathol. Anat.

‡ Hist. de l'Acad. des Sc. an. 1699.

§ Path. Anat. by Townsend, vol. ii. p. 333.

|| Loc. cit.

normal formations by excess. Thus, four or even five valves are occasionally found in the pulmonary artery more frequently than in the aorta. The supernumerary valves are always small, and sometimes appear to have been formed at the expense of the next normal one.

Anomalous connexion of the vessels of the heart. — Our space will only permit us to enumerate the principal observed varieties. 1. The aorta or pulmonary artery, or both, appear to arise equally from both ventricles, the septum of the ventricles being more or less deficient. 2. The aorta may arise from the right ventricle, and the pulmonary artery from the left, the veins preserving their natural position. 3. The vena azygos opens into the right auricle. 4. The hepatic veins open into the right auricle. 5. The ductus arteriosus opens into the right ventricle. 6. Two superior venæ cavæ open into the right auricle. 7. Very rarely the right auricle gives insertion to one or more pulmonary veins, and on the other hand the left auricle receives sometimes the superior vena cava, and at other times the inferior. 8. Meckel states that he has seen the great coronary vein of the heart to open into the left ventricle.* Professor Jeffray, of Glasgow, relates a case in which the inferior cava opened into the upper part of the right auricle, taking the course as well as the place of the vena azygos.

On displacement or ectopia of the heart as a consequence of disease.—The most common cause of *morbid* displacement of the heart is an effusion of air or liquid into one of the pleural cavities. The displacement is most manifest when it follows effusion into the left side, by which the heart is pushed over to the right, the degree of displacement depending on the amount of effusion, and thus alteration of the heart's position becomes one of the diagnostics of empyema, hydrothorax, pneumothorax. In general, the more rapid the effusion the more certainly will the displacement be effected, and the greater will be its extent. In nine cases out of ten, as my friend Dr. Townsend remarks,† when the heart is removed out of its natural situation, the displacement will be found to have arisen from empyema or pneumothorax; and of twenty-seven cases observed by him, the heart was perceptibly displaced *in every instance.* On the other hand, when the effusion is slow and gradual, the extensibility of the neighbouring textures is more completely brought into play, and the displacement of the heart is thus counteracted, whence it happens that in cases of chronic dropsical effusions into the chest, displacement of the heart is not of frequent occurrence, nor is it extensive when it does take place. When the effusion occurs on the right side, the heart may be pushed more to the left, and upwards, than is natural, but to effect this a considerable effusion is necessary. The first notice of this fact is due to my able friend, Dr. Townsend, to whose article I have already referred. In a case of pneumothorax to which he refers, and which I also witnessed, the effusion was on the right side, and the heart was distinctly seen and felt pulsating between the fourth and fifth ribs, near the left axilla. After paracentesis, which was performed by the late Dr. M'Dowel, the heart gradually returned to its normal position, as the displacing force was removed by drawing off the air and fluid contained in the opposite pleura. Moreover, as has recently been ascertained by Dr. Stokes, the absorption of an effusion of the right side will cause the heart to be displaced to that side, the pleural cavity being obliterated by lymph, while the lung of the left side is enlarged so as to aid in occupying the vacant space and pushing the heart over.

It is scarcely necessary to observe that tumours forming in the right or left sac of the pleura may occasion displacement; thus aneurismal tumours may push the heart to the right, to the left and upwards, or even forwards and outwards against the wall of the thorax, or downwards, so that its apex will pulsate in the epigastrium. Of this last displacement, Dr. Townsend* relates an example. I have myself observed, some years ago, a case where the heart was pushed forwards and outwards, and as it were compressed against the ribs by an enormous aneurism of the thoracic aorta; the sounds of the heart were so modified by this compression as to lead to the erroneous diagnosis of concentric hypertrophy. In the case recorded by Drs. Graves and Stokes,† the heart was pushed upwards and to the right side by an abdominal aneurism, so as to pulsate in the intercostal space of the third and fourth ribs. Dr. Hope mentions the displacement to the left by an aneurism of the ascending aorta. Any cause which pushes the diaphragm upwards and prevents its descent, such as distension of the abdomen by an enlarged viscus, a tumour, or an effusion, will change the position of the heart, so that its axis will be directed horizontally; and Dr. Hope has remarked that the same position may be produced by an adhesion of the pericardium to the heart, by which its enlargement downwards is prevented. A diaphragmatic hernia will displace the heart to an extent proportionate to that of the visceral protrusion. In a case recorded by Drs. Graves and Stokes, the stomach and a large portion of the transverse arch of the colon were lodged in the left cavity of the thorax, and pushed the heart and mediastinum towards the right side. When the lung is enlarged from dilated air-cells, the heart may be displaced: it may be drawn considerably downwards by the diaphragm, which yields before the enlarged lung, thus increasing the vertical diameter of the chest; or it may suffer a slight degree of lateral displacement, the mediastinum being pushed to the right side by the lung.‡

Dr. Stokes has related the remarkable, and so far as I know unique case of displacement, or as he terms it "dislocation," of the heart

* This enumeration is taken from Bouillaud, Traité des Maladies du Cœur, t. ii. p. 588.

† Cyclop. Pract. Med. vol. ii. p. 390.

* Loc. cit.

† Dub. Hosp. Rep. vol. v. p. 10.

‡ See Dr. Stokes's valuable work on Diseases of the Chest, pp. 187-191.

from external violence. The patient was crushed between a water-wheel and the embankment on which the axle was supported. Several ribs were broken, as well as the right clavicle and humerus. The heart, which, according to the statement of the patient, had always occupied its natural situation, was now found beating at the right side.*

MORBID ALTERATIONS OF THE MUSCULAR SUBSTANCE OF THE HEART.

1. *Inflammation of the muscular structure of the heart, or carditis* (the carditis *proper* of some pathologists).—The same anatomical characters which would lead us to pronounce any muscular tissue in a state of acute inflammation, would justify a similar conclusion respecting the heart. But from the sparing deposition of cellular tissue around this organ and between its fibres, the anatomical phenomena which denote the previous existence of inflammation are not so marked in it as in the muscles of animal life; and judging from the rarity of these organic signs, as well as from the unfrequent occurrence of those symptoms which so great a morbid process could scarcely fail to produce, we may reasonably conclude that active inflammation deeply implicating the carneous fibres of the heart, and originating in them, is very seldom met with.

The anatomical characters indicative of carditis are a dark, almost black, colour of the muscular substance, the fibres of which have lost in a great measure their cohesive power; they are very compressible and readily torn, and consequently cannot be easily isolated to any great extent, although easily separable *en masse*. When the muscular wall of either ventricle is pressed, the blood oozes out from the divided vessels on the cut surface in much greater quantity than usual. In Mr. Stanley's case, as in all cases, the dark colour of the fibres " evidently depended on the nutrient vessels being loaded with venous blood." When in addition to these signs we find purulent deposits in various parts of the muscular structure, and moreover, when it is manifest that the internal and external membranes are implicated, from the effusion of coagulable lymph on them to a greater or less extent, no doubt can be entertained respecting the exact nature of the lesion. In Mr. Stanley's case, " upon looking to the cut surface exposed in the section of either ventricle, numerous small collections of dark-coloured pus were visible in distinct situations among the muscular fasciculi."† A similar case has been recorded by Dr. P. M. Latham, the anatomical characters of which accorded with those above mentioned. " The whole heart was found deeply tinged with dark-coloured blood, and its substance softened; and here and there, upon the section of both ventricles, innumerable small points of pus oozed from among the muscular fibres."‡

Every anatomist must have noticed how variable is the colour and the consistence of the muscular structure of the heart, even independent of disease of the lining tissues. The pale, soft, compressible, flexible, and, to use a common word, *flabby* heart, strongly contrasts with the firm, plump, fresh-looking elastic one; in the former, the flaccid parietes fall together immediately the cavities are emptied; in the latter, the surfaces retain their convexity, although the contents of the cavities have been completely removed. Between these two extremes there are various grades of colour and consistence, of which Bouillaud particularises three as being the result of inflammation, the *red softening*, the *white* or *grey*, and the *yellow*. The first is probably that which may be said unequivocally to follow primary inflammation of the muscular texture; the other two, however, as Bouillaud admits, occur most frequently in connection with pericarditis: they occur, too, as Dr. Copland observes, where no sign of inflammation is manifest, and where during life there had been no evidence of cardiac disease; in cases of general cachexia and of constitutional disease, attended by discoloration of the surface of the body, arising, in fact, as Dr. Williams explains, from an altered state of the nutrition of the organ, owing perhaps to partial obstructions in the coronary vessels rather than to the immediate influence of inflammation. This last excellent observer makes the following judicious remarks in reference to this matter.* " To judge that the tissue of the heart is especially diseased, we must see that it differs much in appearance from the other muscles of the same subject. You will find, on comparing the same muscles in different subjects, a remarkable variety of colour; and in some there is no freshness in any of the muscles, but all are pale, and verging on a pinkish drab or dingy brick colour." Perhaps the most correct arrangement of the various circumstances under which softening of the heart may take place is that given by Andral. 1st, Softening connected with active hyperæmia of the heart; 2d, softening connected with anæmia of the heart; 3d, softening connected with atrophy of the heart; 4th, softening connected with an acute alteration in the general nutritive process (as in typhus); 5th, softening connected with a chronic alteration in the general nutritive process (as in a variety of chronic diseases); 6th, softening which we are not yet enabled to refer to any morbid condition of the heart itself or of the rest of the system.†

Suppuration.—The occurrence of an abscess uncomplicated with any other lesion in the walls of the heart, does not unequivocally denote the previous existence of carditis, although it may afford strong presumptive evidence of the fact: when, however, we find abscess, with lymph or adhesions of recent date, we may reasonably infer its inflammatory nature. Dr. Copland has introduced in a note to his invaluable and profoundly learned article on Dis-

* Med. Gazette, vol. viii.
† Med. Chir. Trans. vol. vii.
‡ Med. Gazette, vol. iii.

* Lectures on Diseases of the Chest, Med. Gaz. vol. xvi.
† Otto says that violent exertion appears as in other muscles to render the heart easily broken down; thus, for instance, it is found very weak in hunted deer.

eases of the Heart,* an abstract of several cases in which pus was found in the substance of the heart. Those quoted from Corvisart, Raikem, and Simonet, and probably that from Dr. Graves,† may be regarded as examples of purulent formation following carditis, general or partial. So likewise is Laennec's case, in which, however, the carditis was consequent upon pericarditis. There is no anatomical character which will enable us to distinguish whether a simple purulent deposit, surrounded by natural muscular texture, be inflammatory or not, for there is no reason why the heart should be exempt from that which we know often occurs in other muscles, namely, non-inflammatory deposits.

Ulceration.—As true carditis seems to be generally admitted to be rare, so we may conclude that ulceration is equally so. It is by the ulcerative process that some of the perforations or ruptures of the parietes of the heart take place; it is probable, however, that the great majority of the ulcerations we meet with commence from the surface, and result from membranous inflammation rather than from that of the muscular substance; the ulcer commences on the surfaces, either in or immediately subjacent to the internal or external membrane; and as it burrows deeply, it may perforate the muscular wall, and so destroy the membrane on the side opposite to that on which the ulceration had commenced. Sometimes an ulceration of this kind gives rise to aneurismal tumours or sacs, very variable in size, projecting from that part of the cavity which corresponds to the artery. It seems evident that these tumours are produced by the pressure of the contained blood distending the thinned and yielding wall of the heart. We shall return to this subject further on in treating of aneurisms of the heart.

Induration.—This condition of the muscular structure of the heart seems most probably to be a result of inflammation, especially of the chronic kind. It is generally found in small circumscribed portions; it may occur in any part of the heart, and may even co-exist with softening: the hardened portion has become particularly firm, is cut with difficulty, and when struck with the scalpel sounds, as Laennec says, like a leather dice-box. It is harder, denser, less elastic, and as regards colour is paler than the hypertrophied muscular tissue.

Cartilaginous and osseous transformations.—Induration of the subserous cellular tissue of the heart is in general the precursor of many of these transformations. This indurated portion increasing in thickness gradually assumes the appearance of cartilage—in this cartilage the calcareous particles are deposited. I have not been able to ascertain whether this so-called ossification exhibits, on examination by the microscope, the lamellar arrangement of true bone, as osseous transformations of certain permanent cartilages do, those of the thyroid cartilage for example. These calcareous or osseous patches or tumours compress the subjacent muscular tissue, and produce atrophy of them, and according to Andral, sometimes are connected by prolongations of the same material with other calcareous deposits formed round the orifices. Many pathologists believe that these transformations are the result of inflammation. I suppose there can be no doubt that they follow an increased afflux of blood, and so they may be considered, although not an immediate, at least a remote effect of inflammation, or rather of the altered nutrition and secretion to which inflammation gave rise.

In a case recorded by my friend Mr. Robert Smith, of Dublin, the apex of the left ventricle was converted into a dense, white, firm, cartilaginous structure, the division of which with a scissors required the employment of considerable force; the alteration of structure had extended to some of the carneæ columnæ.*

Tubercles.—These productions are very rarely if ever met with in the heart. No reliance can be placed on most of the instances recorded, in consequence of the imperfect and unsatisfactory descriptions accompanying them; what appears to one person to be tubercular may present a totally different aspect to another. Laennec says vaguely, "only three or four times have I met with *tubercles* in the muscular substance of the heart." And Andral states, that they are never met with in the heart, except when they likewise occur in other muscles. Otto says, "although I have dissected a great number of scrofulous men and animals, I have never found a tubercle on the heart, and therefore consider them very rare." Dr. Elliotson† mentions a case in which there were scrofulous deposits in the walls of the left ventricle, surrounded by white and almost cartilaginous induration. In a case which came under my own observation, in a woman between 50 and 60 years of age, there were several white tumours in the parietes of the right ventricle, each about a quarter of an inch in diameter, of uniform consistence throughout, nor showing any disposition to softening in the centre.

Scirrhus.—Equally unsatisfactory are the reports of anatomists respecting this alteration. Rullier and Billard relate cases in which scirrhus had developed itself on the heart. Rullier's‡ case was an instance of degeneration of the whole substance of the heart into a scirrhous mass, which formed irregular knobs on the external and internal surfaces of the heart. Billard found three scirrhous tumours embedded in the heart of an infant only three days old.§

Medullary fungus, or encephaloid tumours.—Of these, several instances are quoted by Andral from others, and he describes two which he saw himself.‖ In the first of Andral's cases the whole of the walls of the right auricle and ventricle were converted into a hard, dirty white substance, traversed by a number of

* Dict. of Medicine, part iv. p. 191.
† Lond. Med. and Surg. Journal, vol. vii.

* Dub. Journal, vol. ix. p. 418.
† Lumleyan Lectures, p. 32.
‡ Bull. de la Faculté, 1813.
§ Malad. des Enfans.
‖ Loc. cit. vol. ii. p. 346.

reddish lines, and possessing all the characters of encephaloid. In the second case, the external wall of the right ventricle was occupied by a tumour extending from its apex to its base, which projected so far externally as to lead him to mistake it for a supernumerary heart, and likewise protruded internally into the cavity of the ventricle. In a case which I saw myself, the tumour resembled the well-known encephaloid or cancerous tumour of the liver, being, like it, raised above the surrounding muscular structure, and irregular on its surface.

Melanosis.—This deposit is also found very distinctly in the heart. It appears in the form of small spots under the pericardium or endocardium, or as tumours in the substance of the ventricle. In a specimen in the Museum of King's College, London, the melanotic deposits are situated, some beneath the pericardium covering the right ventricle, and others on the carneæ columnæ of the same cavity, immediately subjacent to the endocardium. Neither Andral nor Bouillaud notices the occurrence of melanosis in the heart.

Hypertrophy of the heart.—When the walls of any of the heart's cavities experience an increase of thickness, owing to the developement of the muscular substance, they are said to be in a state of hypertrophy; and there is no morbid state of this organ which is more frequently brought under the notice of the physician than this, as affecting the parietes of one or more of its cavities. There is no alteration in the muscular texture apparent to the naked eye, except, perhaps, a slight increase of the red colour—the heart is firm, dense, and elastic; in short, it presents all those characters which we so often see manifested in the external voluntary muscles, the developement of which is increased by frequent use.* Hypertrophy may affect all the cavities simultaneously, but in general it is limited to one or at most two cavities. The left ventricle is that in which it most frequently occurs, next the right, and lastly and rarely the auricles. Nor does the hypertrophy affect necessarily the whole parietes of the cavity, but sometimes it is limited to a small portion, or to the septum, or to one or more of the carneæ columnæ. In some cases, as Andral remarks, the thickening may be at its maximum at the base of the heart, and diminish gradually towards its apex, which sometimes retains its natural thinness, when all the rest of the parietes are three or even four times as thick as natural; or at other times, as Cruveilhier observes, becomes so thin that one is astonished that perforation or dilatation of the heart at its apex is not more common. In other individuals again the thickening is equal and uniform from the base to the apex, which then loses its pointed form and acquires a rounded shape. Lastly, it sometimes happens that the hypertrophy is greatest about midway between the apex and base of the heart, or is even exclusively confined to that part. When the septum is principally affected, the capacity of the right ventricle is so diminished that it sometimes looks like a small appendix attached to the left ventricle.* When the hypertrophy affects chiefly or exclusively the right ventricle, the apex of the heart seems to be formed by it, whereas in the normal state the apex belongs to the left ventricle.

An hypertrophous state of the parietes of all the cavities not only affects the form of the heart by changing it from the oblong to the spherical, but, as was first noticed by Dr. Hope,† its position is altered; "as the diaphragm does not retire sufficiently to yield space downwards for the enlarged organ, it assumes an unnaturally horizontal position, encroaching so far upon the left cavity of the chest as sometimes to force the lung upwards as high as the level of the fourth rib or even higher."

Bertin‡ distinguishes three varieties of hypertrophy of the heart. 1. That in which the hypertrophy is not accompanied with any alteration in the capacity of the cavities of the heart—*simple hypertrophy.* 2. That in which there is dilatation of the cavity along with the increased substance of its walls—*excentric hypertrophy* or *active aneurism* of Corvisart. 3. Where the capacity of the ventricle is diminished as if the walls had encroached by their increase of thickness upon the cavity, or as Bouillaud expresses it, as if the internal muscular layers and the carneæ columnæ were principally the seat of hypertrophy—*concentric hypertrophy.*§ Of these the most frequent is that which is accompanied by dilatation, the dilata-

* Dr. Williams mentions that in leucophlegmatic subjects the muscular texture is soft and flabby and of a duller colour. This is obviously a condition resulting from other causes, and not a character of the hypertrophous heart as such. And the threads or laminæ of dirty white tissue intermingled with the muscular tissue, described by him, seem clearly the result of the inflammation which caused the concomitant adhesion of the pericardium. In the same light I would regard the dense fibrous tissue described and delineated by Carswell.—See *Med. Gaz.* vol. xvi. p. 915.

* Cruveilhier doubts the occurrence of partial hypertrophy affecting the septum or one or more carneæ columnæ.

† Cyclop. of Pract. Med. art. Hypertrophy of the Heart.

‡ Maladies du Cœur.

§ A certain standard of health is absolutely necessary to enable us to determine as to the existence of disease. With this view we transcribe here the table of weight and dimensions drawn up by Bouillaud as the average of health.

In an adult of ordinary size and good constitution the mean weight = 8 to 9 oz.; mean circumference = 8 to 9 inches; mean of the longitudinal and transverse diameters = 3½ inches (the latter generally predominates slightly over the former); the mean of the antero-posterior diameter = 2 inches.

Mean thickness of the walls of left ventricle at the base =	6 to 7 lines.
Ditto, right ventricle at the base =	2½ lines.
Ditto, left auricle =	1½ lines.
Ditto, right auricle =	1 line.

The average capacity of the ventricles is sufficient to contain a hen's egg (that of the right ventricle slightly exceeding the left).

For some useful observations on this subject, and on the normal weight, bulk, &c. of the heart in relation to other viscera, see Dr. Clendinning's Lectures in Med. Gazette, vol. xvi.

tion in all probability preceding and giving rise to the hypertrophy by rendering an increased force of contraction necessary. Simple hypertrophy is the least common, according to Bouillaud; concentric hypertrophy, according to this physician, is not rare. Considerable doubt, however, has been excited recently by the high authority of M. Cruveilhier as to the real existence during life of such a condition as this. This anatomist believes the diminished cavity to be merely the result of a tonic contraction of the muscular wall of the ventricle in death. "The concentrically hypertrophied hearts of Bertin and Bouillaud appear to me," he says, "to be hearts more or less hypertrophied, which death surprised in all their energy of contractility."* The hearts of all those examined by Cruveilhier, who died by the executioner, presented to his observation to a great degree the double phenomenon of increased thickness of walls and diminished cavity, and he has observed the same with persons who died a violent death.† On one occasion I was particularly struck with a similar condition of the heart of a donkey which had been accidentally transfixed by a large trocar, whereby the death of the animal was caused in a few minutes. The muscular structure of the heart was singularly dense. It had contracted at its apex quite to a sharp point, and on cutting into it the cavity of the left ventricle appeared almost obliterated, and the muscular wall much increased in thickness. I have many times, too, observed the fact noticed by Cruveilhier, that the cavity may be easily enlarged or restored to its natural dimensions by introducing the finger and dilating it, or still more easily, if the heart have been macerated in water for a short time previously. This fact is further confirmed by Dr. Budd, who supports the views of Cruveilhier in an interesting paper in the last volume of the Medico-Chirurgical Transactions. In one of Dr. Budd's cases the thickness of the parietes of the left ventricle eighteen hours after death varied from an inch to an inch and a half, on a transverse section made at a distance from the apex of one-third of its length, and the cavity was not large enough to hold the second phalanx of the thumb, and was almost filled by the carneæ columnæ. This heart, in its open state, was put to macerate; *no force was applied to extend it*. At the end of some days, on being folded up, it was found to have dilated very considerably, so that the left ventricle could not then be said to be smaller than natural. Dr. Budd argues against the existence of the diminished cavity from the fact that of eight cases collected by him, no one afforded signs, either during life or after death, of any obstacle to the circulation through the heart. There were no irregularity of pulse, no dropsy during life, no dilatation of the right cavities after death, phenomena which, it may be said, must of necessity be present if there be an obstacle to the circulation in the heart. It is impossible, as he states, to conceive that a left ventricle, which could scarcely hold an almond, should offer no obstacle to the circulation through the heart. Yet Laennec has recorded a case in which the parietes of the left ventricle had acquired the thickness of from an inch to an inch and a half, and the cavity seemed capable at most of containing an almond stripped of its shell. Yet the day before the patient's death his pulse was natural, the breathing perfectly free, "and nothing," says Laennec, "led me to suppose that this man had a disease of his heart."

Hypertrophy with dilatation.—It is in this morbid condition that the heart acquires the greatest increase of size as well as the most striking alteration of form. The *cor bovinum* of some authors, so called from its enormous size, affords an instance of an extreme developement of this form of disease. The extent to which the heart may become enlarged in this way is quite extraordinary. Of certain cases recorded by Bouillaud, in one the right ventricle was large enough to contain a goose's egg, and the left, still larger, the closed hand of a female; in another, the left ventricle was similarly increased in capacity. In a third, the right auricle of a child, aged seven years, was so dilated as to contain a coagulum as large as the closed hand of an adult. The thickness of the left ventricle in Bouillaud's cases varied from 7 to 14 lines, that of the right 3 to 5 lines; but in some instances it was as considerable as from 8 to 10 lines or 11 to 16 lines. The weight of the heart, in some instances, trebled the natural; thus in one case of general hypertrophy the weight was 22 ounces, and others weighed from 13 to 20 ounces. The circumference of the heart was often increased to twelve inches, the longitudinal diameter five inches, and the transverse eight inches. In a patient who died at the Hôtel Dieu in 1834, the heart measured fifteen inches and a half at its base. Hypertrophy seldom occurs in the auricles, except when accompanied by dilatation: the musculi pectinati are generally the seat of the increased muscular developement, and as the number and developement of these muscular columns is greater in the right auricle than in the left in the normal state, (in the left they are only found in the auricular appendage,) the remark of Dr. Hope follows almost as a matter of course, namely, that in the right auricle hypertrophy proceeds to the greatest extent, its walls being sometimes rendered nearly equal in thickness to those of the right ventricle in the normal state.

In the vast majority of cases of this kind the products of inflammatory states of the pericardium or endocardium, or its appendages, are present; in short, a diseased state of the valves constantly co-exists with hypertrophy and dilatation. These conditions of the cavities are very frequently traceable to some obstacle to the circulation through the heart, and sometimes it would seem that the valvular disease preceded and gave rise to the hypertrophous and dilated cavity; but it is not impossible nor unlikely that the valvular disease may follow the hyper-

* Dict. de Méd. et Chir. Prat. art. Hypertrophie.

† Mr. Jackson and Dr. Budd have observed this state of the heart in persons who died of cholera.

trophy, and may result from the violence of contraction of the enlarged ventricle. Dilatation of the aorta at its commencement and its arch is frequently the consequence of this disease in the left ventricle, and dilatation of the pulmonary artery ensues upon it in the right ventricle.

Dilatation of the cavities of the heart.—"When the heart is incapable of sufficiently expelling its contents, whether in consequence of obstruction in the vessels from it, of regurgitation into it through imperfect valves, of want of power, of irritability, or of both, it becomes distended, and in time permanently dilated."* We have already described that kind of dilatation which is the most common, namely, that accompanied by hypertrophy; dilatation also occurs in connexion with an opposite condition of the parietes, namely, attenuation of them. The muscular tissue has lost its tone, and yields, as it were, without resistance to the distending force. It is laid down by authors that a third variety of dilatation may exist, what they call *simple dilatation*, or that in which, while the cavity is dilated, the parietes are of their natural size. It seems to me impossible that any cavity of the heart can, in a dilated state, continue of the natural thickness without hypertrophy, in the absence of which dilatation implies necessarily a diminution in thickness; during diastole the parietes of the heart's cavities are thinner than during systole; what a contracted muscle gains in one dimension it loses in another; and the same may be said of a relaxed or distended muscle. Again, if we contrast a contracted with a dilated bladder, it seems evident that we cannot inflate the former, however incompletely, without producing a manifest diminution in the thickness of its walls. Hence I infer, that if the parietes of any cavity be perfectly natural, they must become thinned under the influence of the force which produces the dilatation; and, on the other hand, if we find that the parietes of a dilated cavity possess the normal thickness, we may be assured that it is slightly hypertrophous. It appears then to be most correct to limit the varieties of dilatation to two, that with hypertrophy and that with attenuation, or the *passive aneurism* of Corvisart.

In this latter form of dilatation, then, we see a manifest alteration of the muscular tissue; it is paler, softer, less resisting, less elastic than natural. When the heart is emptied of its contents, the walls do not at all return upon themselves, but remain flaccid; nor when cut do they show any disposition to retract; and it is this state of the muscular substance which will serve best to enable the anatomist to distinguish morbid dilatations from those which result from mechanical distension of the cavity by a coagulum formed at the time of death. An obviously diseased state of both the internal and external membranous coverings of the heart is constantly present along with this form of dilatation. These membranes lose their transparency in several parts, apparently from some abnormal deposit subjacent to them: the white spot so often seen upon the external surface of the right ventricle is an almost invariable attendant upon the dilated heart. Dilatation may affect any or all of the heart's cavities; but it is met with by far the most frequently in the right ventricle, and very commonly both ventricles are dilated, in which case the right cavity is generally more capacious than the left.

An extreme case of dilatation is afforded in an example quoted by Bouillaud: "the right cavities were so dilated and their walls so attenuated, that the auricle was converted into a kind of transparent membrane, and the ventricle was reduced only to the ordinary thickness of the auricle."

In determining as to the degree of attenuation of the walls which may accompany any particular case of dilatation of the auricles, the anatomist must bear in mind that even in the natural state the interval between the musculi pectinati of the right auricle is only composed of the endocardium and pericardium, separated by a very fine and transparent cellular tissue, and by a few muscular fibres crossing obliquely from one pectinate muscle to the next one. I have twice seen a perfectly natural right auricle carefully put up as a museum specimen of morbid attenuation of the parietes, owing to ignorance or forgetfulness of this fact.

Dilatation of the orifices of the heart.—As a natural result of dilated cavities we meet with dilated orifices of the heart, and the enlargement of which again produces in many cases insufficiency of the valves. Bouillaud gives the measurement of the auriculo-ventricular orifice (which is the most liable to dilatation) in three hearts; in one it measured five inches in circumference, and in another four inches three lines, while in a third the dilatation was stated to be so great that the tricuspid valve could not be closed.

Aneurism of the heart.—A diseased state of the heart occurs not unfrequently, strongly analogous to that which under the same name is so well known as occurring in the arterial system. Most of the varieties too of arterial aneurism find their analogues in the heart: thus we have, 1. the aneurism by simple dilatation, or true aneurism, resulting from partial dilatation of one of the heart's cavities; 2. the false aneurism or that resulting from rupture of one or more of the textures entering into the formation of the heart's parietes; 3. we find the *dissecting* aneurism analogous to that remarkable form of arterial aneurism first described by the late Mr. Shakelton; 4. not improbably, we also meet with what is analogous to the varicose aneurism, and may be designated *spontaneous varicose aneurism of the heart*. To the zeal and acuteness of Mr. Thurnam * morbid anatomists are much indebted for his having arranged, compared, and classified a considerable number of cases of aneurismal dilatations connected with the heart, either observed by himself, or preserved and

* Dr. Williams, loc. cit.

* Vide his valuable monograph on Aneurisms of the Heart in Med. Chir. Trans. vol. xxi. An appendix containing references to cases is added.

recorded by others, whence he has been able distinctly to prove the analogies above-mentioned, and by which much light has been thrown upon those forms of disease.

The partial dilatation of one of the cavities, or true aneurism, is by far the most common of the varieties above-mentioned. In its early stage this disease consists in little more than a bulging of the wall of the ventricle or auricle in a certain direction; as this increases a pouch or sac is formed, which communicates with the heart's cavity by a more or less narrow opening. In some cases this sac does not extend beyond the external surface of the heart, nor would it be detected, were the anatomist to content himself with merely examining the exterior, it is as it were lodged in the fleshy substance of the ventricular paries; but in other instances a tumour is formed projecting considerably beyond the exterior. As in arterial aneurisms, the sacs frequently contain laminated coagula, and, as might be expected *a priori*, the larger the cavity and the narrower its orifice of communication, the more abundant is this lamellar deposit. One or more aneurismal sacs may belong to the same cavity: thus, in fifty-two out of fifty-eight cases collected by Mr. Thurnam, only one aneurism existed in each; but in four cases two were met with in each; in one there were three, and in another four incipient aneurisms. In two instances, Mr. Thurnam states, it is not improbable that two sacs which were originally distinct had coalesced, so as to form a single aneurism, and in another case three sacs appear to have united in this way. We find the aneurismal pouches of all sizes: in nine of the cases referred to in Mr. Thurnam's memoir, the size might be compared to that of nuts; in twenty, to that of walnuts; in seven, to fowl's eggs; in fourteen, to oranges; and in nine cases, it almost or quite equalled that of the healthy heart itself. We cannot always satisfactorily ascertain what textures enter into the formation of these sacs; however, in the majority of cases, the three structures of which the heart's parietes are composed are found in the walls of these sacs; in others the muscular tissue has disappeared, atrophied probably by the pressure, and the wall is composed only of the endocardium and pericardium, and in others again the endocardium is wanting, and the muscular fibres and the pericardium are the only component elements.* In some cases the wall of the sac is strengthened by an adhesion formed with the loose layer of the pericardium.

These aneurisms are always in connection with the left ventricle or left auricle; very rarely however with the latter, and never with the right cavities. In the paper already quoted from, Mr. Thurnam has collected references to fifty-eight cases of aneurism of the left ventricle, and eleven of the left auricle. All parts of the ventricle are liable to aneurismal dilatation, but it occurs most frequently at the apex: next in frequency it is found at different points of the base; less frequently still it occurs in the lateral walls at situations intermediate to the two last-named, and very rarely it is met with in the interventricular septum.

I will give the description of auricular aneurism in Mr. Thurnam's words: "The disease would appear, from the preparations I have inspected, and the cases which have been recorded, to have been nearly uniformly of the diffused kind, and to have generally involved the entire sinus of the auricle. The dilated walls of the cavity are often thickened and the seat of fibro-cellular degeneration. The lining membrane is opaque, rough, and otherwise diseased, and in some cases even ossified, and is lined with fibrinous layers, very similar to those met with in arterial aneurisms. In all these cases, the lining membrane appears to have been continued into the interior of the dilated portion, which consequently merits the name true aneurism. Occasionally the dilatation is confined to the auricular appendage, which becomes extensively distended with lamellated concretions."*

The false aneurism, or that resulting from rupture, must be spoken of merely as a possible and probable occurrence. I know of no unequivocal example of it; but inasmuch as we must admit that partial rupture of the heart's wall may take place, we cannot deny the possibility of the production of cardiac aneurism in a manner similar to that in which arterial false aneurism is produced.

Dr. Hope describes cases, which Mr. Thurnam very aptly compares to "the dissecting aneurism." In those cases, Dr. Hope says, "steatomatous degeneration had caused the formation of a canal from the aorta underneath one of the sigmoid valves and the internal membrane of the left ventricle." But Mr. Thurnam's explanation seems to me much more likely to be the true one. He supposes that the aneurisms had been originally formed in the ventricle, and had subsequently communicated with the aorta, as a consequence of the co-existent disease of the valves of that vessel.

The possibility of the formation of an aneurism resembling the *varicose aneurism*, has been likewise suggested by Mr. Thurnam, from the occurrence of aneurismal pouches in the septum ventriculorum. If such an aneurism were to burst, it would establish a communication with the right ventricle, a portion of the venous system—thus producing "a lesion altogether analogous to that which results from the wound of an artery and its accompanying vein, and to which the name of *spontaneous varicose aneurism of the heart* is perfectly applicable."

Mr. Thurnam mentions a fourth form of aneurism which is not without its analogue in the arterial system, namely, that in which the aneurismal sac is formed by the endocardium and pericardium. This may be compared with a variety of external aneurism in which the lining membrane of the vessel protrudes through a rupture in the middle tunic, constituting a

* Vide Thurnam, loc. cit. p. 219.

* Loc. cit. p. 245.

lesion which has been sometimes designated "aneurisma herniosum," and sometimes "internal mixed aneurism." This form of arterial aneurism has been described by Haller, Dubois, Dupuytren, and Breschet.

In a large number of these cases of aneurism of the heart, the pericardium has been at some period or other of the disease more or less extensively inflamed, and adhesions are consequently found: the endocardium likewise frequently exhibits marks of inflammatory action, opacities, white spots, &c. and this sometimes extends to the valves. In some the muscular substance in the neighbourhood of the sac is degenerated, and assumes the cellulo-fibrous form.*

Atrophy of the heart.—The heart, or a portion of it, may be said to be in the state of atrophy, when its muscular fibres are pale, soft, easily torn, inelastic, attenuated, so that the thickness of the parietes is greatly diminished, and the pericardium covering the heart or the atrophied part of it, is shrivelled and wrinkled. When atrophy affects the whole heart, that organ becomes much diminished in size, the capacity of its several cavities being proportionally diminished; and in some instances the diminution of the general size appears to be more at the expense of the dimensions of the cavities than of the thickness of the walls.

Morbid deposit of fat on the heart (fatty degeneration of some authors). There is an alteration met with not uncommonly in the muscles of animal life, which is very often described as the fatty degeneration of muscle, but which is in truth an atrophy of the muscular tissue, and not at all a transformation into fat. This condition, which resembles fat only in its yellow colour, and may be easily distinguished from it by its fibrous form, has never, I believe, been met with in the heart; a perfect cessation from active contraction must be essential to its production; and as such a state of quiescence cannot occur in the heart during life, this form of degenerate muscular tissue is not found in that organ. We do, however, meet with cases frequently, in which fat seems to take the place of the muscular fibres of the heart: in proportion as they appear to waste away the fat is deposited under the serous membrane, until the muscular parietes of the heart are reduced to a very thin lamina, of a pale colour and easily torn, between which and the pericardium a thick stratum of fat is deposited, so that a superficial examination might lead one to suppose that the walls of the heart were wholly converted into this tissue. The ventricles are generally, if not uniformly, the seat of this deposit, which must be regarded as an increase in the deposit which is found naturally along the course of the coronary arteries. It occurs chiefly in old persons, and it is difficult to say whether the muscular atrophy which is always present is a consequence of the fatty deposit, or precedes it. So enfeebled has the muscular tissue become that persons labouring under this disease very commonly die of a rupture, or rather a giving way, of the wall of one of the ventricles. It occurs in persons of debilitated habits, who either are incapable of active exertion or from circumstances never attempt it, and, what is remarkable, the subjects of this disease are frequently very emaciated: thus M. Bizot* found this condition in fourteen out of twenty-nine emaciated females. The disease is likewise more common in women than in men; and sometimes free oil is present in the blood in inordinate quantity.

Such I believe to be the correct history of this state of the heart, of which most erroneous notions have been formed, owing in a great measure to the name under which the disease has been so often described. The description which I venture to offer has been drawn up from several cases of the disease in various grades of the deposit, which have come under my observation, and on comparing this description with some of the best detailed cases on record, it seems perfectly to consist with the appearances described in them. In Mr. Adams' case,† for instance, "the right ventricle seemed composed of fat, of a deep yellow colour through most of its substance. The reticulated lining of the ventricle, which here and there allowed the fat to appear between its fibres, alone presented any appearance of muscular structure. The left ventricle was very thin, and its whole surface was covered with a layer of fat. Beneath this the muscular structure was not a line in thickness, and was soft, easily torn, and like liver." Two cases, recorded by Mr. R. Smith,‡ presented the remarkable concomitant of an oily condition of the blood; in one "numerous globules of oil were found floating on the surface of the blood which escaped from the divided vessels;" and in the other "the surface of the blood was thickly covered with globules of limpid oil." In this last case the condition of the heart's substance is described as follows: "the heart was remarkably soft, pale, and flaccid, its substance most easily broken, and its surface covered with a layer of fat a quarter of an inch in depth; the parietes of the ventricles were thin." The anatomical condition of the former case is not so precisely described as to admit of comparison. The subjects of both these cases were old women, one aged ninety, the other seventy; and the former died of rupture of the left ventricle.

I am quite unable to account for the following description of a case by Dr. Elliotson. He says, "I once saw the muscular substance of the heart completely changed, *except at the*

* On the subject of aneurisms of the heart, the reader may consult with benefit Corvisart's classical work, Adams in Dublin Hosp. Rep. vol. iv., Breschet sur l'Aneurysme Faux consecutif du Cœur, Rép. Gén. d'Anat. t. iii., Dr. Hope's work, Elliotson's Lectures on Diseases of the Heart, but especially the admirable paper of Mr. Thurnam.

* Mém. de la Soc. Méd. d'Observation.

† Dublin Hosp. Rep. vol. iv. p. 396.

‡ Dublin Journal, vol. ix. p. 412.

surface, to fat. A mere layer of red muscular structure covered the internal and external parts of the heart and the columnæ carneæ: within every spot was fatty matter."*

Rupture of the heart.—A degenerate condition of the muscular tissue is the most common cause of rupture of the heart: the states last described are those in which it most frequently occurs; they correspond to the *senile softening* of Blaud:† the wall literally gives way at a certain point, and a laceration frequently to a very trifling extent is found in that situation on examination after death: in some cases, moreover, several ruptures are found in the wall of the same cavity, and sometimes the rupture is very extensive, or it is large internally and small externally, or vice versa. Any of the cavities may afford examples of this form of rupture, but the left ventricle is by far the most frequent seat of it, as may be understood from the following numerical statement by Ollivier: "out of forty-nine cases the rupture was seated in the left ventricle in thirty-four, in the right ventricle in eight, in the left auricle in three, and in two cases the ventricles presented several ruptures. In these cases the apex was the situation of the rupture in nine; in the rest the rupture took place near the base. Rupture, however, may occur in a healthy state of the organ, from violent bodily exertion; of this a remarkable example was afforded in the case of one of Whitbread's draymen, who in attempting to raise a butt of porter, fell dead, from a large laceration of the left ventricle, the structure of which was perfectly healthy. I had lately an opportunity of examining the preparation of this heart in the Museum of Guy's Hospital.

Rupture is also found to ensue upon abscess in the heart, or upon ulceration and consequent perforation; it is sometimes caused by dilatation of it, and sometimes by contraction of one or more of the orifices.

Partial rupture may occur, i. e. the external fibres may be ruptured to a certain depth, without penetrating the cavity, or the internal ones may be similarly torn, the exterior being unaffected. A more remarkable kind of partial rupture is that in which the carneæ columnæ or chordæ tendineæ are engaged. Cases of this form of rupture seem to have been detailed first by Corvisart, who attributed the rupture to violent efforts. Other cases have been subsequently recorded by Cheyne, Adams, and Townsend. In Dr. Cheyne's case, "the internal surface of the left ventricle was much inflamed, several irregular excrescences were attached to the mitral and semilunar valves. The chordæ tendineæ, which connected the larger portion of the mitral valve to the wall of the left ventricle, were torn off just at the point of their insertion into the edge of the valve; four of these ruptured tendons hung loose into the ventricle."‡

* Croonian Lectures on the Heart, p. 32.

† Blaud, Bibl. Med. an. 1820.

‡ Dublin Hosp. Rep. vol. iv. On the subject of rupture of the heart the reader may consult Ollivier's article (Cœur Rupture) in Dict. de Med., Townsend in Cyclop. Pract. Med. vol. iv. p. 630., and Bouillaud's work.

MORBID STATES OF THE MEMBRANES OF THE HEART.

I. *Morbid states of the pericardium.*—1. *Pericarditis.* The morbid changes of the serous pericardium which most frequently come under the notice of the anatomist, are those which are consequent upon inflammation. What the alterations are which indicate the first onset of inflammatory action it is not easy to determine precisely, as the opportunities of inspecting the parts in this early stage of pericarditis are extremely rare. The following, however, may be stated as indicative of the earliest period of pericarditis. The natural exhalation becomes diminished or totally suppressed, and consequently the surfaces of the membrane do not present their usual moist appearance; the visceral layer of the pericardium is not so transparent as in the natural state, and several red points, which to the naked eye appear like extravasations of blood, are manifested on a considerable portion of the membrane. These spots, however, are not extravasations, but when examined with a lens, they are seen to be produced by a close network of extremely minute capillary vessels; as inflammation advances these spots increase in number, neighbouring ones coalesce, a more or less diffused redness is produced, as well from vessels subjacent to, as in the membrane, the membrane becomes less and less transparent, and now an exudation is distinctly formed on its surface of a very soft semifluid material (coagulable lymph), which, on looking carefully along the inflamed surface, is seen to be developed in minute granules. The further progress of the disease is characterised by the increased deposition of this plastic material, and the effusion of a straw-coloured serous fluid into the bag of the pericardium. These morbid changes, of course, vary in extent; but it is not uncommon to find them extending over the greatest part or even the whole heart, so that in some cases a second complete envelope is formed for the heart between the visceral and parietal layers of the serous pericardium; on the other hand a very circumscribed spot may be occupied by these changes, not exceeding a half-crown or a crown piece in circumference; but we seldom or never have opportunities of seeing the disease on this limited scale in so early a stage, and judge of its occurrence only from the existence of alterations which may justly be regarded as its sequelæ.

Certain varieties are observed as regards the form assumed by the lymph, and the quantity of the fluid effused in this disease. The lymph varies in its characters; almost always deposited in a membranous form, it is sometimes quite smooth and uniform on its free surface; at other times it is rough, and hangs in flocculi into the fluid contained in the sac of the pericardium; again it presents a reticulate appearance, compared by Corvisart, Laennec, and Bertin, to the inner surface of the second stomach of the calf, or, as Laennec suggested, to the appearance produced by quickly separating two slabs of marble which have been applied together, with a small quantity of butter or some similar substance between them. The depth of the depressions in this false membrane varies with the thickness of the membrane itself. Shortly after its deposition the lymph is very tender and easily torn, but when it has been some time deposited, it acquires a considerable power of resistance. The effused fluid in pericarditis varies likewise in quality and quantity. In some cases it is whey-coloured, with flocculi of lymph floating in it; in others it is of a yellowish colour, approaching that of pus, and in some degree of the same consistence: sometimes it is of a brownish colour. When it is in very small quantity it is less turbid; when in large quantity it resembles whey. In some cases the quantity is very considerable. It may be said to vary from a few ounces to more than a pint; but in some extreme cases it goes even far beyond this; thus Corvisart mentions a case in which the effused fluid amounted to eight pounds, and in one described by Bertin the distended pericardium formed a bag seven or eight inches broad, five deep, and ten or eleven in height. Sometimes the effusion cannot be distinguished from pus.

The coagulable lymph is effused not only on the free surface of the visceral layer of the pericardium, but likewise on that of the parietal layer. That which is effused upon this latter layer is, however, often much thinner and more delicate. These two deposits of lymph are continuous with each other at the reflection of the serous pericardium from the great vessels on to the muscular fibres. When the effused fluid has been removed by absorption, the two pseudomembranes being brought into apposition with each other, are as it were glued together; they become organised by new vessels shooting into them from the cardiac vessels, and at length they assume the form of cellular tissue. The cavity of the pericardium thus becomes obliterated by the development of this new cellular tissue. The adhesions thus formed are more or less extensive according to the extent of the primitive inflammation, so that in some cases the pericardium is universally adherent to the heart; in others the adhesion is circumscribed within very narrow limits; in this latter case the new cellular membrane is often of considerable length, inasmuch as the spots to which it adheres on the opposed layers of serous membrane do not at all correspond; but when the adhesion is extensive, the connecting cellular membrane is generally short and close, so much so in some cases that the pericardium and heart appear to be completely identified. The muscular substance subjacent to the inflamed pericardium sometimes appears to participate in the inflammatory process, acquires a greater hue of redness than is natural, and becomes softer, and loses to a greater or less degree its cohesive power.

Such is the ordinary course and termination of pericarditis. Every museum contains many specimens illustrative of the different stages of this disease. The cellular adhesion which fills up the pericardial cavity occasionally exhibits further alterations. Sometimes we find it infiltrated with serum, and quite anasarcous; at other times a sero-purulent or purulent fluid is effused into it. It becomes condensed, fibrous in its character; or cartilaginous or fibro-cartilaginous or even osseous plates are formed in it, which sometimes are of so large a size that the heart appears as if enveloped in an osseous case. This cartilaginous or osseous deposit, however, sometimes takes place in the fibrous pericardium. Dr. Hodgkin mentions a case of osseous transformation so extensive that the osseous plate occupied a large portion of the base of the heart, where it formed a complete bony ring, the apex of the heart, however, being left at liberty. A somewhat similar case is recorded by my friend Mr. Smith. "The pericardium was united to the surface of the heart by close and old adhesions, and around the base of the organ bony matter was deposited in considerable quantity, apparently between the two serous layers of the pericardium; it formed an osseous belt surrounding nearly the entire of the base of the heart; its surface flat and rough, its margin irregular and waving, and its average breadth about one inch. This bony girdle penetrated into the substance of the ventricles, and reached in some parts almost to the lining membrane of the latter."* In Mr. Burns' case the whole extent of the pericardium covering the ventricles, and the ventricles themselves, except about a cubic inch at the apex of the heart, were ossified and firm as the skull.

White spot on the heart.—There is no appearance with which anatomists are more familiar than the white spots on the heart. A single portion of white opaque, or nearly opaque membrane, situated on the anterior part of the right ventricle nearer its apex than its base, and varying in circumference from that of a shilling to that of a half-crown, as thick as the pericardium itself and sometimes considerably thicker, constitutes what I have most frequently seen. They may be found, however, occasionally on the posterior surface as well as the anterior, on the left side as well as the right, on the auricles as well as the ventricles. On careful examination, it is evident that the opacity is occasioned by an adventitious deposit. This deposit, in a great number of the cases in which I have examined it, consisted of a thin lamina of condensed cellular membrane adherent to the free surface of the visceral layer of the pericardium, which could easily be dissected off, and which I have often peeled off with my fingers, leaving the pericardium apparently as if no deposit had been found there. Dr. Baillie, and more recently Laennec and Louis, testify to the facility with which it may be dissected off. Others, however, affirm that the deposit is most frequently under the serous covering of the heart, and consequently in the subserous cellular tissue by which that layer is connected to the heart. Corvisart

* Dub. Journ, vol. ix. p. 419.

maintains this opinion exclusively, and Dr. Hodgkin states his belief that in by far the greater number of cases these patches depend on a deposit on the attached surface. This writer adds—"From the circumstance of their being often found immediately under the sternum, and from their being occasionally met with on other parts of the heart, to which a firm and resisting body has been unusually opposed; as for example, when a bony deposit has taken place beneath the reflected pericardium, or when an uneven and remarkably indurated liver has, even through the diaphragm, presented an unequal pressure against a particular part of the heart, I have thought it probable that such pressure, aided by the movements of the heart itself, may have led to the production of these spots. These formations may certainly take place at a very early period of life. I have met with one rather loose and thick, but in other respects perfectly resembling those found in the adult, on the right ventricle of a child only ten weeks old. Similar thickening of the close pericardium sometimes marks the course of the coronary arteries and their branches; and this circumstance amongst others tends to confirm the idea which I entertain as to its mode of formation."*

Mr. T. W. King, in an Essay on this subject in the sixth number of Guy's Hospital Reports, records a very remarkable example of the opacity. The patch, "a uniform whitish thickening of the close pericardium," nearly equalled in extent the anterior surface of the right ventricle, and was extended over the anterior surface of the pulmonary artery as far as its bifurcation. Two similar patches were found on the under surface of the ventricle. Mr. King inclines to the opinion that this deposit is seated in the proper tissue of the serous membrane, and considers it always inflammatory and pretty constantly the effect of friction and irritation. "The situation of these patches," observes Mr. King, "whenever they occur, implies to my mind a egree of attrition at the part more than belongs to the pericardium generally. They are found on the surface of the right auricle almost as frequently as on the ventricle, but not in so morbid a form; and much more divided, even minute, and often clustered like the rippling of the sand at ebb-tide. One is not unfrequently seen along the anterior face of the great pulmonary artery. All these relate to the right side of the heart, which all pathologists are aware is often, and more than the left, the subject of distensions. The patches may occasionally, perhaps, be seen on any part of the close pericardium. I have seen them behind the left pulmonary veins; but, omitting this instance, the next most common appearance of the kind is that of lengthened, narrow, winding, and even branching lines immediately over the great vessels of the ventricles whenever they are the subject of considerable dilatation. Here, also, we have evidence of a disproportionate space of attrition, resulting from undue prominence."

*Lect. on Morb. Anat. of serous membranes, p. 98.

I am not aware of any well-authenticated instance of ulceration or gangrene of the pericardium. In cases of ulcerative perforation of the heart, it may be said, however, that the pericardium ulcerates as the other parts do.

Tubercular formations.—Tubercles, whether cancerous, melanotic, or scrofulous, are formed subjacent to either serous layer of the pericardium; sometimes, and most frequently they are deposited between the visceral layer and the heart, or they may be found between the fibrous pericardium and the parietal aspect of the serous layer.

Cysts.—The serous cysts which are described as occurring in the heart are sometimes formed immediately subjacent to the serous membrane, and project into the pericardial sac. According to Andral they occur most frequently in this situation. Similar cysts have been found between the fibrous pericardium and its serous lining.

Hydrops pericardii or *hydropericardium.*—This disease consists in an undue accumulation of fluid in the sac of the pericardium. The fluid is either simply serous, of yellowish character, or it may be of a brownish or reddish hue. In quantity it rarely exceeds two pints. The effusion is not generally attended with any evident morbid change either of the heart or its membranes, excepting that in cases of some standing, the heart seems somewhat atrophied, and the pericardium has lost its perfect transparency.

Pneumopericardium.—The presence of air in the pericardium, as the effect of morbid action during life, must be very rare. Laennec, however, speaks very confidently of its existence. "Sometimes," he says, "the air is combined with a liquid, and this is by much the most frequent case; at other times the pericardium is distended by air alone." Could the cases of dry pericardium related by Baillie have been produced by the developement of air in its cavity?

Morbid states of the endocardium.—1. *Endocarditis.* The lining membrane of the heart is so similar in its structure and properties to the pericardium, that their morbid states are very similar likewise. The constant contact of the blood with the former membrane serves, however, to modify considerably the anatomical characters of disease in it. We want, I think, satisfactory proofs of the changes induced by endocarditis in its earliest stage; these changes are described to be, redness of the membrane, with a more or less thickened or swollen condition of it; but the redness is not the result of capillary injection, but seems to be a stain on the membrane, the result of contact with the blood. The stain is not merely superficial, but has sunk into the substance of the tissue, and it cannot consequently be washed off.

The lining membrane of the heart is often found stained of a red colour as a post-mortem result; and this is invariably the case in hearts examined after putrefaction has commenced. The blood contained in the heart has begun to alter, various gases are given out, and the internal membrane more readily imbibes the colouring matter that is brought in contact with it.

Can this redness be distinguished from that which is consequent upon inflammation? It seems to me that there is no *anatomical* character by which the true nature of the discoloration can be proved. The anatomist must be guided in coming to a conclusion upon the question by concomitant circumstances, of which the time which has elapsed after death, the quantity and quality of the blood in the heart, and the state of the other organs or textures of the body, are the most important. If the examination has been made soon after death, that is, within twenty-four hours, if the blood in the heart presents no undue predominance of colouring matter, nor has undergone any decomposition, and if the other tissues retain their natural state, and show no unusual tendency to putrefaction, the redness may be inferred to be morbid and inflammatory; but this inference is confirmed with the utmost degree of certainty, if the redness is accompanied by an effusion of coagulable lymph or of pus, and by an unequivocal thickening or swelling of the endocardium itself; sometimes, also, as Bouillaud remarks, the adhesion of clots, resembling the buffy coat of blood, are among the anatomical signs of inflamed endocardium. The inflamed endocardium is, according to Bouillaud, more easily detached from the internal surface of the heart, owing in all probability to the subjacent cellular tissue having lost its force of cohesion, and become fragile.

Lymph effused on the endocardium does not generally take the laminated form as in pericarditis, nor do we find it covering an extensive surface, as in that disease. Small patches of membranous lymph are sometimes met with here and there, either on the surface of the valves or over some part of one of the cavities; at other times it assumes a granular or warty form, or it projects in papilliform or conical or globular masses from the surface of the valve. Thus are formed the vegetations which are among the most frequent valvular diseases, and which offer the greatest impediments to the adequate action of the valves. When examined recently after their formation, they present all the characters of the albumino-fibrinous exudations of serous membranes, their form being determined by the frequent changes of relation which the inflamed surface undergoes in the heart's action, as well as by the current of blood from the heart continually flowing over it.

The further progress of inflammation of the endocardium induces thickening of the membrane or of the valves, organization of the effused lymph, which thus becomes more firmly adherent to the surface on which it had arisen, and induration of the membrane from cartilaginous or calcareous deposits, which however are generally met with within the fold of membrane constituting the valves, and more intimately connected with the interposed fibrous than with the serous membrane.

When inflammation of the folds of endocardium forming the valves runs its course with great rapidity, it may induce destruction of them to a greater or less extent. Softening, ulceration, and rupture of the affected valve are very speedily produced. "The ruptured and ulcerated portions," to borrow Dr. C. J. Williams's description, "are found loaded with ragged, soft, fragile vegetations, more or less tinged with blood, and these are also sometimes seen adhering to adjacent parts where the endocardium is entire. The remaining parts of the valves are much thickened and opaque yellowish white, with a pink hue; and pink patches are often seen in the aorta with atheromatous thickening." Sometimes a valve is perforated in its centre by ulceration, and the circumference of the perforation is surrounded by warty vegetations.

It is well known that the endocardium of the left side is much more liable to disease than that of the right, whether as regards the valvular portion of it or that which lines the interior of the heart. But the views of Bichat and others, who denied the occurrence of disease on the right side, have been abundantly refuted by modern observations.

Chronic valvular diseases.—Chronic endocarditis affects the valves of the heart in such a manner as in all cases to occasion more or less obstacle to the flow of the blood from the ventricle or auricle. Sometimes, however, the disease is not of a kind to interfere with the valvular action and to permit regurgitation; but at other times the disease has gone so far in one or more of the valves as to prevent its contributing to the perfect closure of the orifice, and consequently to destroy the power of the valves to oppose regurgitation. Hence the subdivision proposed by Dr. Williams, for valvular diseases, into those which more or less obstruct the current of the blood in its proper channel, or the *obstructive*, and those which permit it to pass in the reversed direction, or the *regurgitant*. Thickening of a valve, so as to prevent its complete apposition to the internal surface of the artery or of the ventricle, will occasion obstruction, the degree of which will depend on the degree of perfection of apposition with which the valve may be applied to the neighbouring surface; on the other hand, the degree to which regurgitation is permitted will depend upon the degree of induration of the valve, and the want of extensibility which it manifests.

Thickening of the edges of the valves is among their most common diseased states; the attached margin or base of the valve is also very frequently the seat of thickening, and in both these situations the fibrous tissue seems to be engaged principally in the disease. The intervening portion is generally affected as a consequence of the extension of the disease from these margins. In such cases the thickening arises from a deposit between the layers of the fold forming the valve; in other cases the thickening is produced by a deposit upon the surface of the valve. On the aortic valves this deposit, when on the ventricular surface, is apt to assume the form of two crescents corresponding in position as well as form to the two crescentic portions of fibrous tissue within the fold of membrane by which the valve is formed. This fact was, I believe, first pointed out by Dr. Watson.

Ossification most commonly manifests itself in the fibrous zones which surround the heart's orifices, and therefore it is chiefly to be found at the bases of the valves; but it likewise extends towards their free margin; and it too is apt to be developed in the double crescentic form in the aortic valves. Sometimes the ossification appears to involve principally the margin of the valve in whole or in part, and this occurs much more frequently in the semilunar than in the auriculo-ventricular valves. Osseous deposits in the valves are either in the form of thin calcareous laminæ or spiculæ, small rounded points, or large masses more or less rounded, and often projecting to a considerable extent beyond the surface of the valve.

The effect which the developement of these new deposits on or in the valves has upon their size and form, as well as upon the size and form of the openings which the valves surround, is very various and very interesting to the pathologist. The almost invariable alteration which they produce in the size of the valve is to shorten it or diminish it in depth; the valve becomes corrugated, its free margin thickened, or folded in the direction of the current, or in an opposite direction, the whole valve presenting a curled appearance. The orifices are always more or less diminished in size when one or more valves have acquired this rigid, inelastic, and contracted form; the diminution is produced by the valve or valves always projecting more or less into the orifice; but the greatest degree of narrowing of the aperture is occasioned by the adhesion of two or more valves at their free margins; and in this way, as may be readily conceived, an orifice becomes sometimes almost completely obliterated. The same causes change the shape of the orifices, and consequently we find altered size and shape constantly going together. It is in the left auriculo-ventricular opening that these changes are most commonly seen; they rarely occur to so great an extent in the aortic orifice, and seldom at all in the apertures of the right heart. My friend, Mr. Adams, has made some most valuable remarks upon the contracted auriculo-ventricular orifice of the left side, in his very valuable paper on diseases of the heart in the Dublin Hospital Reports. His description of the anatomical characters of the disease corresponds so exactly with what I have many times witnessed, that I cannot refrain from quoting it. "When the dilated (left) auricle is cut into and cleared of the blood it contains, at its lowest part, instead of the mitral valve, a concave membranous septum of a yellow colour is seen, which is perforated by an oblong fissure, about half an inch in length, and one or two lines broad; this fissure I have observed to be always obliquely situated, and to run parallel to the septum of the ventricles; it generally is of a semilunar form, the concavity of the curve looking towards the root of the aorta, the convexity backwards; the first formed by the larger portion of the mitral valve, the latter by the smaller; the edges of this oblong fissure are generally studded with long depositions; viewed from the left ventricle, the membranous septum is convex, and the angles of the fissure are connected by shortened chordæ tendineæ, with two very thick fleshy columns, the one in front, the other behind."

Dilatation of the valves.—We sometimes find the valves of the heart in a dilated or aneurismal state. Laennec has placed on record an example of this affecting the mitral valve:* "A little pouch, half an inch long and more than four lines in diameter, projected on the superior surface of this valve," i. e. into the left auricle. Mr. Thurnam has appended the detail of several cases to his memoir already quoted on Aneurisms of the Heart.† He describes a specimen, preserved in the Hunterian Museum, affording an example of four aneurismal pouches of the tricuspid valve. The same writer likewise records a case in which there was congenital absence of one aortic valve; the two, which were present, were thick and fleshy, and rough on their ventricular surfaces. The edge of the one was smooth, that of the other rugged; there was a deposit of ossific matter at their points of attachment. From the ventricular surface of the valve with the smooth border, there projected a little bag that would hold a swan-shot, and which opened by a little round mouth on the aortic surface of the valve. It had two little slits in its most depending portion, and was evidently formed by a dilatation of the valve itself."

Atrophy of the valves.—We have a familiar instance of atrophy of valves in the case of the Eustachian valve, which undergoes as it were a sort of natural atrophy from the commencement of extra-uterine life. The valve becomes cribriform, and the holes by which it is pierced gradually enlarge and coalesce, and in this way the valve is worn away. We often find one or more of the semilunar valves perforated by openings of a similar kind, without the co-existence of any other disease; the margin of the opening is always smooth, and the valve itself thinner and more flaccid than is natural. According to Dr. Williams, the wasting affects the posterior portion of the mitral valve, "the membrane of which is often annihilated by it, the cords being inserted directly into the auricular ring." The anterior lamina is also occasionally found much shortened, and without those fine thin expansions of membrane which commonly unite the cords to each other, below their insertion into the thicker part of the valve.

Entozoa in the heart.—The occurrence of entozoa in the human heart must be considered to be extremely rare, at least the cases on record which may be depended on are very few. Andral states that he found the cysticercus once in the human heart, but has seen it frequently in the hearts of measly pigs. Many examples are mentioned by various authors of ascarides, filariæ, cercariæ, and other entozoa in the hearts of dogs and many other of the in-

* Quoted in Bouillaud's work, t. ii. p. 510.
† Loc. cit.

ferior animals, Mammalia, as well as birds, reptiles, and fishes.*

States of the blood in the heart after death.—What appears to be the natural state of the contents of the heart after death is as follows. The right auricle contains a coagulum of dark blood, and the right ventricle contains a similar one, of less size; a very small quantity of coagulum or of fluid blood is found in the left cavities, and it is not uncommon to find a coagulum extending into the aorta; white coagula are often found in these cavities. Sometimes these coagula, especially at the right side, adhere closely to the wall of the cavity in which they are situated, and appear as it were moulded upon it, sinking into the interstices between the fleshy columns, so as to render it difficult to remove them. The modification which we most frequently meet with in this state of the heart's contents, is that in cases of asphyxia; affording, however, merely an instance of aggravation, if I may so speak, of the natural state; the right cavities and the vessels leading to and from them are gorged with dark blood, liquid or coagulated, while the left cavities are nearly empty. Such states of the heart's cavities, it is obvious, are formed in articulo mortis. Fibrinous masses, either mixed with or deprived of the colouring matter of the blood, have been many times found, which it cannot be doubted were formed in the heart some time prior to death, and probably gave rise to symptoms of a serious nature; these are the *true polypous concretions* of the heart. The manner in which Mr. Allan Burns, one of our earliest British writers on the heart, explains the formation of some of these concretions, is deserving of attention. "If," he says, "we strictly scrutinize all the reputed cases of polypus in the heart, we shall reduce the real examples of this affection to a very limited number indeed. Still we shall leave a few, where there is reason to believe that the concretion had been formed a very considerable time before death: but it must be understood, that these concretions are seldom found except in hearts otherwise diseased. In health, the blood does not tarry for any length of time in either the heart or vessels; it is incessantly in motion, circulating with greater or less rapidity, according to the state of the heart and arteries. The blood never in health remains so long in contact with the surfaces of the heart, as to allow of its being changed by their action. In some diseases of this organ, irregular actions are excited by very trifling causes; the blood stagnates longer in the heart than it usually does or ought to do, while here it undergoes changes by the reciprocal action of the blood on the heart and the heart on the blood; new organized matter is deposited, and adheres to the parietes of the cavity in which it is lodged. This concretion slowly increases, the first particle acting as the exciting cause for the deposition of the second, and so on."

The strongest evidence of the formation of such coagula some time before death consists in their being organised: in a case recorded by the writer from whom the preceding passage was quoted, a large and fully organised polypus was found in the right auricle; its attachment was by a rough surface to the musculi pectinati, and its body hung down into the right ventricle. It very much resembled a nasal polypus, and it was so firmly fixed to the heart, that it allowed the whole mass of the heart and a considerable portion of the lungs to be suspended by it, without showing any tendency to separate. It was pendulous and tapered from below upward; its structure was dense and lamellated, and not a single red globule entered into its composition." In this case, as in other similar ones quoted by Andral, the adhesion of the polypus seemed due to an inflammation of the endocardium, either excited by the contact, or before the formation of the coagulum. That such coagula may be permeated by bloodvessels is proved by the cases of Bouillaud and Rigacci, quoted by Andral: in the latter cases, these reddish filaments passed from the columnæ carneæ and entered the substance of the polypous mass: they had all the appearance of bloodvessels, and when injected with mercury were found to divide into a number of small branches that ramified through the substance of the polypus. By careful dissection it was ascertained that the tumour was formed altogether of a mass of fibrine, such as is found in the sac of arterial aneurisms Pus is occasionally found in the centre of these fibrinous concretions, but whether carried to the heart in the blood, and accidentally enclosed in the coagulum during its solidification, or formed in the coagulum by some action within it, it is impossible to decide. Osseous and cartilaginous deposits too have been found in them, as in the case from Burns, in which one of these polypi was ossified in several points, and so perfectly organized that on inflating the coronary vein, a number of minute vessels on the surface and in the substance of the tumour became distended with air.

(R. B. Todd.)

HEAT, ANIMAL.—Judging merely by our sensations, we should infallibly conclude that our bodies undergo very considerable changes of temperature. This belief was indeed necessarily entertained previously to the time when natural philosophy had discovered a means of ascertaining the true state of the matter. The application of the thermometer has dissipated the error. But then error of an opposite kind was run into, and the results of a very limited number of observations led men to conclude that the temperature of the human body was invariable or nearly so. Still the measures of temperature given by different observers did not perfectly accord, though each presented his conclusions as the temperature of the race. It was but reasonable to imagine that these discrepancies arose not from any want of accuracy in observation, but from diversities inherent in the subjects observed. This is now known to be the case. But though proofs of this truth have been greatly multiplied, the

* For a list of the references to such cases, see South's edit. of Otto, Path. Anat. p. 293.

whole subject has never been presented in a connected and systematic manner.

Since it is proved that the temperature of the human body varies, we can only obtain an approximation to its actual amount by taking the mean of all the good observations that have ever been made, being particularly careful to include the extremes; for a mean gives but a very imperfect idea of a term that ought to represent a variable number, if the limits are not at the same time assigned and taken into the account. The best observations of this kind, provided they be sufficiently numerous, will be those that have been made by the same individual, inasmuch as there is great likelihood that he will always have made use of the same procedure and of the same instruments, by which the results become more readily comparable one with another.

Temperature of the human body.—In the following observations we shall make use of the measures of temperature given by Dr. John Davy. These amount to one hundred and fourteen in number, and were made on individuals of both sexes and of different ages in three quarters of the world, in Europe, Asia, and Africa, in different latitudes, under various temperatures, and among individuals of different races. But, as the knowledge of the mean and extreme temperatures of the body of man would have little value apart from the statement of the circumstances and conditions under which they were ascertained, we shall at the same time give the ages of the subjects and the temperature of the air at the time of the observations.

The mean age of the subjects of Dr. Davy's observations was twenty-seven years. The mean temperature of the air was 23°, 3 c. (74° F.*) between the limits of 15°, 5 (60° F.) and 27°, 8 (82° F.). In these circumstances the mean temperature of the body, which was always taken in the mouth, was 37°, 7 (100° F.) between the extremes 35°, 8 (96°, 5 F.) and 38°, 9 (102° F.). The greatest difference in one hundred and fourteen observations, therefore, scarcely exceeded three degrees. The temperature of the human body thus obtained might be considered as exact if the conditions of age and external atmospheric temperature approached pretty closely to their respective means. This, in fact, was the case as regards the first term, but not as concerns the second; for some of the observations were made under very intense degrees of heat, such as 27°, 8 (82° F.), but none at the opposite extreme, or at a temperature which could be reputed cold, a temperature of 15° (59° F.) being already sufficiently agreeable. So that if the temperature of the air influences that of the body, a question which we shall examine by-and-by, the mean which we have stated as the temperature of the species would be too high.

It is of some consequence to pursue these inquiries among the lower members of creation, among animals; and the writer to whom we are indebted for the observations quoted upon man has also made a great number upon the lower animals. We shall therefore continue to make use of this series of experiments, as we have already made use of that which bore upon man individually.

Temperature of the Mammalia.—The observations here were made on thirty-one different species taken from among the principal divisions of this class, and under a mean temperature of the external air equal to 25° (77° F.), between the limits of 15° (59° F.) and 30° (86° F.).

The mean temperature of the body of the Mammalia was 38°, 4 (101°, 10 F.), the maximum being 40°, 5 (105° F.), the minimum 37°, 2 (99° F.). The extent of variation consequently presented by the Mammalia, 3°, 3 of the centigrade scale (6° F.), is nearly equal to that exhibited by man. But there is this difference between the two scales, that the extremes and the mean in the case of man are inferior to the corresponding terms in the case of the Mammalia.

Temperature of Birds.—The observations here were made on fifteen species in different orders. The mean temperature of the air was 26°, 1 (79° F.), between the extremes 15° (59° F.) and 31°, 5 (88°, 75 F.). The temperature of the subjects of the experiments offered a mean of 42°, 1 (107°, 86 F.), the superior limit being 43°, 9 (111° F.), the inferior 37°, 2 (99° F.). The temperature of birds, therefore, presents a scale much more extensive than that of man and the Mammalia, amounting to as many as 6°, 7 degrees centigrade (12° F.). It also stands above both of the others in the point of its mean, which is higher by 3°, 7 (6° F. nearly) in its upper limit, and 5° centigrade (about 9° F.) higher in its lower limit. The lower limit, in fact, corresponds very nearly with the mean term of the heat of the Mammalia as exhibited in the preceding scale. But in neither scale can we say much in regard to the inferior limit, inasmuch as no observation was taken at a temperature lower than that of fifteen degrees centigrade (59° F.).

When we compare the preceding statements of the temperature of animals, it is apparent that it varies but little between one species and another of the same class. In passing to different classes, however, the difference becomes very considerable, and though the observations are here much fewer in number, they are perfectly satisfactory as regards the general result.

Temperature of Reptiles.—From nine observations made on members of the four orders of Reptiles, Dr. Davy found, the external air having a mean temperature of 26°, 5 (79°, 75 F.) between the extremes 32° and 16° (89°, 5 and 60°, 75 F.), that the temperature of Reptiles was not higher than 28° (82°, 5 F.).

Temperature of Fishes.—If from Reptiles we pass to Fishes, corresponding and even more remarkable differences are perceived. Dr. Davy, indeed, gives the temperature of

* [The valuations according to Fahrenheit's scale the editor desires may be regarded as mere though close approximations to the indications according to the centigrade scale.]—Ed.

no more than five species, but they belonged to very different orders. The mean external temperature being 22°, 3 (72°, F.), that of fishes was found to be but 23°, 2 (74° F.), which is very little more than one degree centigrade higher. This difference becomes even more striking, if possible, as we descend in the scale of animals.

TEMPERATURE OF INSECTS.—From eight observations on Insects of very dissimilar species, the mean temperature of the air being 24° (75°, 5 F.), that of the insects was 24°, 2 (75°, 75 F.)

TEMPERATURE OF THE CRUSTACEA.—Two species of Crustaceans, the cray-fish and crab, presented a still more interesting phenomenon. The mean temperature of the air was 24°, 4 (76° F.) at the time of experimenting, that of the Crustacea 24°, 1, or somewhat lower than the ambient medium. This we do not presume to present as the rule, but we would say that the temperature of the Crustacea is nearly equal to that of the medium in which they are plunged.

TEMPERATURE OF THE MOLLUSCA.—In observing the temperature of a single Mollusc, the common oyster, the temperature of the sea being 27°, 8, (82° F.) that of the animal was 27°, 8 also.

It is obvious, therefore, that the differences in the temperature of animals from reptiles inclusively downwards is very inconsiderable. All these animals, indeed, may be united under a single category, and regarded as constituting a single group characterised by the state or degree of their temperature. The same may also be done with reference to the animals of the two higher classes, Mammalia and Birds, which in point of temperature are so nearly akin to each other.

There are consequently two grand divisions of animals as regards temperature; the one comprising the Mammalia and Birds; the other including Reptiles, Fishes, Insects, Crustaceans, and Molluscs. The first is known under the name of *warm-blooded animals*, the second under that of *cold-blooded animals.*

To characterize the first under the view of temperature, the mean of the temperatures of the respective classes which compose it must first be taken. From the experiments of Dr. Davy the mean temperature of Mammalia appears to be .... 38°, 4 (101° F.)
that of birds .... 42°, 1 (108° F.)

Mean of both classes 40°, 25 (104°, 5 F.)

We may therefore say that the mean temperature of warm-blooded animals, including man, surrounded by a moderate external temperature is in round numbers 40° (104 F.) between the limits of 36° and 44° (97° and 111°, 5 F.), by which we have a scale of difference amounting to 8° (about 14° F.).

The other class, that, namely, including the *cold-blooded animals*, having no peculiar temperature proper to them, may be characterized in the following manner:—their temperature differs little or not at all from that of the surrounding media in which they live, when this is at a degree which may be called moderate; so that the differences are either inappreciable, or do not exceed the limits of + 4 (39°, 50 F.). We shall return by-and-by upon this character, which requires development.

General conditions of organization in relation with the production of a greater or less degree of heat.

So wide a difference in the heat of the two categories of animals might lead to the presumption that there is also a very great difference in point of structure. If, indeed, this relation exists and is easily detected, we may be led to discover the general conditions of organization upon which the production of heat depends. Is there an organization common to Mammalia and Birds, distinct and different from that belonging to the other classes of animals? This question can be answered in the affirmative: there is a well-marked diversity of organization which distinguishes Mammalia and Birds from all other animals.

I. The most prominent feature of diversity exists in the sanguiferous system, which is divided through its entire extent into two distinct parts without direct communication between them, the heart presenting a complete median septum, the bloodvessels in like manner forming two systems of canals, which have also no immediate communication in their trunks.

II. This peculiarity of structure, which is only met with among animals having warm blood, is regularly associated with an organ adapted for aerial respiration. The character which distinguishes this respiratory organ from the one met with among cold-blooded animals, reptiles especially, is this,—that either in itself or its appendices (the air-sacs of birds) it presents a much larger extent of surface in relation with the air.

III. Warm-blooded animals are farther distinguished from the cold-blooded by important modifications of the digestive canal. 1. The first portion of the apparatus from the mouth to the stomach is much more complex in them; for instance, it presents either a much more perfectly developed dental system, fitted to divide the food, or a sac, as among birds, fitted to macerate the aliment, and cause it to undergo a kind of preparatory digestion before it is passed to the stomach. 2. The stomach is more distinct; either the entrance to and exit from this pouch are better marked, being often provided with a valve, as in the Mammalia, or its structure and form are more special, as we observe it among Birds. 3. The intestinal canal is much longer in the warm than in the cold-blooded tribes.

IV. The nervous system presents diversities still more important and well-marked. The most striking character exists in the proportion of the principal trunk of this system, and especially of its encephalic extremity, which is much larger in the warm than in the cold-blooded animals.

The most remarkable structural conditions of warm-blooded animals, then, are four in number, three of which are referable to the organs of nutrition, the fourth to the nervous system, which may be briefly related in the following order:—1. higher complication and greater extent of the digestive apparatus; 2. entire separation of the circulating apparatus into two systems, the venous and arterial, without direct communication between them; 3. organs of aerial respiration presenting a much larger surface to the contact of the atmospherical air; 4. a nervous system of which the axis, and especially the encephalic extremity, bears a very high ratio to the whole.

These structural characters determine the following modifications of function. 1st, The complexness and greater extent of the digestive apparatus in warm-blooded animals produces a more perfect elaboration of the matters which serve for the formation of blood. 2nd, The arrangement of the parts of the circulating system maintains the arterial blood quite distinct from the venous, and in a state of complete purity. 3rd, The respiratory apparatus, by the great extent of its surfaces in contact with the air, secures that its distinguishing qualities be imparted in the highest possible degree to the arterial blood, which moreover is elaborated in larger quantity. The predominance of their nervous system, and especially of its encephalic extremity, renders all the parts of the body much more excitable, and gives the greatest energy to the nutritive functions. The whole of these organic conditions are mutually dependent, and may be reduced to the expression of these two general conditions:—1st, *the formation and distribution of the arterial blood, the particularly exciting and nutritive blood of the body*; 2nd, *the most powerful influence of the nervous system.*

As these characters of primary significance in the animal economy coincide in Mammalia and Birds with the greater production of heat, and thus distinguish them from all other animals, it is probable that between these organic conditions and caloricity or the power of evolving caloric, there is a relation of the nature of cause and effect. It is even almost impossible that this should be otherwise than as it has been stated; for the characters of organization and the peculiarities of function, coincident with the greater evolution of caloric, are almost the sole points of any importance that distinguish warm from cold-blooded animals.

It is therefore nearly certain that the conditions requisite to the production of heat must exist within the circle of the functions which we have described. And if this relation do actually exist—as these functions are in a state of mutual dependence,—it follows that one of them cannot be modified, the others remaining, so to speak, in the same condition, without modification resulting in the calorific capacity likewise. It is of great consequence to verify this assumption, because if it be well-founded, the probability already elicited of the power of engendering heat being dependent on the state of the functions in the relations which have been indicated, becomes matter of certainty. So that it is of the highest import to follow the modifications of these functions presented by animals and man in order to compare them with the respective varieties of calorific power presented by each. And if we find that they coincide, and accord with the principle established, we shall have discovered the conditions of organization and of function upon which the production of caloric depends.

Conditions of organization and of functions may be entitled the physiological causes of the production of animal heat. If we succeed in determining these, we ought to rest satisfied. If, indeed, to this knowledge we could add that of the immediate cause of this phenomenon among animals, or what is the physical cause, it would be a great gain for science. This, accordingly, was the object of the labours of the majority of physiologists who have given their attention to the subject of animal heat. But they could not possibly succeed in their researches, for the simple reason that natural philosophers themselves have not yet discovered how heat is produced in the inorganic world; although indeed they have presumed that they were acquainted with it. It is not to be wondered at, then, that attempts have been made to detect this presumed cause amidst the complicated phenomena of life. But natural philosophers have lost confidence in the theory which they had formed, and are searching for a new one. Meantime they are doing what ought always to be done under such circumstances; they are studying with care the various conditions and circumstances in which it is produced; determining these with precision, and measuring with rigour the quantity of heat produced. Of late, therefore, many distinguished physiologists have entered on the same path, and by experiment have endeavoured to ascertain the physiological conditions of the production of heat. But if their predecessors have not attained the object they had in view, they have nevertheless rendered very essential services to science; for in searching after the physical cause of heat, they have determined with precision the physiological conditions of the production of animal heat, which are of very great importance. Independently of the simple observation of the actual temperature of animals, the labours of physiologists on this subject consist almost entirely of experimental facts, that is to say, facts created by science.

But there is one source of inquiry into the laws of animal heat which has been little dipped into, although it is beyond all comparison the most abundant. I allude to that presented to us by nature in the all but infinite variety of modifications of organization and phenomena exhibited in the vast chain of animated things, not only in the diversities of species, but also in the varieties of age and constitution, and the changes induced by the states of health and disease. In making this an object of peculiar study, we become acquainted with the greatest possible number of phenomena connected with animal heat; and in determining the physiological conditions of its production, we shall lay up a store of theoretical knowledge peculiarly applicable to practice, the end and object of all physiological investigation.

The means of comparing these modifications, however, and of judging of their importance are not always easy. We shall do as much as the actual state of our knowledge permits if we inquire first, by what means we can appreciate the modifications relative to the arterial blood.

1. As regards the *quantity* of the arterial blood, we shall view this point of the inquiry less with reference to the whole amount of blood circulating in the body, than to the quantity which is formed at a time, as it were, in the lungs; because it is evident that if the arterial blood influences the phenomenon of heat, the more that is formed at any given time the greater ought to be the direct or indirect influence upon the production of heat. *a*. As it is not always possible to have a direct and precise measure of the relative quantity of blood in the organs, we must be content with an approximative mode of estimating this, which consists in ascertaining in what degree the lungs are loaded with blood. *b*. An aid to the judgment may also be derived from the relative size of the lungs, the tissue being presumed to be nearly alike throughout their entire mass. *c*. With an equal volume of lungs, the greater or less compactness of the tissue must be taken into the account. The closer the tissue is, the more are the surfaces in contact with the air multiplied. *d*. The extent and rapidity of the respiratory motions form another element in the calculation; for to increase the amount of relation with the air is analogous to the formation of a larger quantity of arterial blood within a given time.

All the foregoing data refer to the absolute or relative quantity of arterial blood. But there are other particulars connected with its constitution which it is necessary to mention. The blood, for instance, is composed of a fluid and solid part, the latter existing under the form of globules. It is obvious that the fluid is not the characteristic part of the blood, inasmuch as this is met with elsewhere, whilst the globules of the blood are only known as constituents of this fluid. *The arterial blood consequently ought to have qualities by so much the more distinctive and energetic as it contains a larger proportion of globules.* Now this is a character that may be appreciated with exactness, and measures of it have been given. But the globules of the blood are not invariably of the same nature, a fact which may be judged of by outward and very obvious and appreciable characters, namely, size and form. The smallness and more or less perfectly spherical or rounded form of the blood-globules distinguishing animals with warm blood, coincide in the Vertebrata with a higher capacity to produce heat. For we do not institute this comparison here save in reference to animals included in this division, inasmuch as the characters of the blood have only been studied under these relations among them. We shall, therefore, hold the energy of the calorific power to be connected with the smallness and rounded form of the globules of the blood in vertebrate animals.

2. The materials of the blood being supplied by the digestive apparatus, we might judge, all things else being equal, of the perfection of the blood by the perfection of this apparatus. But there is likewise a necessary co-relation between the result of the function, and the aliment; for instance, when the apparatus shall be found nearly alike in any two cases, the difference of food necessarily influencing the qualities of the blood, the comparison must be established, every other circumstance being equal, according to the higher or lower nutritive qualities of the food.

As the use of the arterial blood is to excite and nourish the different parts of the body, there will be a necessary correspondence between the blood and the result of the nutrition which may become manifest in the nature and quality of the tissues. And in this case it would be fair to make use of these characters of tissues to form an estimate of the nature of the blood in reference to its aptitude to produce heat; and this we shall accordingly do. But even in the event of all these characters failing us, there is another source whence we can derive comparative measurements, which are susceptible of very rigorous application.

Since it is necessary that the venous blood should pass through the lungs in order to become arterial from contact with the air of the atmosphere, it is obvious that it cannot undergo any change in its constitution without the air at the same time suffering a change. That the air is altered by the respiratory act is well known to all, and as there is a necessary co-relation between the blood aerated during respiration and the air which it alters, the amount of alteration undergone by the one may be estimated from the change suffered by the other. The quantity of air altered by respiration, all other things being equal, ought to be found in relation with the production of heat.

The different characters which we have mentioned all refer directly or indirectly to the blood. There still remains one of another order which may also serve us as a guide in making comparisons in reference to the production of heat. The allusion here made is to the nervous system, the superior value of which in warm-blooded animals has already been commented on. It is thus, then, that we may assume the predominance of the nervous axis, and particularly of its encephalic extremity, as a condition favourable to the production of heat, and which, in circumstances of parity among the other conditions, must tend to the production of a greater quantity of heat. Such are the modes of proceeding which we shall follow in investigating the modifications of the organic conditions and of the functions which coincide with the greater evolution of heat. To ascertain whether this coincidence is to be viewed as being in the mutual relation of cause and effect, it imports to know whether or not their variations are in relation with those of the heat produced. If they coincide whenever we compare them, provided these comparisons are but sufficiently numerous, we shall be safe in admitting a necessary connexion between them. We were led to the relation which engages our attention in the course of our comparisons of warm-blooded animals with those having cold blood considered in general. Let us now enter upon a comparison of the same kind, but more particular, whilst we take account of the most important subdivisions of these two great groups in order to verify our first inductions.

We shall first compare Mammalia and Birds to determine which of the two classes, in conformity with the principle to which we have been led, has its organization most favourable to the production of heat.

The lungs of Birds, although smaller, are more loaded with blood than those of the Mammalia, and are in communication with extensive air-cells, spreading all through the body and even penetrating into the cavities of the bones, so that the air may be said to penetrate the body generally, and to be in contact with the ramifications of the aorta as well as with those of the pulmonary artery; the blood of these animals is therefore in the most extensive relation imaginable with the air of the atmosphere. Again, if the nature of the blood of Birds be considered, independently of this extensive relation with the air, the organic condition here will not appear less favourable to them. The globules of this fluid, indeed, are a little larger and less spherical than in Mammalia, which is a disadvantage; but the proportion they bear to the fluid part is so favourable to Birds that this circumstance must give them immensely the advantage in reference to the character which engages us. With regard to the nervous system, if the encephalic extremity is developed in a minor degree in Birds, their circulating and respiratory systems act with greater quickness. Lastly, and as an effect of the whole of these conditions, the consumption of air is much greater among Birds than among Mammalia.

From all that precedes, it follows, if the principles already laid down be correct, that Birds ought to produce the greatest quantity of heat; and this is actually the case, as we have seen when we were speaking of the actual temperatures of the different classes of animals—the mean temperature of the Mammalia is 38°, 4 (101° F.), that of Birds 42° 1 (108 F.). Here, then, is a powerful confirmation of the relation which we have recognized between the conditions of the organization and the production of heat; it is of so much the more value as the relation being based on the comparison of two classes so numerous, the verification is made on a scale of proportionate extent. We shall extend it still farther by contrasting in the same manner the two other classes of the Vertebrata, Reptiles and Fishes.

1. The organs which prepare the materials of the blood—the digestive apparatus is more complete among Reptiles than among Fishes; 1st, in the dental apparatus when it exists; 2d, in the more distinct stomach; 3d, in the greater length of the intestines.

II. The blood of Reptiles is superior to that of Fishes both as regards the nature of the globules and their relative proportion, their size being smaller, and their numbers greater, than among Fishes.

If the whole of the blood in the Reptile is not transmitted through the organ of respiration, whilst in the Fish it is, a larger quantity of this fluid is brought into contact with the air in the same space of time in consequence of the greater extent of surface of the organ in the Reptile, and then the Reptile has the farther immense advantage of a pulmonary or aerial respiration, whilst that of the Fish is branchial or aquatic. To conclude, the nervous system of Reptiles is much more developed in the cerebro-spinal axis, and especially in the encephalic extremity, than in Fishes.

From this comparison it follows that the organic and functional conditions, judging of these in conformity with the principles which we have taken as our guide, are much more favourable to the development of heat in Reptiles than in Fishes. This theoretical deduction is fully confirmed by direct observation, as we have seen above, and this verification becomes a new confirmation of the accuracy of the principle.

We continue to pursue this parallel by a summary comparison of the organization in its relations with the production of heat in the cold-blooded Vertebrata and the Invertebrata generally. A glance suffices to shew the vast inferiority of the Invertebrata in this as in every other respect. In the first place their blood is so little of the same nature as that which has been recognized most favourable to the production of heat, that it wants the characters whether of arterial or of venous blood. The blood of the Invertebrata, with the exception of a very small group (the worms with red blood), is colourless. In the structure and number of its globules it is also greatly inferior. The globules, indeed, may be smaller, but then they are of a much more simple structure, aod consequently lower in the scale, in other words more imperfect. In the relation to the fluid part of the blood too, they are in much smaller proportion than among the Vertebrata. An analogous character is manifest in the tissues generally, the proportion of water in them being incomparably larger in the Invertebrate than in the Vertebrate series of animals. Finally, there is an immeasurable inferiority in the nervous systems of the Invertebrate compared with even the lowest of the Vertebrate series of animals.

From all this it results, agreeably to the principle of which we are now showing the application, that the Invertebrate ought to have a much smaller capacity of producing caloric than even the cold-blooded Vertebrate animals; and this is exactly as we found matters to be by direct experiment in regard to the temperature of the different classes, the results of which have been already stated. The comparison might be carried out in regard to Insects and the Mollusca, which present some appreciable differences. If attention were confined solely to the structure of the greater number of the organs of nutrition, which are much more largely developed in Molluscs, it might be inferred that they had a higher calorific power than Insects; but when we take into the account, 1st, the final result of the nutritive functions, the quality of the tissues, which in the Mollusc are much more loaded with watery fluid, by which they acquire a greater degree of softness and flaccidity, (whence the class has its name,) whilst in the Insect they are, on the contrary, as remarkably dry and firm;—2d, when the most general mode of respiration is compared in the two divisions, it being in the Insect aerial, in the Mollusc aquatic; 3d and lastly, when we glance on the one hand and on the other at the state of the nervous system, and observe how much less perfectly this is developed in most of the Molluscs than in the Insect, it is impossible not to perceive that according to the principles influencing the production of heat, the Mollusca must be inferior in this respect to Insects. This is indeed the result of observations of all kinds, however imperfect or limited these may have been, as we have seen above.

It is impossible to carry the comparison further; the phenomena connected with heat in the lower grades of the animal creation become inappreciable; and this even in virtue of the same principle that has been announced; for the tissues are found to become more and more watery as we descend in the scale, till at length the solid constituent is almost inappreciable. Of course the circulating fluid must be watery in a still greater ratio; it contains but few globules; and then the nervous system falls off in a still greater proportion; it becomes more and more imperfect, till at length no trace of it is to be discovered. We thus arrive at the last links of the chain, after having run over the whole animal kingdom, and we have found one uniform principle of correspondence between organic modification and calorific power. It were difficult to imagine any more satisfactory proof of a principle than has been afforded; indeed as this has on no one occasion been found belied, we are fully authorized to regard it as established.

We have as yet examined but two points in reference to animal heat; 1st, the temperature of man and of the different classes of animals; 2d, the general relations of organization with the production of heat. In mentioning the temperature in any case, we have spoken of it as determinate; and farther, to have data that should be always comparable, the temperatures have been taken regularly in the same places,—viz. the mouth in man, and the other extremity of the intestinal canal in animals. We have still to ascertain whether the temperature varies or is identical in different parts of the body.

Temperature of different parts of the body.—There is no need of the thermometer to tell us that all parts of the body do not at all times preserve the same temperature. We are often certain that the extremities are colder than the trunk for example; and a law of decrease of temperature in the ratio of the distance of parts from the heart had even been deduced from this observation. But when exact measurements came to be taken, this law was soon found to be at fault, as will be seen by-and-by in the course of these observations. Dr. Davy, in taking the temperature of the different parts of the body of a lamb, found that of the right ventricle of the heart 40°, 5 (105° F.), that of the left ventricle 41°, 1 (106° F.). The left ventricle was therefore higher in temperature than the right to the extent of a degree of the scale of Fahrenheit's thermometer. The temperature of the rectum corresponded with that of the right ventricle.

In my inquiries along with M. Gentil into the relations in point of temperature of certain external parts, we found in a strong man, perfectly at rest in mind and body, in the month of July, the external air being at 21°, 25 c. (71° F.), the temperature of the mouth 38°, 75 (102° F.); that of the rectum corresponded. The hands presented the next highest degree, marking nearly 37°, 5 (99°, 5 F.). What is remarkable is that the axillæ and groins, which corresponded with one another, were very sensibly lower in temperature than the hands; they did not raise the thermometer higher than 36°, 96 c. (99° F.). The cheeks marked 35°, 93 (96°, 5 F.), the temperature being ascertained by enveloping the bulb of the thermometer in the skin of these parts. The feet were a little lower, 35° 62 (about 96° F.); their temperature being determined by placing the thermometer between the two, so that the bulb was surrounded on every side. The temperature of the feet was, therefore, notably lower than that of the hands, differing to the extent of 1°, 88 of the centigrade scale (above 3° of Fahrenheit's thermometer). Placed on the skin between the thorax and abdomen the thermometer was at its minimum, not rising higher there than 35° (95° F.); but here a part of the bulb being in contact with the air, there must have been considerable cooling.

As the question here is not of absolute but merely of relative temperatures, we can make great use of the results come to by the different writers quoted. We shall present a summary of these under the following head.

Relations between the temperature of internal parts.—1st. The warmest part of the body, according to John Hunter, is in the abdomen close to the diaphragm. 2d. The next part in point of temperature is the left ventricle of the heart. 3d. The right ventricle of the heart is the next in succession. The rectum and the mouth shut are of the same temperature. The greatest difference consequently between the temperature of these internal parts does not amount to more than 1° centigrade, or at the utmost 2° Fahrenheit.

Supposing the relations in temperature of the internal parts to be pretty constant in the normal state, the temperature of the right ventricle of the heart and of the rectum may be determined by taking the temperature of the closed mouth; that of the left ventricle will be found by adding 0,44 c., or 1° F., to the degree indicated.

Relations in point of temperature between external parts.—We have only data for instituting comparisons in regard to the hand, the axilla, the groin, and the feet among the external parts of the body. In a moderate summer-heat the hand appears to be the part which is most susceptible of showing a high, the feet the parts most susceptible of exhibiting a low temperature. The axilla and groin generally exhibit nearly the same degree of temperature; and the amount in which they differ in this particular from the mouth may be stated at about 1°, 75.

When we direct our inquiries with a view to ascertaining any general relation in the temperatures of different parts of the body, whether external or internal, we soon discover, as has been already stated, that this has no connexion of an inverse kind with their distance from the heart. At the same time there is a general condition discovered influencing the temperature of the different parts. This is their situation in reference to the surface or inside of the body. The temperature is higher, for instance, within the trunk than on its outside. Whatever other reason may be assigned for this, there is one which is purely physical, that must influence it powerfully. It is obvious that the surface of the body and limbs must cool much more rapidly than the interior of the body. So that, supposing the temperature at first to be every where uniform, the difference in the rate of cooling would very soon suffice to cause a notable reduction on the exterior beyond that which took place in the interior of the body. This cause, however, can only be charged with its own share of influence; there are others which must act with considerable effect, and among these especially the one upon which the production of heat depends. We have seen that the condition of the functions of nutrition most closely in relation with animal heat was connected with the arterial blood. Now inasmuch as the arterial blood is that which is most intimately connected with the production of caloric among animals, we might fairly expect that the temperature generally would be rather above that of the venous blood. And we have seen that there was actually a difference between the temperatures of the two ventricles, that of the left being the higher. Experiment has also shown that there was a corresponding difference in the temperatures of the two kinds of blood circulating in the arteries and veins; arterial blood is actually higher in temperature than venous blood to the extent of a degree of Fahrenheit's scale. We shall add here, and in conformity with the same principle, that it is to this difference of temperature of the two kinds of blood that the difference in the temperature of the right and left ventricle of the heart is owing. We need not be hindered in adopting this conclusion from the circumstance of the blood of either ventricle being found in a slight degree inferior in temperature to the ventricle itself, inasmuch as the blood abstracted from the canals that contain it, and exposed to the air, begins to evaporate, and loses heat rapidly. Nevertheless it is not demonstrated that the difference in temperature of the blood out of and of the blood in the ventricles of the heart depends on this cause. There may be another at work; the influence of muscular contraction for instance, a point which we shall examine generally by-and-bye. New means of estimating variations of temperature have been lately discovered, by which changes that entirely escaped us as judged of by the thermometer are made abundantly obvious; by which, indeed, the temperature of parts inaccessible in their natural and normal condition to the thermometer are now investigated without difficulty. In using the thermometer as the means of estimating temperature, it is evident that this instrument could not be introduced into the external parts without injuring the tissues, without incisions, &c., which would necessarily alter them materially, and produce so much disturbance in their functions, that an increase or diminution of temperature must almost necessarily have been the consequence. The thermometer, besides, however small its dimensions, has the inconvenience of always either absorbing or giving out a considerable quantity of heat according to circumstances, before it gets into equilibrium with the parts with which it is brought into contact. A necessary fall or rise in the absolute temperature of these parts is the natural consequence of this. Further, the thermometer is incapable of showing sudden variations in temperature; several minutes must always elapse before it gets into a state of equilibrium in regard to temperature with the parts or medium surrounding it. If a thermometer, for instance, be placed in the mouth, three or four minutes must elapse before it will cease to show any increase of temperature. Now if any calorific phenomena of short duration were developed in that time, it is evident that all idea of their occurrence would escape us.

These considerations led to the adoption of thermo-electrical means by Messrs. Becquerel and Breschet. The processes they employed in procuring indications of temperature were the following. The only means we have of penetrating into the interior of organs without injury is to make use of a needle similar to that employed in acupuncture. Now it is easy to arrange this needle so as to obtain thermo-electric indications, which proclaim immediately and with the greatest precision the temperature of the part or medium with which the point happens to be in contact. It is enough to compose this needle of two others in metal, two of the extremities of which are soldered together in a few points only, whilst the other two are placed in communication with one of the extremities of the wire of an excellent thermo-electric multiplier. The slightest changes of temperature at the points of junction give origin to an electrical current, which, in reacting on the magnetic needle, causes it to deviate by a certain number of degrees, which consequently become indices of the temperature of the point of the needle, and therefore of the medium in which it is placed. The multiplier ought to be so sensitive as to show a deviation of one degree of the magnetic needle for each one-tenth of a degree of temperature as measured by the centigrade scale, an amount of temperature made sensible by the union of the two ends of the wire which forms its circuit with an iron wire soldered by its ends.

So much for the general principle upon which and by which the inquiries of Messrs. Becquerel and Breschet were conducted. As to all the precautions necessary to render researches of the kind fruitful, as these are numerous, we beg to refer for an account of them to the memoir of the authors themselves.

Difference of temperature according to the depth.—By the means contrived by Becquerel and Breschet the temperature of the calf of the leg at the depth of four centimetres from the surface was found to be 36°,75 (about 98° F.), and at one centimetre 34°,50 (about 94° F.), a difference of 2°,25 (4° F.). In the chest the temperature at the depth of the pectoralis major, compared with that of the superficial cellular tissue at the depth of one centimetre, showed a corresponding difference; the deeper parts were 2°,25 (about 4° F.) higher than the more superficial. In seven experiments made on the arm the mean difference of temperature between the deeper strata of the biceps and the superficial cellular tissue over the same muscle amounted to 1°,59 c. in favour of the deeper parts.

The next point of inquiry was to know whether it was enough to penetrate to the depth of three or four centimetres into the trunk and limbs to attain the points of highest temperature in these parts. With this view we have compared the observations made by the authors mentioned, in the same individual, with regard to the temperature of the mouth and of the biceps muscle, and we find that the mean temperature of the mouth was 36°,89, that of the biceps 36°,88, (about 98° F.),—a result which may be called identical with the former. The mean of seven other experiments, however, shows the relation of 36°,89 c. for the mouth, of 36°,75 c. for the biceps; the difference here is evidently in favour of the mouth. It were to be wished that inquiries in this direction were multiplied in order that absolute certainty may yet be attained.

In the preceding experiments, in penetrating to different depths, the nature of the tissues attained also differs, a circumstance which must tend to complicate the results; for it is possible that the nature of the tissue may have some influence on the evolution of heat. This is even an inference which we should deduce from the principles already established, were it merely in consideration of the different quantities of blood they contain. And this conclusion is even confirmed by the experiments of the parties mentioned; for on compressing the humeral artery strongly, the motion of the needle immediately announced a fall of temperature to the extent of several tenths of a degree. This experiment is interesting from the rapidity and precision of the effect. There are other cases well known by which we are led to a corresponding conclusion; but nowhere else is the fact seen in so simple a guise, or in so manifest a relation of cause and effect. In operations for aneurism, indeed, and other cases requiring the ligature of a large artery, the temperature of the parts supplied by the vessel tied falls so low as to require to be supported by artificial warmth; but then a severe and bloody operation has been performed by which the conditions are complicated. In the experiment mentioned, on the contrary, nothing occurs to disturb the state of the economy; the effect instantly follows the cause, and its amount is even at the same moment ascertained.

Seeing, then, that in the same tissue the freer or more interrupted access of arterial blood causes the temperature to vary, it is fair to infer that the relative freedom of access or quantity of this fluid which circulates through other tissues should have an influence upon their temperature; in other words, that tissues differ in their power of producing heat according to the quantity of blood which circulates through them. We can scarcely doubt, therefore, but that the differences of temperature observed between the deeper and more superficial parts are complicated by the mere fact of difference of distance from the surface, and also by the circumstance of difference of tissue. The superficial layer in the preceding experiments was cellular membrane; the deeper layer was muscular. But the muscles receive a much larger quantity of blood than the cellular membrane, and their temperature, from this circumstance alone, ought to be higher.*

* [Messrs. Becquerel and Breschet, in a memoir lately read before the Royal Academy of Sciences, (Ann. des Sciences Nat. Mai 1838,) entitled, "Further Observations on the Temperature of the Tissues of the body of Man and the lower Animals, as ascertained by means of thermo-electric effects," have made a few additional observations which deserve quotation in this place. The temperature of the mouth being used as the standard of comparison, the temperature of the biceps muscle was found to be but 36°, 20 c., instead of 36°, 60, which was the term derived from previous experiments, and to fall short of the temperature of the mouth by as many as 4° c. (above 7° F.)

In making experiments upon the influence of the temperature of surrounding media upon that of the tissues, Messrs. Becquerel and Breschet introduced the needles of their thermo-electrical apparatus into the biceps muscles of two young and healthy individuals, the air at the time marking 16° c. (61°F.). The magnetic needle did not deviate in the least; so that the two muscles possessed precisely the same temperature. One of the arms was now immersed for a quarter of an hour in water of the temperature successively of 10°, 8°, 6°, and 0° c. (50°, 47°, 43°, and 32° F.). The deviation of the needle did not amount to more than two degrees of its scale in favour of the muscle of the arm which was not plunged into the water. The partial cold bath, consequently, bad only caused a depression of temperature to the extent of about one-fifth of a degree c. The arm being now plunged into water

We might even deduce from this a fact of great importance in the animal economy, viz. that muscular contraction is a cause of heat, inasmuch as it determines the afflux of blood towards the muscles themselves as well as towards all the surrounding parts. It is very difficult to conceive an occasion of verifying this position in its simplicity; for bodily efforts, in which the skin becomes red and injected, are always accompanied with some disturbance of the respiration and motion of the blood. We have, however, had an opportunity of seeing one individual of athletic powers, who, by merely throwing the muscles of the fore-arm into strong contraction, could cause the integuments of the forearm to become red. During the act of muscular contraction consequently, the temperature must have a tendency to rise.

at the temperature of 42° c. (108° F.) for fifteen minutes, the temperature of the muscle as compared with that of the other was found to have increased onefifth of a degree. When the whole body was plunged in a hot bath at the temperature of 49° c. (120° F.), the deviation of the needle varied from 12° to 13° and 14° of its scale, which indicated a rise in temperature of from one-fifth to two-fifths of a degree c. The pulse was increased to 112 beats per minute, the body being immersed in this bath. The temperature of the body before immersion was 36°, 70 c. (98° F.), a degree to which it immediately returned after coming out of the bath. In trying experiments of the same kind subsequently, but with baths at a somewhat lower temperature, namely, 42°, 50 (109° F.), no rise of temperature was indicated. The immersion in these cases was not continued for more than twenty minutes. Had it been protracted for a longer time, the result might have been different. When a dog, whose muscles indicated a temperature of 38°, 50 (102° F.), was plunged into a hot bath at 49° c. (120° F.), the temperature rose rapidly by half a degree, a degree, and finally two degrees c.; but the animal had become so much enraged that it was found necessary to take him out of the water. The needle of the apparatus being passed into the chest, a like rise in temperature was indicated; but the rise in temperature was found to happen principally when the animal became angry; and it is doubtful how far the state of exasperation influenced the results.

In one experiment the one needle being passed into the biceps muscle of a young man, the other into the long radial supinator of a man aged forty-five, no sensible deviation of the magnetic indicator ensued. A vein was then opened in one of the arms, as near as possible to the point at which the needle had been introduced, but no change of temperature took place either during or after the flow of the blood. The common iliac artery of a dog was now isolated and a ligature thrown loosely round it, so that it could be compressed or left free at pleasure, and one of the needles of the apparatus plunged into the fleshy part of the thigh. The current of blood having been interrupted, the temperature of the limb began to fall, but not until after the lapse of an interval of twenty minutes, when it still amounted to no more than about half a degree c. The free access of blood having been restored, the temperature soon rose again to the normal point. The effect, though trifling in this case,—and the same experiment was repeated several times always with the same result,—is still sufficient to show that the arterial blood exerts a direct influence upon the temperature of the animal tissues. The effect, however, it is obvious from the time which elapses before it becomes apparent, is to be attributed, not to the blood which is circulating in the trunks and branches of the vessels, but to that which is contained in the vascular rete.—Ed.]

This fact is demonstrated in the most satisfactory manner by the delicate experiments of Messrs. Becquerel and Breschet as follows. When one of the joinings *(soudures)* is kept uniformly at a temperature of 36° c. (97° F.). and the other is inserted into the biceps muscle with the arm extended, the magnetic needle was found to deviate about .10 of a degree. On the arm being bent, however, the amount of deviation was observed to increase suddenly to the extent of from one to two degrees. Waiting till the oscillation of the needle and its return are completed, if the arm be bent anew so as to give a fresh impulse to the needle for several times in succession, a deviation of fifteen degrees is obtained at length, equivalent to a difference of five degrees in comparison with the original deviation, and corresponding to an increase of about half a degree of temperature as measured by the centigrade scale. If the needle be inserted into the biceps, and the arm be used in the action of sawing for about five minutes, the temperature is observed to rise considerably, sometimes to the amount of a degree centigrade.

In these researches, then, we have evidence of facts of which we could not have acquired any precise information by our ordinary means of investigation. Every one, indeed, knows that exercise warms the body; but every one also sees that in producing this effect, besides the contraction of the voluntary muscles, exercise is accompanied by an acceleration in the motions of the heart and organs of respiration. In this simultaneous concurrence of a variety of phenomena, it was impossible to distinguish the share which each had in the general result. Such an analysis could only be made by an experiment of the delicate and ingenious description of that which has been detailed.

It would appear that it is by the repetition of the muscular contraction after each relaxation that the highest evolution of heat is obtained, each contraction producing a slight increase of temperature, which, with the addition of that which follows, mounts to a certain limited point which it cannot pass. Let us remark, however, that the mere persistence of a primary contraction ought to have the effect of causing or maintaining a temperature higher than that which is evolved by a contraction followed immediately by relaxation; indeed it is now known that a permanent muscular contraction is but a series and succession of smaller and imperceptible contractions, following each other with extreme rapidity.

It were well to observe here, that neighbouring parts must increase in temperature at the same time much less in consequence of the direct communication of heat in virtue of contiguity than by the afflux of blood, which, transmitted to the muscles in larger quantity, must also be more copiously than usual distributed to adjacent tissues. The relaxation of the muscles ought, on the other hand, to have a tendency to reduce the temperature, and this by so much the more as the relaxation is more complete. From all this it follows that the attitude and state of the body will be favourable to cooling in the ratio of the general relaxation of the muscles, and of the degree in which each of them in particular is in a state of quiescence. This is what happens in sleep, of which we shall speak by-and-bye.

In the rise of temperature observed along with muscular contraction, we have in the first place only considered the action of the blood; but neither contraction of the muscles nor the afflux of a larger quantity of blood could take place without the nervous influence; for it is the will which determines the muscular contraction, and the will only acts through the medium of the nerves which are distributed to the muscles. From this consideration it follows equally as from general relations previously exposed, that whatever lessens the nervous influence will likewise tend to reduce the temperature. Here we are, then, reverting to the two general conditions which we had already found to be the most influential in calorification, namely, the arterial blood and the nervous system.

This examination of the relative temperatures of the different parts of the body has led us, by the immediate comparison of the superficial and deeper layers, to the consideration of the

Influence of external temperature.—An inert or inanimate body of higher temperature than the surrounding medium will of necessity cool faster at its surface than in its internal parts. A living body, likewise, having within itself a permanent source of heat, which we shall suppose equally distributed through it, will lose more caloric from its surface than from its interior. This loss will become apparent by the cooling of the surface, so long as the source of heat remains everywhere equal. If, on the contrary, it be unequally distributed, if it be greater towards the surface, so as to compensate the greater loss which takes place there, the surface will have the same temperature as the interior. Without such a supposition it were necessary that the surface of the body should be lower in temperature than the interior. This, indeed, is the actual state of the case. The external parts of living bodies are colder than the internal parts, because on the one hand the focus of heat is less, by reason of the nature of the component tissues, and on the other because the loss of heat there is greater. When the external temperature falls, then the outer layers will tend to sink in temperature also, and will, in fact, sink so long as the internal source of heat remains the same. This partial refrigeration will be propagated internally, and the general temperature will be lessened unless the economy provides against such an occurrence by an increase of activity in its calorific powers.

The same reasoning is applicable to movements of the temperature of bodies under the influence of that of the air. Heat will be propagated from without inwards, and will raise the general temperature of the body, unless it lessens in the same proportion as it receives external temperature, that which it produces of itself.

The consideration of the changes in the intensity of the internal focus, in other words, in the faculty of producing heat, and of the conditions which determine these, is the most important point of all in the study of animal heat, on account of the multitude of practical applications which result from it.

It is obvious from what has already been said that there is an essential difference between inert or inanimate and animate bodies subjected to the influence of external temperature. The temperature of the former depends solely on the general laws which regulate the propagation of heat, whilst the temperature of the others is subjected to the influence of another element, namely, the heat which they themselves produce. Did this element continue fixed and invariable, it would be possible to determine, by the application of the known data of physics, what must be the temperature of a living body under the influence of a given external temperature. But if this element varies, and the laws according to which it varies are unknown, it becomes impossible to predict in what manner the temperature of an animal will be affected by that of the medium in which it lives. It is only very lately, therefore, that the temperature of man and warm-blooded animals, with the exception of those that hybernate, has been believed to continue unaffected in the midst of extensive variations in the temperature of the surrounding atmosphere.

Variations in the temperature of animal bodies in a state of health, independently of external temperature.—Duly to appreciate the inquiries that have been instituted in this direction, the first question to be asked is, whether or not the temperature of the body presents variations, although external conditions continue the same, or nearly the same? The answer here must be in the affirmative: the body varies in temperature at different times, external circumstances as to temperature continuing nearly the same. This is apparent in the observations of Dr. John Davy instituted with another view, but quite available here. We perceive that the individual designated No. 1, having a temperature of 37° 8 (100° F.), when the air was at 26°, 4 (79° F.), had a temperature of only 37°, 5 (99°, 75 F.) when the air was at 26°, 7 (80° F.), that is to say, the same person showed a third of a degree c. less of temperature, when the air, instead of becoming colder, had actually become warmer in the same proportion. The temperature of No. 3 was 37°, 2 (99° F.), when the air marked 25°, 5 (78° F.), and on another occasion it was only 36°, 9 (98° F.), when the air was 26° (79° F.); in other words, the temperature of the body, instead of rising, had actually fallen by 0°, 7 cent., when that of the external air had risen 0°, 9 cent.

Influence of the natural temperature of the air on that of the body.—It must be obvious from the facts of the last paragraph that the influence of external temperature cannot be appreciated without having recourse to means of observation calculated to make variations dependent on foreign causes to disappear.

To render the comparison of the mean sums obtained more certain, we shall confine ourselves to the observations of the inquirer just quoted, made upon the same individuals at different temperatures. The following series is after the data supplied by Dr. Davy :—

Temperature of the air.	*Mean temperature of five men.*
15°, 5 (60° F.).....	36°, 85 (98° F.)
25°, 5 (78° F.).......	37°, 16 (99° F.)
26°, 4 (79° F.).......	37°, 32 (99° 5, F.)
26°, 7 (80° F.).......	37°, 58 (100° F.)
27°, 8 (82° F.).......	37°, 70 (100° 5, F.)

It is apparent that these differences, even the extremes, do not surpass the limits of the variations which the same individual exhibits, or may experience spontaneously under the same temperature of the air. But when it is considered that these differences are mean results, forming a series increasing with the rise of the external temperature, it is impossible to doubt of their standing in the relation to one another of cause and effect. If this dependence and connection actually exists, we must allow that it is very little obvious at the temperatures within the limits of which these observations were made; for whilst the temperature of the air varied to the extent of 12°, 3 c., the changes in the mean temperature of the body did not exceed 0°, 9. Such slight differences being apt to leave uncertainty in the mind as to the cause producing them, we shall confirm the impression they are nevertheless calculated to make by citing others, for which we are indebted to Dr. Reynaud, surgeon of the corvette La Chevrette, in a voyage of discovery in the Asiatic seas undertaken in the year 1827. The instruments used were furnished by the best makers of Paris, and were compared by M. Arago with those of the Observatory; and the observations were made conjointly with M. Blosville, lieutenant of the vessel, charged by the Academy of Sciences of Paris with various researches in natural philosophy.

Mean temperature of the body deduced from observations four times repeated upon each of eight men, under the torrid zone, the external temperature varying from 26° to 30° c. (79°, 86° F.)	37°, 58 (100 F.)
Mean temperature of the same eight men observed three times in the temperate zone, the external temperature varying from 12° to 17° (53° to 62° F.)	37°, 11 (99° F.)

These results confirm those of Dr. Davy by so much the more as they were made within the same limits of external temperature. The mean rise of the temperature of the body under the influence of that of the air is also equally confirmed; but the amount is still less than as given by the English observer.

It seems impossible, then, to doubt that the natural variations in the temperature of the air affect that of the body of man; but this is only in a very trifling degree, at least within the limits of temperature in which any extant observations have been made. It is greatly to be regretted that neither of the observers quoted had opportunities of ascertaining the effects of much lower temperatures than those they have given. There are, it is true, many isolated observations made by voyagers in the Arctic regions, both upon animals and man, and although conducted in no regular series, or as points of comparison with one another, they still lead to the same general result, namely, that great differences in the temperature of the air cause slight differences in the temperature of the body of animals. Thus, in the voyage of Captain Parry it was observed that the temperature of the Mammalia was very high. With the external thermometer at — 29°, 4 (— 21°, F.), the temperature of the white hare was + 38°, 3 (101° F.). With the thermometer at — 32°, 8 (27° F.), the temperature of a wolf was + 40°, 5 (105 F.); the temperature of the Arctic fox, under nearly the same circumstances, namely, when the thermometer was standing at — 35° (—31° F.), was as high as + 41° 5 (107° F.). Similar observations have since been made in the same high latitudes upon man.

The variations in the temperature of warm-blooded animals according to that of the seasons has been studied by the present writer, who confirms the results just stated. The experiments of the writer were made upon a great number of sparrows recently taken at different seasons of the year, which is preferable to keeping these creatures in captivity for any length of time. The mean temperature of these birds rose progressively from the depth of winter to the height of summer, within the limits of from two to three degrees centigrade. The observations made on sparrows exhibited the greatest differences. In the month of February the mean temperature of these birds was found to be 40°, 8 (105° F.); in April 42° (108° F.), in July 43°, 77 (111° F.). The temperature from this time began to decline, and followed, in the same ratio in which it had increased, the sinking temperature of the year.

Influence of media upon temperature.—The media in which animals live do not act solely in the ratio of their temperature, but also by virtue of the intensity of their cooling or heating power. Thus air and water at the same degree of heat will have a very different influence on the temperature of the bodies plunged in them. The power of air in heating or cooling is commonly known to be very inferior to that of water. Bodies acquire or lose temperature much more slowly in air than in water. A water-bath according to its temperature communicates sensations of heat or cold far more rapidly and powerfully than an air-bath. The writer and M. Gentil made the following experiment:—A young man seventeen years of age, of strong constitution and in good health, after remaining for twenty minutes in a bath the water of which marked 13° R. (61°, 5 F.), whilst the air was 14°, R. (63° F.), half an hour afterwards was found to have lost half a degree of his original heat in the mouth and hands, and a degree and a half in the feet. This temperature of the air may be regarded as a mean, or intermediate between heat and cold, and may be termed temperate (61° to 62° F.). It was superior to that of the water by a degree R., and yet the water of the bath, after immersion in it for no longer a time than twenty minutes, had reduced the temperature of the body according to its parts from half a degree to a degree and a half R.

Effects of external temperature upon an isolated part of the body.—Under this head let us examine, 1st, the extent of the effect, and 2nd, its influence on other parts. The facts we shall borrow from the researches just quoted, those namely of myself and M. Gentil. The hand, at 29° R. (98° F.) having been kept immersed in a tub of water cooled down to + 4° R. (41°F.), in all during twenty minutes, five minutes after it had been taken out of the water, marked no higher a temperature than 10° R. (55° F.) This experiment shows how rapid and extensive, and how much beyond what could have been anticipated, may be the refrigerating effects of cold water applied to an extremity. Another not less remarkable result is the singular slowness with which the temperature of an extremity is regained, although exposed to the gentle warmth of the air. The hand in the above experiment, after the lapse of twenty-five minutes from the time it was removed from the water, was still no higher than 16¼° R. (69° F.), and after the expiration of an hour and a half it was only 24½° R. (87° F.). The foot, in the same circumstances, gave nearly analogous results.

In a number of experiments of the same nature as the last, where one hand was plunged in water cooled down by ice, the other hand, which was not subjected to the action of the cold bath, lost nearly 5° R. in temperature.

It is therefore apparent, 1st, that partial chills, or the exposure of individual parts to low temperatures, may be and are felt very extensively even when the cold is not very severe; 2nd, that the chilling of a single part, such as the hand or the foot, may cause a loss of temperature in all the other parts of the body, even far beyond what could have been presumed as likely or possible. These facts give a key to the right understanding of the immense influence which partial chills are capable of exercising on the state of the general health

Of the effects of partial heating.—The hand being immersed in water heated to the temperature of 34° R. (109° F.), rose one degree of the same scale, and the temperature of other remote parts not immediately exposed to the influence of heat were found to have risen in a corresponding degree. Whence follows this axiom,—*that we cannot either raise or lower the temperature of any one part of the body without all the other parts of the frame being affected, and suffering a corresponding rise or fall in temperature, more or less according to circumstances.* We may further presume from the comparison of these facts, that the body and its parts are liable to variations of temperature towards either extremity of the scale from the mean, much more considerable than are generally imagined. This latter fact will appear very evidently from the other inquiries which are now to engage our attention.

Effects of an excessively high or excessively low external temperature upon the temperature of the body.—Hitherto we have only considered the changes in the temperature of the body produced by moderate degrees of external heat and cold. We now pass on to the examination of the effects caused by extreme external temperatures, and first of those that follow from excessive heat; designating by excessive heat any temperature that surpasses that of the human body. On a summer's day, the temperature of the air being 37°, 77 c. (100° F.), Franklin observed that the temperature of his own body was nearly 35°, 55 c. (96° F.). This fact, which is perhaps the first of the kind noted, is highly deserving of attention. It proves that man, and by analogy other animals, have a power of keeping their temperature inferior to that of the air. As in the observation quoted there is no means of knowing what effect the excessive external temperature had produced upon the temperature of the observer, recourse must be had to other facts. In numerous experiments made in England by Dr. Fordyce and his friends, and subsequently by Dr. Dobson, in which these experimenters exposed themselves to very high temperatures, which on some occasions exceeded that of boiling water, the heat of the body was never observed to rise more than one, two, three, or four degrees of Fahrenheit's scale at the utmost. As in these experiments the object especially proposed was to determine the degree of external temperature which the body could bear, all the attention which would have been desirable was not given to determine the temperature of the body before, during, and after the experiments. This is an omission which is common to the experiments of Fordyce and Dobson. The highest temperature of the body noted by Dr. Dobson is 102° F., but he does not mention the heat before the experiment, nor does he notice the rate of cooling subsequent to its termination. The highest temperatures of the human body exposed to excessive heats ever observed, were remarked by Messrs. Delaroche and Berger in their own persons. The temperature of M. Delaroche being 56° 56 c. (98° F.) increased 5° of the centigrade scale, by remaining exposed in a chamber the temperature of which was 80° c. (176° F.). M. Berger, whose temperature was the same as that of M. Delaroche, gained 4° c. by remaining for sixteen minutes in the hot chamber at 87° c. (188°, 5 F.). These experiments are liable to this objection,—that the temperature was taken in the mouth in an atmosphere of much higher temperature, which might have some influence in raising the thermometer. To arrive at conclusions against which no kind of objection could be raised, Messrs. Delaroche and Berger exposed themselves in succession in a box, out of which they could pass their head; the hot air or vapour of the interior being prevented from escaping by means of a circular pad of soft napkins placed between the edge of the outlet and the neck. The temperature of the mouth, in this way, if it was increased, must be increased in consequence of a rise of temperature in the parts of the body included in the bath. After a stay of seventeen minutes in the bath, heated from 37°, 5 to 48°, 75 c. (99° to 120° F.), the temperature of M. Delaroche's mouth rose 3°, 12 c. Under similar circumstances, the temperature of the bath being from 40° to 41°, 25 c. (104° to 106° F.), the temperature of M. Berger's mouth increased 1°, 7 c. in the course of fifteen minutes.

It is pretty obvious that experiments upon the human subject cannot be pushed far enough to ascertain the highest amount of temperature that can be acquired under the influence of exposure to air of excessively high temperature. To judge of this analogically, recourse must be had to warm-blooded animals of the two classes, Mammalia and Birds. Messrs. Delaroche and Berger consequently exposed different species of Mammalia and Birds to dry hot air of different temperatures, from 50° to 93°, 75 c. (122° to 201° F.), leaving them immersed till they died. The whole of the animals that were made subjects of experiment, in spite of diversity of class and species, and of the varieties of temperature to which they were exposed, had gained an increase of temperature nearly equal at the moment of their death. The limits of the variations being between the terms 6°, 25 and 7°, 18 c., the amount of difference did not exceed 0°, 93 c. which is a very trifling quantity. It may therefore be inferred that man and the warm-blooded animals cannot, under the influence of exposure to dry air of excessively high temperature, have the heat of their body raised during life to a greater extent than from 7° to 8° c. The temperature of the body being increased to this extent becomes fatal. It is in fact only attained at the moment of dissolution; perhaps death has virtually taken place before it is attained.

We have seen that Franklin observed the temperature of his body to be lower than that of the air on a very hot day. Such a circumstance is rare in what may be called natural conditions as regards man and the warm-blooded animals; inasmuch as it rarely happens that the temperature of the air surpasses that of their bodies generally. The case is different, however, as regards the cold-blooded tribes. It is not at all necessary that the temperature of the air be very high to afford opportunities of observing the phenomenon in question among cold-blooded animals. This was observed for the first time by Sir Charles Blagden in a frog, which on a summer's day, when the heat was by no means excessive, he observed to be lower in temperature than the surrounding air. A fact of this kind could not remain isolated and unconnected with others. Accordingly we observe among the experiments of Dr. Davy such facts as the following:—The temperature of the atmosphere being 32° c. (90° F.), that of a tortoise was only 29°, 4 (85° F.). The air marking 26°, 7 (80° F.), a frog indicated 25° (77° F.). The air being at 28°, 3 (83° F.), the blatta orientalis was at 23°, 9 (75° F.). The air at 26°, 19 c., (79°, 5 F.), a scorpion was at 25°, 3 (78° F.). It is therefore apparent that the phenomenon is general among animals with cold blood; that during the highest heats of summer, the temperature still falling short of excessive, the heat of their bodies is below that of the air. There is thus a limit of summer temperature which separates two orders of phenomena relative to the temperature of cold-blooded animals. Starting from a mean temperature of the air, that of cold-blooded animals, the vertebrate as well as the invertebrate tribes, is superior to this mean, only varying in this respect within the narrow limits of from a few fractional parts of a degree to about four degrees centigrade, until the air attains the summer heat. Towards this limit the differences decrease, and the term 25° or 26° c. (77° to 79° F.) attained, they become *nil*. The inverse phenomenon is also observed: the temperature of the greater number is inferior to that of the air, and the differences go on increasing with the rise in temperature of the external air.

These phenomena are of great interest in themselves, but of still greater from the light they cast on questions of a similar kind relative to man and the warm-blooded tribes of creation. The slight evolution of heat by the cold-blooded animals rendering their condition more simple, allows us to appreciate distinctly the influence of external causes.

We now proceed to treat of a third condition influencing temperature, namely,

Evaporation.—The fluids so far surpass the solids in the bodies of animals that they certainly constitute the larger portion of their masses; and, further, the exterior surface of animal bodies generally is extremely porous. Animals are consequently subjected to the ordinary physical laws of evaporation. It is very long since, in addition to the sweat or visible perspiration, the existence of an invisible perspiration has been recognized. The latter is owing in great part to the effects of evaporation. Now evaporation cannot take place without the occurrence of cooling or loss of temperature in the ratio of the quantity of vapour formed. Without keeping this cause of refrigeration in view, we should fall into serious mistakes in estimating the heat of animals. If, for example, we would compare the heat of two animals, which, unwittingly to the observer, should be under different conditions of evaporation, we should deceive ourselves greatly in regard to their respective temperatures.

It is even so with reference to another fact bearing upon temperature, which is often forced on the attention, and which has almost always led inquirers into error. There are many animals among the inferior classes of the Invertebrata, which tried by the thermometer exhibit no difference in temperature from that of the surrounding air. These creatures do not, consequently, appear to have any faculty of producing heat. But in the mere fact of their maintaining the temperature of the air about them, an inherent capacity to produce heat is apparent. Did they evolve no caloric, they would fall below the temperature of the air, in consequence of the evaporation which goes on from the surface of their bodies. They must of necessity produce as much as is necessary to repair the loss which takes place from this cause.

What we have said of animals is equally applicable to vegetables. To explain the progression of the temperature of cold-blooded animals, which we have exposed above, regard must be had to the relation which connects the quantity of vapour formed with the degree of external temperature. Within moderate limits, which may be styled *temperate*, the vapour formed will be nearly as the degrees of temperature of the air. But under higher temperatures, evaporation will go on in a greater ratio than that of the external temperature. Thus when the air is cool or moderately warm, evaporation is trifling, and among the superior classes of cold-blooded animals heat enough is produced to maintain their temperature above that of the air. But when the air becomes warmer, as in the height of summer, evaporation and the cold which results from it increase in a far greater ratio than the temperature of the body, so that the body remains at a temperature inferior to that of the air, and this by so much the more as the external temperature rises higher. Twenty-five degrees is the limit at which this change commences in regard to cold-blooded animals. But it is obvious that a higher degree must be necessary to observe such phenomena in man and the warm-blooded tribes, inasmuch as the heat from without is for a long time added to that produced internally, and which among the warm-blooded tribes is so much greater in amount than it is among the cold-blooded.

Relations of the bulk of the body with animal heat.—If the temperature of the larger animals be compared with that of the smaller, it will be found that the former do not mark so high a degree as the latter. In the elephant and horse, for instance, no higher a temperature than 37°, 5 c. (100° F.) has been observed, whilst in the rat and squirrel temperatures of 38°, 8, and of 39°, 4 (102° and 103° F.) have been noted. To prove that the difference is less owing to the order or species than to the simple size, we shall contrast several animals belonging to the same order, selecting the ruminants. The temperature of the air being the same, namely, 26° c. (79° F.), the temperature of the ox was found to be 38°, 9 (102° F.), whilst that of a castrated he-goat was 39° 5 (103° F.), and that of the she-goat and sheep 40° (104° F.).*

It is evident that smallness of size must in itself be one of the conditions unfavourable to height of temperature among animals, when this is merely viewed in relation with the ambient medium. As the external temperature is almost always lower than that of the bodies of animals, the ambient medium tends to lower their temperature; and small bodies having a more extensive surface in reference to their mass than large bodies, small animals must have a greater tendency to lose heat than larger animals. But, on the other hand, the circulation and respiratory motions generally increase in rapidity in proportion to the smallness of size; and we have seen that acceleration of these motions had an influence in keeping up the temperature. With a small size of the body, consequently, we find associated a higher activity of function which tends to compensate the disadvantage resulting from inferior size in reference to temperature. In fact it constantly happens that this higher activity more than compensates the cooling disposition from inferiority of size, and causes the balance to incline towards the side of higher temperature. It must be apparent, however, that there is no occasion for such a preponderance always existing in the case of small animals. And then we know that the motions of circulation and of respiration cannot be greatly accelerated without causing inconvenience and even danger to health and life. It follows that the external temperature being liable to fall disproportionately low, small animals have not, under like disadvantageous circumstances, the same power as larger animals of supporting their temperature. The relations of size naturally lead us to consider those that depend on age.

Relations of age with animal heat.—The size of the body changes with the age. The same relations between bulk of body and development of heat ought therefore to be exhibited in youth as compared with adult age. In early life the greater rapidity of the motions of circulation and respiration, all things else being equal, ought to increase the heat. At the same time the constitution differs in other respects, and if these were unfavourable to the evolution of heat, it would be impossible to foresee the result of these two opposite tendencies. Nevertheless it is probable, from what we have seen to happen in warm-blooded animals of different sizes, that there might occur a period in early life when the heat would be higher than in adult age. A confirmation of this inference may be found in comparing the different observations of Dr. Davy, who has given a table of the temperatures of fifteen children from four to fourteen years, the mean age of the whole being nine years and nine months. The mean temperature of the bodies of these children was 38°, 31 (101° F.). But the mean temperature of twenty-one adults was no higher than 37°, 82 (100° F.); a difference that seems the more worthy of being confided in from the temperature of the air having, at the time of the observations, been more favourable for the adults than for the children, this having, in reference to the former, been 26° and 26°, 7 (79° and 80° F.), whilst when the latter were made the subjects of investigation, it was but 24° and 26° (75°, 5 and 79° F.).

It seems impossible, therefore, to doubt from what precedes, that size is not an element which has much influence in the particular

* Vide Observ. of Dr. Davy.

direction we are considering. We have seen that with a decrease in the size of adult Mammalia the circulatory and respiratory motions were progressively accelerated, and that by this means the disadvantages as regards cooling in consequence of a smaller relative size of the body, are in some measure compensated, sometimes, indeed, we have seen the balance inclined the other way, and the greater rapidity of the motions more than compensate for the diminished size of the body. Great rapidity of the respiratory and circulatory motions may co-exist with other organic conditions having an opposite tendency as regards temperature; and, according to the relations of these, and as the one or the other predominates, we may have two different states of temperature in early life. This proposition is even made apparent when we compare the constitution in early youth and in adult age. In early life the celerity of the motions has led to the belief that all the functions of nutrition were peculiarly active. But strength or energy is not always an accompaniment of simple celerity; on the contrary rapidity is generally indicative of absence of power. It is quite true that in early life not only are circulation and respiration, but digestion, assimilation, and growth likewise, much more rapid than in the adult state. But does it follow from this that the materials of the blood are elaborated in the same degree of perfection, or that the products of the action and contact of this fluid, the various tissues, &c. of the body, are all as completely formed? Everything conduces to make us believe that the reverse is the case. If on the one hand rapidity of movement be a character of early life, weakness is a feature still more manifest. If the nervous system therefore, although acting rapidly, is less energetic, in the same proportion there may be an age at which the influence of this weakness on the production of heat may be manifest. And, as the weakness is greater as the being is younger, it is in the very earliest periods of independent existence that this relation must be investigated. Now such a relationship does actually exist, although an opinion to the contrary had always been entertained until direct experiments settled the question definitively. These experiments were performed by the writer, and a summary of them is here given. If the temperature of new-born puppies lying beside their mother be taken, it will be found from one to three degrees inferior to that of the parent. The same thing obtains in regard to the young of the rat, the rabbit, the guinea-pig, &c. and is probably universal among the Mammalia. Among Birds the same circumstance presents itself in a still more marked degree. If they be taken out of the nest in the first week or even fortnight of their existence, the difference of temperature extends to from 2° to 5° c. between the young and the parents. The fact has been ascertained in regard to the sparrow, the swallow, the martin, the sparrow-hawk, the magpie, the thrush, the starling, &c. &c., and is probably, as among Mammalia, universal. Whence we may conclude that the phenomenon is general as regards warm-blooded animals. We might have taken it for granted that man was comprised within the category, but it is just as well to have the assurance that he forms no exception to the law, that he has no peculiar privilege in this respect. To have a precise term of comparison, the temperature of twenty adults was taken at the same time, the thermometer being applied in the axilla. The temperature of these twenty persons varied between 35°, 5 and 37° c. (96° and 99° F.); the mean term was therefore 36°, 12 (97° F.). The temperature of ten infants varying from a few hours to two days in age, ascertained in the same manner, varied between 34° and 35° 5 c. (93°, 5 and 96° F.). The mean was therefore 34°, 75 c. (about 94°, 5 F.). There was consequently a difference of nearly two degrees between the temperature of the adult and of the newly born babes. Man is therefore proved to be subjected to the same law here as animals having warm blood in general, the young of which, so far as they have been examined, and we may presume universally, are inferior in temperature to their parents.

There are, therefore, two periods in youth at which the bodily temperature differs from that of the adult age. These may be distinguished as the first and second periods of infancy or youth. The first extends from birth to an indefinite period, but which is nearer or more remote from the period of birth in different cases. The second is included between the fourth and the fourteenth year; the limits cannot be more accurately determined. In the first the temperature is lower than in adult age, in the second it is higher. The differences of temperature in the first age of infancy, and the adult age, although very sensible and important as regards the economy, are indices of a difference incomparably greater than their numerical indication might be taken to imply. In fact, if the manner of observing be altered, results of so extraordinary a character are come to as to surpass all expectation. To develope these the temperature of the newly born being must not be taken only when it is in contact with its mother. If, after having ascertained the temperature of a puppy in this position, it be removed from the mother and kept isolated, the temperature will be found to fall rapidly; and this phenomenon takes place not only when the air is cold, but when it is mild. The phenomenon does not commence after a term; it is apparent from the moment the separation takes place, and is very sensible after the lapse of a few minutes. The following is the rate of cooling of a puppy twenty-four hours old, the external temperature being 13° c. (about 55°, 5 F.), taken at intervals of ten minutes; the series of course represents the successive losses of temperature in the course of the small intervals of time indicated: —temperature in commencing the observations 36°, 87 c.; the declensions in temperature at intervals of ten minutes successively, 0°, 63, 1°, 12, 1°, 38, 1°, 25, 1°, 29, 0°, 87, 1°, 63, 0°, 25, 1°, 0; in thirty-five minutes the temperature declined farther 1°, 25; in thirty-five minutes more it fell 3°, 12; in thirty minutes more 2°, 50; in twenty-five minutes more 1°, 25; in thirty minutes more 1°, 25; so that in the course of four hours in all the temperature declined by the amount of 18°, 12 of the centigrade scale (about 33° F.)! Not only had the temperature of the animal sunk by so large a quantity in so short a period of time, the external temperature being pleasant, but it actually could maintain its temperature at no higher a grade than 6°, 75 c. (44°, 5, F.) above that of the atmosphere. Experiments of the same kind performed on three other puppies of the same litter presented results in all respects analogous. The cooling may even go much further by protracting the period during which the young animals are kept apart from their parent. For instance, four puppies, twenty-four hours old and of much smaller size than the subjects of the former experiments, after having sunk 16° c. in four hours and thirty minutes, lost six degrees more of temperature in the succeeding eight hours and thirty minutes, the air remaining all the while at 13° c. (55°, 5 F.). They consequently lost twenty-two degrees centigrade in thirteen hours; and, what is very remarkable, their final temperature was but one degree above that of the surrounding air. Kittens and rabbits of the same age exhibited similar phenomena, if possible in a more striking degree. Some kittens were observed to cool twenty degrees centigrade within the short interval of three hours and a half, and some young rabbits suffered the same depression of temperature in two hours and ten minutes, the air being at the time at 14° c. (57°, 5 F.). These phenomena are unquestionably among the most remarkable we witness in warm-blooded animals. For here we have species of different genera of the Carnivora and Rodentia, which at two periods of their existence present the extremes in the production of heat. They may be said to be, to all intents and purposes, cold-blooded animals, with reference to temperature, during the earliest period of life; they are only truly warm-blooded animals in a later stage of their existence. The same phenomena undoubtedly present themselves in many other species; but it would not be reasonable to suppose that they were exhibited by all.

The phenomena being connected with the state of constitution, it may be expected to vary in different genera and families; and this, in fact, is what actually happens. A young guinea-pig, for instance, having a temperature of 38° c. (101°, 5 F.), will maintain this temperature when the atmosphere is mild, although separated from its mother. It is the same with the goat. These instances are enough to give us a key to the external characters in relation with the different capacities to produce heat inherent in the young Mammalia. In the first place we observe a manifest relation with the state of energy of the nervous system: on the one hand we have the puppy, the kitten, the rabbit, which are born extremely weak; on the other we have those animals that come into the world in a condition to walk, to eat, and, as it were, furnished forth to a certain extent with the means of providing for their wants. The question, however, is to discover some zoological character in relation with these differences. If this were to be derived from the state of the organs of locomotion, of the faculty of walking, we should sometimes be led into error; for man, at the period of his birth and long afterwards, is not in a condition to hold himself erect, and yet his temperature is maintained to within one or two degrees of that of his mother, if the external temperature be but mild. There is, however, one character that appears general; this is the state of the eyes. *Those species of Mammalia which in the earlier period of their existence do not maintain their temperature, that of the external atmosphere being mild or warm, but cool down to the standard of the cold-blooded animals, are born with their eyes closed; whilst those which maintain their temperature, that of the external atmosphere being mild, are born with their eyes open*; and this, whether they can walk about like the guinea-pig, the kid, &c., or cannot do so, as is the case with the human infant in particular.

This general view of the state of energy of the nervous system in relation with the production of heat in early life, comes in aid, in a very remarkable manner, of the general principles which have been already deduced in regard to the calorific power. In going more deeply into the subject, the confirmation becomes more manifest and more complete. The state of the eyes affords a mere external and zoological indication. It is but an indication of other deep modifications of the economy, which it is essential to determine more closely. Now in examining the state of the organs generally of puppies at the period of their birth, we observe a remarkable disposition of the sanguiferous system. The ductus arteriosus continues pervious and of large size. The consequence of this structure is that a free communication is established between the arterial and venous blood, by which they are mingled in large proportion one with another. And here we have precisely the physiological character derived from the nature or quality of the blood which distinguishes the cold-blooded from the warm-blooded Vertebrata (in the adult age understood). This character is exactly the same in the other species of Mammalia which we have mentioned as losing temperature and attaining the standard of the cold-blooded tribes. On the other hand, in the guinea-pig, to take an individual instance, which from the first day of its extra-uterine existence maintains its temperature nearly on a level with that of its parent when the air is temperate, the ductus arteriosus is closed immediately after birth. The arterial remaining distinct from the venous blood, this creature is therefore born with the organization characteristic of warm-blooded animals, and presents phenomena having reference to calorification of the same kind as adult warm-blooded animals.

This relation is preserved in the young Mammalia in every modification in a peculiarly interesting manner. The young Mammalia which are born with the eyes closed, at first present the phenomena of refrigeration nearly in the same degree during the two or three first days of their life; though they afterwards exhibit differences of great extent in this respect. Thus a young rabbit two days old had cooled down to 14° from 23° c. (to 58° from 74° F.) in the course of three hours fifty minutes, the air being at the time temperate; another three days old took seven hours twenty-five minutes to cool through a range of 18° c., when the process of refrigeration ceased. A third, of the age of five days only, lost 5° c. in temperature in the course of one hour fifty-five minutes, and maintained itself afterwards at this temperature. During the following days, smaller and smaller depressions of temperature were observed, till the eleventh day after birth, when the power of sustaining the temperature a little below that of the adult female parent seemed to be acquired permanently. When the modifications of internal structure are examined during this interval of time, we find that the ductus arteriosus has been contracting in the same proportion as the faculty of maintaining the temperature has been increasing, and that it is entirely closed at the epoch when the temperature becomes stationary, the external temperature being understood all the while as mild or pleasant. At the same period precisely too, the eyes are unsealed, a circumstance which confirms the exactness of the character derived from the state of this latter organ, as distinctive of the young of those Mammalia which are born as it were cold-blooded animals, from those that come into the world with the distinguishing attribute of warm-blooded animals.

Among the young of Birds we observe as marked differences in the calorific function as we have just acknowledged among Mammalia. Some lose heat rapidly when separated from the mother; others maintain their temperature to within a little of that of their species. Sparrows, for instance, which have been hatched but a short while, present a temperature from 4° to 5° c. lower than that of their parents when still contained in the nest, where they contribute to each other's warmth. But taken out of the nest and isolated, although the temperature be that of summer they begin to cool with extreme rapidity. A young sparrow a few days old lost as many as 12° c. in the short space of one hour seven minutes, the air at the time marking 22° c. (72° F.). The same thing happens with swallows, sparrow-hawks, &c. But the law is not universal; it does not hold in reference to all the genera. There are several that have the power of sustaining their temperature in spring and summer at a degree but little below that of their parents. Birds, therefore, form two groups as regards the production of temperature, just as the Mammalia do. The first cool down to the standard of cold-blooded animals; the second preserve their warmth, when the air is mild or agreeable as it is in the spring and summer. But the zoological characters that distinguish them are not the same as among mammiferous animals. All birds are hatched or born with their eyes open. But there are other characters which coincide with the difference of temperature; and this consists in the absence or presence of feathers. The covering of those that are hatched so provided, consists in a kind of down, very close and very warm, so that we might imagine the differences observed in the liability to lose heat or in the capacity to engender it, belonged to the coat. This has undoubtedly some influence, but analogy even will not suffer us to ascribe the chief effect to this cause. In the Mammalia which are born with their eyes closed, the refrigeration takes place to the same extent whether they are born with a fur-coat, as the kitten, the puppy, &c., or come into the world naked like the rabbit; the cooling is only more rapid in the latter than in the former. What further proves, and directly proves, that the refrigeration is not entirely due to the difference in the external condition as regards covering, although this of course must go for something, is that when the want of natural covering is artificially supplied, the cooling does not go on the less certainly on this account, and to the same ultimate extent; it only takes place somewhat more slowly. The counter-proof is attended with the same result. An adult sparrow which has had all its feathers clipped off does not at first suffer loss of temperature to the extent of more than a degree, and by-and-by recovers even this; whilst a young bird of the same species, though furnished with some feathers, cools rapidly and to a great extent, as we have already seen. *Birds are therefore divided into two groups as regards the production of heat. The one comprises those that are hatched with the skin naked, and which cool in a temperate air in the same manner as cold-blooded animals; the other embraces those that are produced with a downy covering, and maintain their temperature at a considerable elevation in the ordinary heat of spring and summer.*

There is not a less remarkable contrast between these two groups of birds in point of calorific power, than between the two groups of Mammalia already mentioned; but the zoological or external characters which distinguish them in the present instance are not of the same kind. The state of the eyes does not apply here, for all Birds are disclosed with their eyes unsealed. They also all come into the world with the ductus arteriosus closed or nearly so,—a circumstance which might have been predicated, or inferred from analogy. Yet the young of Birds in the power of producing heat present diversities no less remarkable than are observed among the young of the Mammalia. The separation of the two kinds of blood consequently is not the only condition which influences the production of heat; but all that modifies the blood on the one hand, and the nervous system on the other, as we have had occasion to observe in a previous part of this paper. Now it happens that we have an opportunity of applying this principle in a very particular manner in the instance of the two groups of Birds that engage us, and that differ so essentially in their powers of engendering caloric. In the one and in the other we observe the same difference in the state of the general strength which we have observed in the corresponding groups of the Mammalia. In the one which cools rapidly, there is the same state of weakness, of general impotency; in the other the young are in a condition to walk, and in a certain sense to shift for themselves as soon as they have escaped from the shell.

We perceive then in the first place, that the nervous system is much less energetic in the former than in the latter group; and in the second place, that the digestive powers are in an equal degree inferior in strength; for they are not only unable to take food of themselves from muscular incapacity, but also from the lack of the requisite instinct, and, farther, from their digestive organs not being in a condition to elaborate food to any extent. It is on this last account that the parents supply their young with food which has suffered maceration in their own crops, or has even in their stomachs undergone a kind of incipient or partial solution; or otherwise the parents have the instinct to select such articles as are easiest of digestion, and best fitted for the weakly state of the digestive organs of their progeny. We have already observed that a defect in the powers of digestion implies a corresponding imperfection in the blood. Whence we must conclude by analogy that the blood in the birds of the first group is inferior in quality to that of the birds of the second group. We consequently still find the two general conditions which regulate the production of heat throughout the animal kingdom—the state of the blood, the state of the nervous system.

The same principles are applicable to the first period in the existence of all animals, without distinction of groups, as compared with adults. On the one hand we have ascertained that all without exception have a temperature lower than that of their parents; on the other, nothing can be more manifest than their inferiority with reference to the energy of the nervous system. And more attentive and extensive examination shows that this extends in like manner to the digestive functions, and consequently to those of nutrition generally.

Let us first turn our eyes to the Mammalia. All of these are evidently inferior in this respect to the adult. This is proclaimed in the distinguishing character of the class: the females are provided with glands for the purpose of preparing a food appropriate to the state of weakness of their young. The state of the mouth of the young is a sufficient index of the defective power of the digestive organs; the jaws are either wholly or partially without teeth. The softness, delicacy, paleness of colour, and insipidity of the tissues of young Mammalia, complete the evidence of the imperfect elaboration of the nutrient juices. If, therefore, the first and last products of the nutritive functions are in an inferior condition, can we suppose that the intermediate product, the blood, will not participate in this inferiority? We have already shown in what this consists among the Birds of the first group. With regard to the second, the general considerations relative to the difference of the tissues is equally applicable to them, and these considerations possess a high value. When very young warm-blooded animals, without any exception, are compared in this respect to the cold-blooded Vertebrata, we perceive a great analogy in their component tissues, which are softer and less savoury than among the adults of warm-blooded animals. It is thus that we can account for a striking anomaly in the nervous system of young warm-blooded animals, especially Mammalia. Their nervous system, particularly the encephalon, bears a higher proportionate ratio to the whole body than it does in the adult; but the softness and the other characters of the tissue of this organ in early life cause it to approximate in a remarkable manner in appearance and character to the same tissue in the cold-blooded Vertebrata. If, therefore, the relative volume predominate in early life, one of the conditions favourable to calorification, the inferiority in respect of tissue counterbalances this advantage, and is only compatible with very inferior manifestations of energy.

It is obvious then that there is a universally pervading analogy between warm-blooded animals in the first stages of their existence and adult cold-blooded Vertebrata, and that the parallel holds good, not merely with reference to their inferior power of producing heat, but also with regard to the functions of nutrition generally and the functions of the nervous system. There is one point upon which it is highly necessary to insist, inasmuch as it is of the greatest importance, both theoretically and practically; it is this: that the analogy in the direction indicated is by so much the more remarkable as the warm-blooded animal is born with characters which distinguish it more strikingly from those it possesses when arrived at maturity. If it is born with the eyes closed, or without fur or feathers, instead of with the eyes open and the body covered with a fur coat or a thick down, it is because the creature comes into the world less perfectly developed in every respect, and the whole economy is more closely allied to that of inferior orders. This, in other words, is as much as to say that the creature is born at a period relatively precocious, or in a more imperfect condition. Whence it may be inferred that those warm-blooded animals which are born at a period short of the ordinary term of utero-gestation among the more perfect species, will present a more marked analogy with the cold-blooded tribes. Man himself will form no exception to this rule, which must be quite general. The verification of this law has been completed by the physiological experiments of the writer. A child born at the seventh month, perfectly healthy, and which had come into the world with so little difficulty that the accoucheur could not be fetched in time to receive it, had been well clothed near a good fire when the temperature was taken at the axilla. This was found no higher than 32° c. (under 90° F.). Now we have seen that the mean of the temperature of ten children born at the full time was 34°,75 c. (94°,5 F.); the temperature in no case descending lower than 34° (94° F.), and ranging between this and 35°,5 c. (96° F.). Let it be observed that at the seventh month the membrana pupillaris no longer exists; the infant has, therefore, at this epoch of its development, the essential characters of warm-blooded animals capable of supporting a high temperature when that of the surrounding atmosphere is mild. But if it were entering the world some considerable time before the disappearance of the pupillary membrane, it would be in a condition analogous to the Mammalia which are born with their eyes shut; it would no longer be in a condition to maintain an elevated temperature, and without doubt would lose heat precisely as they do without precautions to the contrary.

When we take a general view of the first and second periods in the early life of warm-blooded animals, we find that they are under the influence of two general conditions relative to calorification; conditions which, acting inversely, tend to compensate each other mutually; on the one hand, the celerity of the motions; on the other, the imperfection of the nutrient and nervous functions. The celerity of the motions of circulation and respiration diminishes, whilst the development of the nutritive and nervous functions increases with age. These two conditions influencing the production of heat are, therefore, in an inverse ratio to one another. And according to the nature of these relations will the temperature vary. Were the opposite effects equal, there would be exact compensation in the whole phases of the evolution, from the moment of birth to that of perfect adolescence, and the temperature of the body would be the same at every period of life. But the progression in the celerity of the movements on the one hand and of corporeal development on the other, is unequal; and there is but a single epoch in the whole course of childhood when such an equality or balance exists, and at which consequently the temperature of the child is the same as that of the adult. Previous to this epoch, the nutritive and nervous functions are so imperfectly developed, that their influence, inimical to the production of heat, surpasses the favourable tendency to this end, which we have in the celerity of the motions of circulation and respiration. It follows that the temperature of the body is inferior at the preceding limit or to that of the adult state; with the progress of time, however, the child attains this limit, and then we have a new relation established. The evolution of the nutritive and nervous functions continues, and although it have not yet attained its ultimate term, the defect of heat which results from this is all but compensated by the celerity of the motions, which is still sufficiently great, to surpass in a marked degree the celerity of the motions in the adult. The temperature at this period will, therefore, be above that of the adult. This period lasts for several years in childhood or youth; but then comes a gradual retardation in the motions both of respiration and circulation, and with this a reduction of the temperature to the standard of the adult.

There are consequently four states of the temperature from birth up to adolescence inclusive. In the first period the temperature is at the minimum; in the second, it attains the adult degree; this might be entitled the period of the mean temperature; in the third, the temperature exceeds that of the adult; finally, in the fourth, it sinks to the mean, that is, the temperature of the adult.

There are, therefore, *constitutions* in the same class of animals which are more or less favourable to the production of heat; for it is so among individuals that differ in age in the limits between the moment of birth and that at which adolescence is completed; and this leads us to new considerations.

Differences of constitution in relation with the production of heat among animals.

Since the body and the functions are progressively developed, and without interruption between the two grand periods named, there is in the course of this long interval as much difference in the state of the constitution as there are sensible degrees of development; a circumstance that implies a long series of varieties. But these intimate differences are not manifested externally by corresponding states of temperature of body. For we have seen that this undergoes but four sensible variations in this respect, and that, of these four modifications, two were of like import. It is every way worthy of attention to observe that, at the point which separates the first from the second period of infancy, the temperature should be equal to that of the adult.

It is difficult to imagine that this equality can exist under every variety of external circumstance, when we see that the elements upon which it depends are so different. And this leads us to consider the production of heat under a new point of view. Under what circumstances has this equality of temperature between the infant and the adult been observed? It was when the external temperature was mild or even warm. Would the same thing have been observed had this been cold or severe? It is evident that if the faculty to produce heat is the same at this period of infancy as it is in adult age, the heat of the body will always remain the same, making abstraction of the differences that depend on those of simple corporeal bulk. Thus, all things else being equal, a young animal at this epoch ought to cool to the same degree as an adult under the influence of external cold, if it have the same power of producing heat. If, however, it be inferior in its calorific powers, it will not be competent to maintain its temperature to the same degree as the adult, and it will fall under this limit in a proportion determined by the difference which exists in the faculty of producing heat. On making application of the principles which have been already announced, let us try if we cannot predict the effects. By reason of the inferiority in energy of the nervous system in early life, it is difficult to suppose that a young animal will resist the action of intense cold in the same manner as an adult. This inference is fully borne out by the following experiment. A young guinea-pig a month old, the temperature of whose body was high and steady, the temperature of the external air being mild, was exposed along with an adult to the same degree of diminished temperature—the air was at 0° c. (32° F.). In the course of an hour the young creature had lost 9° c. in temperature, whilst the adult had only lost 2°,5 c. This experiment, repeated several times with the same species of animal, always gave the same result. Young and adult birds of the same species, treated in a similar manner, showed the same diversity in their powers of resisting the effects of external cold, from which we may infer that the law is quite general. Several young magpies, for instance, whose temperature was stationary in a mild spring atmosphere, were placed with an adult in air cooled to + 4° c. After the lapse of twenty minutes, one of the young ones was found to have lost 14° of temperature. The others, examined at intervals, none of which exceeded one hour and ten minutes in length, had cooled from 14° to 16° c. The adult bird, on the contrary, similarly circumstanced, did not suffer a greater depression of temperature than 3° c. The loss of heat sustained by the young birds was so great as to be incompatible with life, if continued; that endured by the old one was trifling in amount, and not inconsistent with health. It is quite true that the difference in point of size and quantity of plumage has an influence upon this inequality of cooling; but at the period of development, when the experiment was tried, the difference was not remarkable in regard to either point; nevertheless it is only proper to take notice of it. By prolonging the period during which the adults were exposed to the cooling process, the advantages they derive from their greater size and closer plumage may be counterbalanced or compensated. It is essential to observe that in the course of the first hour the adult bird had only lost temperature in the proportion of one-fifth of that lost by the young birds, which obviously bears no ratio to the difference in point of size, plumage, &c. And then, the operation of the cold being continued, the adult suffered no further depression of temperature: it fell three degrees centigrade, and then became stationary. We cannot, therefore, ascribe the entire difference in the cooling to that of the physical conditions of size and plumage; a difference of constitution must go for a great deal; there are inherent diversities of constitution, favourable or the reverse, to the production of heat. The truth of this conclusion appears much more clearly if we continue to subject young birds to the same kind of experiment at successive epochs not so close to one another. The rapid progress they make in the power of evolving heat is, indeed, a very remarkable fact. A few days later, and they lose temperature in a much less considerable degree when exposed to cold under the same circumstances, although there was little or no apparent difference in the external appearance of the birds. And this is a new and convincing proof that the inequality in the disposition to lose heat obvious at different periods of life under exposure to a low external temperature, is principally owing to inherent inequality in the faculty of producing caloric.

It is of great importance that a precise idea be formed of this expression. Up to a very recent period in the investigation of animal heat, no one thought of comparing animals save with reference to the temperature of their bodies only: and when it was found that this was the same or different by so much, the account was closed, the comparison was pushed no farther, under the impression that every thing was included under this single ostensible character. Undoubtedly, it must be granted that, all else being alike, equality of temperature is an indication of equality in the capacity to produce heat. But animals in one set of circumstances may actually produce the same quantity of caloric, and not continue to do this the circumstances being changed. It is of consequence to distinguish the actual production, from the power to produce under different conditions. The one is *an act*, the other a *faculty*, a distinction of the highest importance in philosophical language in general, and especially in that of physiology. But animals of the same size, subjected to the same variations of external conditions, if they continue to exhibit corresponding degrees of temperature, whether these are higher or lower, have evidently the same faculty of producing heat. If, on the contrary, they present different degrees under the influence of precisely similar external variations of circumstance, it is obvious that they must possess the faculty of producing heat in different degrees. Unless we be actually persuaded of the value of this expression, so simple in other respects, and so constantly held in view in all analogous circumstances, the study of the phenomena of animal heat would remain as it were barren, whilst the investigation of the diversities of constitution in relation with this faculty is fertile in interesting and useful applications.

We have seen how constitutions differed in this respect according to age in the earlier period of life and in the adult state. It is probable that there are other varieties dependent on other causes; for example, differences of season, climate, &c. This point it will be our next business to examine.

INFLUENCE OF SEASONS IN THE PRODUCTION OF ANIMAL HEAT.

The temperature of an animal is the result, 1st, of the heat which it produces; 2d, of that which it receives; 3d, of that which it loses. The proportion of heat which is lost depends on two principal conditions, the relatively colder temperature of the atmosphere, and the amount of evaporation that takes place from the surface of the animal. In cold and temperate climates these two conditions of cooling are in inverse relations to one another in the opposite seasons of winter and summer. In winter the temperature of the air is lower; in summer the amount of evaporation greater. These two conditions of refrigeration, therefore, tend to compensate one another, and consequently to maintain the equilibrium of temperature as regards the body in the two opposite seasons. They have unquestionably a considerable share in this business; and it was long believed that the simple difference indicated in the external conditions sufficed to preserve the temperature of the body alike during the two periods. But in reflecting on the phenomena presented by cold-blooded animals with the changes of the seasons, which have already been spoken of at length, we find such an opinion or view to be inadmissible. For in examining those species of cold-blooded animals which from their structure are liable to lose more by evaporation than any other animal, we see that no such compensation takes place. Frogs, for example, the skin of which is so soft and permeable, and whose bodies besides are so succulent that they must be presumed in the most favourable circumstances to sustain loss by evaporation, ought to preserve the same temperature in winter and in summer if the low temperature in winter were compensated by the excess of evaporation in proportion as the heat of the season augments. But we know that the temperature of these creatures follows, to a very great extent, that of the atmosphere, between 0° and 25° c. (32° and 77° F.), differing at no time from it by more than a degree or two. The phenomenon here is simple, by reason of the slight evolution of caloric by the frog, and leaves no doubt upon the mind. We must, therefore, have recourse to other conditions, in order to explain the slight difference that is observed in the summer and winter temperature of man and other warm-blooded animals. Since external conditions do not appear to explain the phenomena, it must undoubtedly mainly depend on certain changes effected in the animal itself. Now, since the internal conditions which influence the temperature of the body are those also that regulate the production of heat, it is here that the change must be effected.

It is obvious that the cause of refrigeration in winter being more active, to meet the greater expenditure there must be the means provided for furnishing a larger supply—the calorific faculty must be more active in winter than in summer. The inverse of this takes place in summer; so that the temperature of the body in the two seasons is determined in the following manner:—in winter there is a *more active production* with a *greater loss*; in summer a *less production*, with a *smaller loss* of heat. In this way is there compensation, and a perfect equilibrium maintained at all seasons. To render this relation more evident, it may be expressed in another manner; as, for example, in summer the body receives more heat from without, and produces less; in winter it receives less and produces more.

These considerations carry us farther. As this difference in the production of heat lasts as long as the various seasons, and takes place progressively, it is to be presumed that it belongs to an intimate and more or less enduring change effected in the state of the body. In other words, the constitution alters, and the faculty of producing heat changes in the same degree. The fact thus expressed is immediately susceptible of an interesting application. If the faculty of producing heat is less in summer, the temperature of the body will not be maintained to the same point in the two seasons under sudden exposure to the same degree of cold. By subjecting animals to the test of experiment in the two seasons, it is easy to judge of the justice of the preceding deductions, as well as of the principles which led to them. To have the mode of refrigeration precisely the same, attention must be had not merely to the thermometric temperature of the air, but also to its humidity, which ought to be the same in both instances. A difference in the hygrometric state of the air will certainly produce a difference in the effects of refrigeration. The apparatus employed consisted of earthen vessels plunged amidst a quantity of melting ice. Air thus cooled soon reaches the point of extreme humidity. The air being at zero c. (32° F.), the animal is introduced, placed upon a stage of gauze to prevent its coming in contact with the moist and rapidly conducting surface of the vessel. A cover, also piled over with ice, is then placed over the apparatus, but so arranged as still to permit the ready renovation of the air contained in the interior. Still farther to secure the purity of the included air, a solution of potash, which of course absorbed the carbonic acid produced with avidity, occupied the bottom of the vessel. In winter, in the month of February, the experiment was made at the same time upon five adult sparrows, which were all included in the apparatus. At the end of an hour they were found one with another to have lost no more than 0°, 4 c., or less than half a degree; some of them having suffered no depression of temperature whatsoever, others having lost as much as, but none more than, 1° c. The temperature of the whole then remained stationary to the end of the experiment, which was continued for three hours. In the month of July the same experiment was performed upon four full-grown or adult sparrows. The temperature of these birds at the end of an hour had undergone a depression, the mean term of which was 3°, 62, and the extremes 6°, 5 and 2° c. At the end of the third hour the mean term of the refrigeration suffered was 6°, the extremes being 12° and 3°, 5 c. It ought to have been stated that in the experiment in the winter month, the birds had been for some time kept in a warm room, so that the sudden transition was the same in both instances, in the winter as well as the summer experiment. The diversity in the constitution of these birds, consequently, with reference to the powers of producing heat, was an effect of the difference of the seasons. Each month the temperature of which differs in any degree from that of the month before or after it, has an obvious tendency to modify the temperament or constitution in the manner which has been indicated. In summer we may presume, nay we may be certain, that the differences obtain in degree according to the mean intensity of the heat proper to each. This is even to be proved by direct experiment. The month of August, as commonly happens, was not so hot as the month of July, and six sparrows treated in the same manner as those that were the subject of the July experiment already detailed, were found not to suffer refrigeration to the same extent. After the lapse of an hour the mean temperature of the six had sunk 1°, 62, and after three hours 4°, 87 c., from which it is obvious that with the successive declensions of the external temperature the faculty of engendering heat increases. This is demonstrated by the experiments quoted. The animals that were the subjects employed suffered a relatively less degree of refrigeration in the cooler month than they had done in the hotter, when exposed to the same measure of cold. In the first set of experiments performed in one of the coldest months of the year, the power of resisting cold was made particularly manifest. The sparrows, kept for three hours in an atmosphere at the temperature at which ice melts, scarcely suffered any loss of heat at all. The results of the three series of experiments detailed confirm, in every particular, the conclusions which had been come to analogically and *à priori*. They do more than this. They bear out equally the principles which had been deduced with reference to the constitutions more or less favourable to the production of heat. It is apparent, in the first place, that the influence of the summer and that of the winter act on the constitution in the same manner as the two opposed periods of early youth and adult age. Let us therefore inquire in what manner these different conditions tend to produce analogous effects. We have seen that the constitution of early life differed from that of adult age, especially in the inferior energy of the functions of innervation and nutrition. Now this is that which constitutes or causes the principal difference between the winter and summer constitution of man. We generally feel ourselves weaker in summer than in winter, and our digestive powers are then also decidedly less vigorous. What completes the analogy is that the motions of circulation and respiration are accelerated in summer; and as a complement of the whole of these data, the temperature is somewhat higher in summer; just as we have seen that there is an epoch in youth when the temperature exceeds that which is proper to complete manhood. Thus, the parity between the constitution of youth (in the second period of childhood,) and that of the body in summer, contrasted with the constitution of the adult age and that of the body in winter, exists in the three following relations:—1st, a lessened faculty of producing heat; 2d, greater activity in the motions of circulation and respiration; 3d, a higher temperature of the body.

But this faculty of adaptation to the different seasons inherent in the body is only observed in the better constitutions. That it may be manifested, it is necessary there be present a certain energy of the nervous system; without this even the moderate colds of winter will not be resisted. Without this the adult will have a constitution that will present analogies with that of early infancy. At present we merely mention the kind of constitution; we shall return to the subject by-and-by.

Differences according to the nature of the climate.—The preceding facts render direct experiments to ascertain the influence of the temperature of different climates on the calorific power altogether unnecessary. This is so far fortunate; for it were no easy matter to institute them to the extent and with the precautions necessary to security and satisfaction. The knowledge of these effects is a necessary consequence of the researches that precede. The temperature of warm climates is represented by the summer temperature of temperate climates, with this difference, that it is higher, and that with slight variations it continues through the whole year. Whence it follows that warm climates taken generally must produce effects upon the constitution analogous to those produced by summer with us, only of greater intensity by reason of the higher thermometric range and longer continuance of the heat. The inhabitants of hot climates ought consequently to have an inferior degree of calorific power than those of temperate or cold countries, whatever be the season. And we find, in fact, that the natives of the warmer latitudes of the earth present the characters in general that distinguish the constitution of the body in the summers of temperate countries, and characterizes the second period of youth—more rapid motions of the circulatory and respiratory systems, and a higher temperature, conjoined with an inferior degree of energy in the functions of innervation and nutrition.

We shall not here enter upon the examination of the effects upon the natives of these warmer latitudes from change of climate. We shall speak of this elsewhere. After the periodical changes depending on the seasons we shall pass to others of shorter duration, but which revert much more frequently, and are under the influence of other causes.

INFLUENCE OF SLEEP ON THE PRODUCTION OF HEAT.

In the course of the twenty-four hours the body is in two very different and in some sort opposite states — the states of *sleeping* and *watching*. These two states are principally contrasted in the energy and weakness of the nervous system: from a perfect consciousness of all that is passing, we suddenly observe a complete suspension of this office in the whole circle of the functions of relation. At the same time the motions of the circulatory and respiratory system become slower. No more is needed to lead to the conclusion that in this state the temperature must be lower; this is an inference we draw without risk of error. But the degree in which these motions are retarded is extremely limited; and the depression of temperature must be expected to be in the same proportion: it is in fact very slight, although appreciable. What would happen were the retardation in the important motions mentioned more considerable? The temperature would suffer a corresponding and great depression, and various consequences might be conceived as calculated to ensue. If the degree of cold did no injury to the economy, the sleep would last the time required to repair by rest the energy which the nervous system had dissipated or lost by its activity during the period of watching. If, on the contrary, the refrigeration attained a considerable degree, it would by the consequent pain stimulate the nervous system so much as to cause it to wake up to general consciousness; but in case the nervous system were not in a condition to feel this excitement, in other words to re-act and produce waking, it would sink into the state of lethargy.

These divers states which we deduce as possibilities, as what might be expected to occur in sleep according to the relations of the functions, do in fact present themselves frequently in nature. It commonly enough happens that we are aroused from our sleep by a feeling of cold, although the external temperature has not changed. With regard to the lethargic state, although it certainly occurs but rarely, still it has been acknowledged by the most respectable authorities, and its occasional occurrence seems indubitable. That, however, which is rare as regards man may be common and even usual as animals are concerned.

Phenomena presented by hybernating animals with regard to the production of heat.—If during the height of summer and during the state of watching a dormouse or a bat be examined as to their temperature, this will be found the same as that of many other warm-blooded animals. But if either of these animals be examined whilst asleep at the same season of the year, the temperature will be found to have declined considerably. These changes have been determined by Dr. Marshall Hall, to whom we are indebted for many observations of high interest upon the state of the circulation in hybernating animals. The writer also observed the same diversities in the temperature of these animals according to their state of sleep or watching; but he had not published his observations at the time Dr. Hall's paper appeared. Here, then, we have several species of warm-blooded animals which, during the hottest season of the year, exhibit in the two states of sleep and watching a very marked contrast in regard to the temperature of their body, which is high during the waking period, low during that of sleep, the external temperature having no part in the phenomena. The difference of temperature coincides very evidently with the state of the nervous system—its energy in watching, its enfeeblement in sleep—a state which we have already seen to influence in a very great degree the rapidity of the motions of circulation and respiration, which are accelerated during the energetic condition, retarded during the period of inaction. A higher temperature in the one case and a lower temperature in the other are necessary consequences.

These facts are interesting under two points of view. 1st, They show precisely the kind and extent of the influence which the states of watching and sleep exert in general on the production of heat in animal bodies; 2d, they are remarkable in the particular instances under consideration, in this, that the differences exhibited during the two states are extreme. It must be allowed, therefore, that those animals in which they take place must have less energetic nervous systems than other warm-blooded animals. From this tendency in the animal economy, there must also be in different species a diversity rather than an equality in the degree in which the phenomena are exhibited. And this is confirmed by observation. Some cool to a much greater extent than others during their sleep in the summer season. They may be said severally to have just as much nervous energy as is requisite to sustain a high temperature in the summer season during their state of highest activity, i. e. during the period of watching, and no more. When the state of excitement ceases, and the collapse that follows excitement supervenes, the languor manifested is much greater than that of other animals in the same condition, and their temperature sinks in proportion. The energy possessed by hybernating animals seems barely sufficient to enable them during the summer season to maintain a temperature of body equal to that of warm-blooded animals in general. They subsequently present another phenomenon with regard to their temperature well worthy of particular attention, although it be no more than a consequence of the first. Since it is a defect of energy in the nervous system during sleep which prevents their maintaining the degree of rapidity in the motions of circulation and respiration so essential in their turn to the maintenance of a temperature of the body but little inferior to that pertaining to the state of watching in summer, how are they to preserve their temperature even during the watching state when the summer declines into autumn, and the autumn into winter?

It is evident that if they follow the general rule their respiratory and circulatory motions will be retarded with the fall of the atmospheric temperature, and this by so much the more as their nervous system shows a less degree of energy. It is even presumable that owing to the decline of atmospheric temperature in autumn, they will exhibit a temperature of body during the period of watching analogous to that which they manifest in the heat of the summer season during sleep. And this is precisely what happens. M. de Saissy paid particular attention to the state of these animals at intervals from the month of August onwards. On the 6th of August, the temperature of the air being at 22° c. (72° F.), a dormouse and a marmot marked 36,° 5 (98° F.), and a hedgehog 34° c. (93°, 5 F.) in the axilla. On the 23d September, the external temperature being

18° (64°, 5 F.), the temperature of the hedge-hog was lower by 2° c., that of the marmot by 5°, 25 c., and that of the dormouse by 5°, 5 c. than it had been at the previous date. This is a considerable depression, if it be remembered that the decline in the atmospheric temperature was by no means considerable; that the air was in fact still at a point which made it be felt as *warm* to the generality of persons. The same individual animals examined on the 7th of November, the atmospheric temperature being 7°, presented the following state. The marmot had lost 9°, 25 c., the dormouse 15°, 5 c., and the hedge-hog 21°, 25 c. of their respective temperatures during the month of August, so that their absolute temperatures were now as follows: that of the marmot 27° (81° F.), that of the dormouse 21° (70° F.), and that of the hedge-hog 13°, 75 c. (57° F.). Here, therefore, we have several warm-blooded animals which in autumn approach very closely to the cold-blooded tribes with regard to their calorific power.

If they be next observed during the period of sleep, the relationship will be observed if possible in a more striking degree. If, during the state of watching, they suffer such a loss of temperature as has been specified with the gradual decline of the temperature of the year, they will certainly suffer still more remarkable changes during the state of sleep, in conformity with the principles already fully developed. The sleep of these animals will also become longer and deeper in proportion as the nervous system loses its power, under the influence of the external cold, a loss which will be manifested by a farther retardation in the motions of circulation and respiration. But what is the increasing weakness of the nervous system during sleep but a more or less marked state of torpor? The same degree of cold continuing, or the degree of cold becoming gradually greater, the disproportion as regards the animal will increase also, and will necessarily attain a term at which the torpor during sleep will become *lethargic*. If the external temperature goes on declining, and attains a point at which it becomes dangerous to the life of the creature, the cold, within certain limits, ought to have the power of withdrawing the animal from its state of lethargy. The excitement which appertains to the waking period, by accelerating the motions of circulation and of respiration, will then cause the temperature of the body to rise. But if the external temperature does not become more favourable, or if the animal finds no means of abstracting itself from its influence, it has not sufficient resource within itself and must perish.

We have seen above that the changes in the seasons produced great modifications in the constitution of warm-blooded animals in general. But it were difficult to imagine any greater or more striking than those presented to us by the species which we have just named, which belong to the family of hybernating animals; changes which arise from their passing the winter months in a state of lethargy. When these animals are recalled from this state towards the end of autumn, and during the course of the winter, they may seem to resume the characters which distinguish the vitality of warm-blooded animals in general, but they are in a very different state at this epoch from what they are in summer. Their constitution has undergone important changes, which it is necessary to examine and appreciate exactly. These changes are inversely as those which the most perfectly constituted warm-blooded animals experience. These, under the influence of the increasing cold of autumn and winter, acquire new vigour, and their faculty of producing heat increases in consequence. Those, on the contrary, naturally much less energetic even at the most favourable period of the year, require to be excited and supported by the high temperature of the summer or warmer months, to permit them to exhibit all their activity and strength. It is in the warm season of the year that these animals have the greatest degree of energy—energy which has a certain duration even after the external conditions which have developed it have ceased to operate; for they have been as it were *tempered* by the continuity of favourable circumstances, especially of the high atmospheric temperature. This is the reason why they are so slightly affected by the diurnal variations of the warm season of the year; and even when this begins to wane, and they are no longer stimulated by the temperature proper to summer, they find sufficient energy in the store accumulated, as it were, during the fine season to enable them to resist for a time and to a certain extent the unfavourable influences with which they begin to be surrounded. These continuing, however, and even increasing, they gradually yield to their influence, and sink lethargic, till revived by the return of spring with its milder temperature. Their languor even augments not only with a progressively lower degree of atmospheric temperature, but with the persistence of a degree which in itself is not by any means excessive.

These hybernating animals, whilst they present the structure of the warm-blooded tribes in general, still approach in a very remarkable degree to the cold-blooded tribes in their defective energy, or their indifferent powers of reaction. This is to be regarded as the principal source of the phenomena they exhibit in the current of the year, phenomena which are unknown among the more perfectly constituted warm-blooded animals, but which are absolutely of the same nature as those presented by the cold-blooded Vertebrata in the same circumstances, and which only differ in degree. This analogy or resemblance in the phenomena appears to arise from analogy not of structure but of constitution. Very opposite organizations may have analogous constitutions; cold-blooded animals for example present the greatest diversities of structure, and all are affected and bear themselves in the same manner under similar circumstances in very many respects. They have thus a common constitution which characterizes them, the fundamental principle or distinguishing feature of which is a defect of energy, or of power of reaction. This principle, so simple in itself, and which is but the true expression of the various facts reduced to unity, renders plain and obvious much that otherwise appears anomalous or contradictory. In studying the phenomena of animal heat under new relations, we shall find the confirmation of what precedes.

Of the system upon which the external temperature acts primarily and principally.

Our sensations admonish us that it is the nervous system that is acted upon primarily and principally by changes of external temperature. In the first place the impression is felt instantaneously; in the second place the intensity of the sensation is in relation with the degree of external heat or cold; in the third place the impression is not limited to the various degrees of the corresponding sensation of heat or cold; it extends to the other faculties of the nervous system, increasing or diminishing the general or special sensibility; in the fourth place it acts powerfully in increasing or diminishing the activity of the muscular system, principally through the medium of the nervous system.

Influence of temperature on the vitality of cold-blooded animals.

If the functions of respiration and general circulation be destroyed by the excision of the lungs and heart of a cold-blooded animal, of one of the Batrachia for example, life may still continue for a time. Of the three principal systems of the economy the only one then left untouched is the nervous; so that the animal may be viewed as living almost exclusively by the agency of this system. If several animals in this condition be plunged in water deprived of air, they will live in it different spaces of time according to the degree of its temperature, the extremes compatible with their existence being zero and 40 c. It is towards the inferior limit, zero, that they live the longest. Towards the upper limit they die almost immediately. Temperature, consequently, presents in the scale of variations just mentioned very remarkable relations with the vitality of these animals. Towards the lower limit or that of melting ice, it is obviously most favourable to life; towards the upper limit, it is most inimical to life, extinguishing it almost immediately. Here it is impossible to mistake the system upon which the variety of temperature exerts its first and principal effects—the nervous system.

If respiration only be annihilated by plunging these creatures under water deprived of air, the temperature of which is caused to vary as above, they will be found to present the same phenomena according to the degree of the heat or cold, but in a more striking manner. Temperature in this case has the same kind of influence, but the effects are more manifest, from the circulation of the venous blood prolonging life at every degree short of the one at the upper limit of the scale, at which life is extinguished quite as suddenly as in the former instance.

Such are the direct and instantaneous effects of temperature upon the vitality of cold-blooded animals. But there are others which flow from its *successive* agency, during a considerable length of time. If the series of experiments just quoted be made in summer, and the different lengths of life at different degrees of temperature of the frogs immersed in water be noted, (between the limits which we have pointed out above,) and the same experiments be repeated in autumn, the length or tenacity of life manifested by the animals will be much greater at the same degrees of temperature—they will in general be found to live twice as long now as they did in summer, at corresponding and equal temperatures of the medium in which they are immersed. The depression of atmospheric temperature in the autumn has modified their constitution, and actually increased their vitality, precisely in the manner indicated above. The slight effects of each successive fall in the general temperature have accumulated in the constitution so as to render their vitality or tenacity of life much greater, a fact which is made abundantly manifest by the faculty of the animals to remain for a much longer time immersed in water without breathing than they could have done in summer. If a third series of experiments of the same description be made in winter, the tenacity of life will be found to have increased in a very high degree. At the same degree of temperature frogs will be found to live immersed in water deprived of its air at least twice as long in winter as they could have done in autumn. The same cause—the depression of the atmospheric temperature—has continued to act with greater intensity and for a longer period, and the constitution, gradually modified by greater and longer continued cold, has acquired greater tenacity of life.

The opposite effect takes place with the successive rises of the temperature from that of winter to that of summer; so that among cold-blooded animals the maximum of vitality, i. e. tenacity of life, corresponds to the depth of winter, the minimum to the height of summer. The slight and from moment to moment inappreciable effects produced by the external temperature, whether tending to increase or to diminish the vitality, accumulate with their repetition through the period of each season, and produce a corresponding change in the constitution with regard to tenacity of life. These accumulated effects of the different portions of the year constitute the influence of the seasons on the constitution with respect to many of the most important relations of life. The first of these we have just examined cursorily—that is, the faculty of living in air according to the influence of the actual temperature, or of that of the past temperature, in other words the season that has immediately preceded. The second of these fundamental relations consists in the various proportions of air necessary to the maintenance of life according to their relations with the temperature. We have seen that it is at the minimum of temperature that the cold-blooded animals possess the greatest tenacity of life, as regards the most essential relation, in other words they are in the condition the most favourable to enable them to do without air; at this point they are in a state to live for the longest time without breathing. It is obvious that here they must require less air than under any other circumstances; they must necessarily require so much the less, as their life will continue longer here than under any other circumstances without any access of air at all. It is, however, essential to appreciate duly this fundamental relation, namely, that at the lower limit of the scale of temperature mentioned, cold-blooded animals require less air to live, and what is more, they consume less air than under any other circumstances, and are even incapacitated from consuming more than they do. The minimum temperature of this scale consequently is an index of the maximum of vitality or tenacity of life, and at the same time of the minimum of respiration. In the same proportion as the temperature rises, the vitality or tenacity of life declines, which makes it necessary that this declension should be compensated by a corresponding increase in their relation with the air, in order that the vivifying influence of this fluid may neutralize the deleterious effects of the increase of heat. And this is what actually happens. With the rise in temperature the sphere of activity of the respiration extends, and the vivifying influence of the air, which increases with the quantity of the fluid consumed, compensates the successive decrements in vitality or tenacity of life, dependent on successive increments of temperature. We shall therefore express in a very few words this fundamental relation between the temperature of the air and the maintenance of life among the invertebrate series of animals,—a relation entirely deduced from direct experiment, which we can but refer to here, but which we shall lay before our readers with all the requisite details in our article on RESPIRATION. The rise of temperature in the scale from zero to 40 c. exerts upon the nervous system of cold-blooded animals an action the tendency of which is to diminish its vitality; the air, on the contrary, exerts a vivifying influence on this system. It becomes necessary, therefore, to the maintenance of life that their respective relations with the economy be such that their effects compensate or counterbalance each other.

The principle relative to the influence of temperature on the vitality of cold-blooded animals just laid down, is applicable in every particular to the changes experienced and the phenomena presented by the hybernating tribes among the warm-blooded series of animals. Their vitality changes with the wane of the year, i. e. under the influence of prolonged exposure to cold, in the same manner They are then in a condition to exist with a supply of air by so much the less as this influence has been more intense and more protracted; and precisely as the cold-blooded tribes, if entirely deprived of air in winter, they will live for a much longer time in this deleterious position than they would have done in summer.

Influence of temperature on the vitality of warm-blooded animals and of man in the states of health and disease.

These principles and considerations lead us to examine what happens among warm-blooded animals in the same circumstances. There being great and manifold analogies between them and the preceding tribe of animals, there must also be some community in the application of the principles laid down; but as they also differ in many important respects, this application must be correspondingly restricted. In the first place, then, there is complete analogy between the one and the other with regard to the influence of the superior thermal limit on the vitality of the nervous system. To seize the analogy properly, it is however necessary to regard the temperature which modifies this system in each series, from a point of view that is common to both. Whether the temperature proceeds from without or from within, we may presume that it will influence or modify the nervous system in the same manner, if not to the same degree, inasmuch as this system presents differences. Warm-blooded animals having in general a high temperature at all seasons of the year, they must be compared in this respect with cold-blooded animals in the height of summer. On the one hand, heat within certain limits tends to increase sensibility and motility; warm-blooded animals, therefore, with a few exceptions, which always present a high temperature, constantly exhibit also, with a few exceptions, a high degree of sensibility and motility. The same thing can only be said of the cold-blooded tribes during the continuance of the warm weather. On the other hand, again, high temperature tends to lessen the vitality proper to the nervous system, or the faculty of living without the agency of the ordinary stimuli. This is also the reason why, if respiration be interrupted among warm-blooded animals at all times, and among cold-blooded animals during the warmer seasons of the year, they all perish alike speedily or nearly so. The difference in the time that elapses before life is extinct still depends on, or is in relation with, the difference of temperature. For in the hotter season of the year, cold-blooded animals never attain the temperature of the warm-blooded tribes, even in the most burning climates of the globe. Their nervous system will consequently have a higher degree of vitality in the sense already indicated; that is to say, they will not perish so promptly in summer under deprivation of air; but if they be immersed in water at the mean temperature of warm-blooded animals generally, which is about 40° c. (104° F.), they will die as suddenly—(at least this is the case with those of small size upon which the experiment has been made)—as the warm-blooded Vertebrata when deprived of the contact of air.

The analogy on either hand consists in the effects of temperature. But the differences that must necessarily occur between natures that vary in so many other respects are especially encountered in the dissimilar effects of cold. Here we observe a general compensation which distinguishes in the most marked manner the Vertebrata having a constant or all but a constant temperature, from the hybernating tribes or Vertebrata whose temperature varies, and the cold-blooded series generally. The relation of cold, or of a low temperature relatively to the standard of the more perfect beings of creation, is one of essential importance, and requiring our most careful investigation.

Cold, as has been said, tends to diminish sensibility and motility; but cold itself is perceived by causing a diminution of the general sensibility; among animals of superior organization it even acts indirectly as a stimulus: the blood flows into the parts that had been chilled, if their temperature has not fallen too low, for then all sensibility is extinguished and reaction never occurs. The afflux of blood to the external parts is manifested by the increased redness; and the skin becomes red in proportion as the parts it covers are susceptible of acquiring a high temperature, such as the hand. We have shown that the consequence of the afflux of blood is an increase of temperature which tends to counterbalance the effects of the refrigeration. The compensation, however, is not perfect. For in winter the temperature continues above that of summer, although there is a greater production of heat in winter than there is in summer, as we have shown above.

The constitution of the Vertebrata having a nearly constant temperature differs essentially in the power of reaction it possesses; a power which cannot better be expressed than by the word energy, and which must necessarily be referred to the nervous system. The power of reaction under the influence of cold is exhibited in two modes: the first is that which has just been mentioned, in which the stimulus of the cold calls the blood into the capillaries of the surface, without exciting any kind of violent motions in the circulating and respiratory systems; the second consists essentially in this last kind of excitement. The sharpness of the cold stimulates the respiratory motions, which become accelerated, and the quickening of the motions of the heart follows or accompanies those of the lungs. These two modes of reaction must be viewed as two degrees of the same power: 1st, an afflux of the blood to the capillary vessels; 2d, acceleration of the motions of the thorax and heart. There is, however, between these two processes a difference which it is of the greatest consequence clearly to understand. The first, so long as it remains within certain and suitable limits, is a reaction that maintains the economy in a state of health. The second tends to produce salutary effects, but becoming excessive it brings the body into a state of disease. The first is sufficient to enable those creatures whose system is energetic to resist the effects of rigorous cold, by preserving their general activity and the normal state of their functions. The second is the resource of those animals, which, although of the same species, are so constituted that the energy of the nervous system is less than in the former. This is what occurs universally in very early life. It is a reaction the tendency of which is salutary, but which is not the less on this account the index and essence of a proper pathological state. It is one of the cases in which the *vis medicatrix naturæ* is peculiarly and most strikingly manifested. This position is made singularly evident by the following experiment:—when a young bird, bare, or but scantily covered with feathers, is taken from the nest, and exposed to the open air, even in the summer season, its respiration will be seen to be accelerated in the ratio of the cold it experiences. It is peculiarly worthy of remark that this salutary reaction, taking place under the influence of the nervous system, acting, in the case quoted, independently of the will, is in a great measure the same as that which we bring into play by means of the will to combat the same evil. When in health, for instance, we are exposed to and feel the impression of cold severely, and have no resource but in ourselves, we begin immediately to take exercise, and move about; and if we do this with sufficient vigour, the motions of respiration and circulation are very soon increased in rate, and our heat returns; it being always understood that the external cold is not at too rigorous a degree. From what precedes, we are in a state to appreciate the part which each function has in causing the developement of heat by exercise. The experiments of Messrs. Becquerel and Breschet, referred to in an early part of this paper, have proved that the contraction of the voluntary muscles is accompanied by the evolution of caloric, and that the heat increases by a succession of muscular contractions. The first source of the heat evolved in exercise, therefore, lies in the contractions of the muscles, that is, in the voluntary motions. These, vigorously called into play, are followed by increased rapidity in the action of the muscles of respiration, and of the central muscle of circulation, the heart; and these, by the increased energy they impart to the functions over which they preside, cause an increase in the temperature in conformity with the general principles already laid down. It is well to follow the effects of exercise in the various modifications under the influence of cold. They produce phenomena which extend farther than the state of health, and which appear in other conditions and circumstances from analogous reasons. Exercise, according to its degree and the degree of temperature of the external air, is adequate not only to compensate a chill, and to restore the body to its pristine temperature in every part, but even to do more than this. If the exercise has been sufficiently prolonged, but not been excessive, it may be suspended; and the body, now restored by its means to its temperature, will be apt to retain it longer than it had done when exposed to cold without any preparation of the kind implied; it will resist impressions of cold longer after exercise than it would after a state of perfect quiescence; the nervous system has acquired new energy; the economy is in a condition to react with greater effect than when depending on the process just described, that, namely, which takes place independently of the agency of the will. The repetition of the effects that follow exercise taken at due intervals, hardens the frame to such a degree that the body at length acquires the power, by means of the *insensible and involuntary* reaction alone, to resist degrees of cold which it could not have borne without the violent and voluntarily induced reaction of active muscular exertion.

The different states of the body in the circumstances just referred to deserve special attention, because they are reproduced in others, where the cause not being apparent they seem to be spontaneous, though they are in fact, as we shall have occasion to see, under the influence of an analogous cause. We suppose that on the first exposure to cold during rest, the reaction from the afflux of blood to the capillaries is slight, and that the cold is even sufficiently intense to produce an opposite effect, that is, paleness of the part chilled. To this symptom of the action of cold, shivering is superadded in various degrees of intensity. If recourse be now had to exercise, this state will last for a period long in proportion to its intensity, until violent and prolonged motion have restored the temperature. If the exercise be continued, the heat increases, and even rises above its degree at starting; in this case it first restores the proper heat of the skin, and then causes this tegument to assume a red colour, which may become extremely intense. To this second state succeeds a third, in which the skin, which had hitherto been dry and unperspiring, becomes soft and finally bedewed with moisture. Here, then, we have three different states induced under the influence of cold acting at first without opposition on the part of the system, and then combated by powerful and voluntary reaction. First, we have coldness, paleness, and shivering; secondly, heat and redness; thirdly, moisture of the skin and sweating. In making the application here of what has been said above upon the repetition of these acts, we perceive that at the same degree of external temperature the effects which at first, and under other circumstances, would follow the impression of such a degree of cold, may cease to be felt. This happens from the constitution having improved under the actions and their effects, which have been detailed, and that it is in a state, with the assistance of its own inherent powers of insensible and involuntary reaction, to resist refrigeration. But do we not, when we strengthen the constitution to such a pitch as enables it to resist an influence which was a cause of inconvenience to it previously, cure it of an infirmity? It is obvious from what precedes that the temperature of the body may be indifferently affected, either by a great fall in that of the air, or by an insufficient production of heat. The temperature of the body tends to sink equally when, producing a great deal of heat, it is exposed to severe cold, or when, producing little heat, it is exposed to a moderate warmth. In either case the effects upon the economy will be analogous without being identical. In each case there will be a keen sense of cold according to the depression of the external temperature on the one hand, or the slightness of the evolution of heat on the other. In the latter case the insensible reaction will be extremely limited, as well as the voluntary reaction, on account of the deficient energy. But there are still resources within the economy. It is then that the involuntary and violent reaction of which we have already spoken takes place. The circulation and the respiration increase in rapidity spontaneously. In the case which we have just supposed, there will be certain series of phenomena, analogous to those we have described as occurring in the instance of a strong individual exposed to the influence of severe cold, who suffers from it at first, and subsequently opposes and vanquishes it by means of a violent and voluntarily superinduced reaction. When the faculty of engendering heat sinks to a certain term, there will be not only a vivid sensation of cold even in summer, but all the other consequences of exposure to a low temperature, such as paleness, shivering, &c.; by-and-by the involuntary reaction will not fail to take place; the respiration and circulation are accelerated, and end by restoring the temperature, if the lesion of the calorific power have not been too extensive, the skin being first hot and dry, and subsequently hot and moist. Here, consequently, we have the three periods precisely as in the case previously described: 1st, coldness, pallor, and shivering; 2d, acceleration of respiration and circulation, accompanied in the second period by dry heat, and in the third by sweating. There is therefore the strongest analogy in the two cases. They resemble one another in the character of the phenomena, and the order of their succession. This is so obvious as merely to require mention; there can be no occasion for more particular illustration. They have also the strictest relationship in their causes, without these, however, being identical. In the first case the individual produces a great deal of heat, but he cannot engender enough by the ordinary and insensible reaction, in consequence of which he has recourse to the violent and voluntary reaction, which soon produces the desired effect. In the second, the individual produces little heat, and the economy may suffer from this diminution of the calorific faculty to the extent of finding itself incapable of restoring a sufficient degree of heat by means of a violent and voluntary reaction. The violent and involuntary reaction then succeeds, and produces all the effects of that which is put into play under the empire of the will. Nor is the resemblance limited to immediate results. It further extends to the remote and definitive effect. For in either case the violent effort ceases after a certain interval of variable extent, according to various circumstances; and a state of tranquillity comes on in which the body has recovered the faculty of engendering by the ordinary means the quantity of heat necessary to the comfortable existence of the individual. After this the repetition with greater or less frequency of the same acts ends by restoring the calorific function to the state in which insensible reaction suffices to maintain it in its sufficiency. In the first case it is a strong individual able to make the voluntary and energetic efforts required to remedy the inconvenience he suffers. In the other instance it is an individual who has not the strength requisite to make such efforts. In this case nature supplies the deficiency by exciting directly the motions of circulation and respiration by the painful impression of cold. Although the condition of the first be the state of health, and that of the second properly a morbid state, they nevertheless have many relations in common, which differ principally in degree. Does not the robust individual experience an inconvenience for which he finds a remedy in violent and repeated efforts? However robust he may be under ordinary circumstances, in the extraordinary condition in which he is placed the usual vital processes no longer suffice him. He must have recourse to violent means which disturb the economy; and by a repetition of the same efforts at different periods, that is to say, in fits or paroxysms, he ends by so far fortifying himelf as to be able to do without them. Is not this tantamount to remedying a relative infirmity of constitution? Let its degree increase but a little, and the infirmity becomes disease. This parallel is not founded on vague and superficial resemblances, but on determinate and fundamental relations. There is not one essential point in the comparison which does not rest on the result of direct experiments, most of which have been quoted in preceding parts of this article. What must be done to justify the similitude of these two states? With regard to the state of health the connexion of phenomena having reference to the hygienic and voluntary reaction is well known. With reference to the relation between the symptoms in the morbid state and the morbid reaction, it remains to be proved that under circumstances where there is but slight production of heat, the feeling of cold may induce acceleration in the respiratory and circulatory motions. Now it has been established by experiments already quoted, that there is reaction of this precise kind in such circumstances. We have seen, for instance, that when a bird, naked or scantily covered with feathers, is taken from the nest and exposed to the air even in summer, it speedily begins to shiver, and to exhibit a reaction in accelerated motions of respiration, which is followed by, and indeed implies increased rapidity in the motions of the heart and current of the blood. It were also proper to show that the cold state may, by means of the violent and involuntary reaction, induce the restoration of heat. This is also susceptible of proof by means of direct experiment. To this end an individual (a young bird from the nest) must be chosen of such an age that the temperature will not be apt to fall too low on exposure to the air. If the choice have been fortunate, it will be found that the temperature sinks in the first instance, and then rises, so that it may even surpass the degree it showed at first, under the influence of the reaction occasioned by the acceleration of the motions of respiration and circulation. The proof here is, therefore, extremely satisfactory. A creature in a state of health is taken and placed in circumstances in which the same essential symptoms are produced in the same order as in the morbid state which we have described. It can scarcely be necessary to say that the morbid state which we have described in man is that of simple intermittent fever. Not only in the beginning of this disease is there a feeling of cold, but recent accurate observations have shown, by means of the thermometer, that there is actual refrigeration. There is, therefore, lesion of the calorific function in the sense previously indicated, that is, there is decrease in the power to produce heat. Subsequently the temperature rises whilst there is still more or less of the sensation of cold remaining; but this only happens by virtue of a general disposition of the nervous system. The same thing, in fact, occurs in a state of perfect health; when the body has for some time been exposed to severe cold, the sensation continues for a certain interval after it has been restored to the normal temperature. It is of little consequence, as regards the subject which engages our attention, that there are some intermittent fevers which do not exhibit the phenomena of temperature that have been described. We are only interested in proving that some do occur which present them all,—a fact that has been demonstrated by the best authorities.

There is consequently in these cases a lesion of the calorific function, a lesion of which the essence consists in a diminution of the faculty of producing heat. In a constitution capable of re-acting by the acceleration of the respiration and circulation, we may observe upon this occasion two principal modifications of the morbid state, which both depend on the same cause, but which differ in degree. The first is that described in which the reaction suffices to restore the calorific power to the degree compatible with health after one or more fits or paroxysms. With regard to the second, the diminution of the function of calorification may be so great, that the reaction may prove inadequate to restore it, not only permanently but even momentarily. There are in fact diseases of this kind; there are many regular intermittent fevers that have no tendency to spontaneous cure; there is also one particular form of the disease which proves speedily fatal without the intervention of art. This is that form of intermittent which is known at Rome especially under the name of the *febbre algida*, or cold fever. It often happens that the patient, unless suitably treated, dies in the cold stage of the second or third paroxysm; sometimes he will even perish in the first.

It is easy to produce at will the essential symptoms of these affections even in their most formidable shapes, in animals in a state of health. All the young birds, for example, belonging to the group of those which at their birth have the weaker calorific powers, can be made to exhibit the phenomena in question. If, at the period of their exclusion or shortly after this, they be taken out of the nest, we have seen that they lose heat rapidly even in the summer season; and we perceive that any reaction of which they are capable by the acceleration of their respiratory and circulatory motions avails them nothing; their temperature sinks in spite of this, till all reaction ceases by the increasing and now benumbing influence of the cold, so that they speedily perish. In these two extreme cases of diminished production of heat, there is similarity in the symptoms which ensue, with this difference, that in the *algid intermittent* there is lesion or a morbid state of the calorific faculty; whilst in the other case the scanty production of heat is a normal condition in relation with the age of the subject. In the first, the constitution is seriously altered; it must be restored or otherwise the individual dies; in the second, there is no alteration of any kind; the individual only requires to be placed in circumstances favourable to the normal manifestation of the function to be restored. In the one the lesion is so great that there is no resource in nature abandoned to her own efforts; art must interfere. In the other, nature provides against the scanty production of caloric in giving to parents the instinct to warm their young by the heat of their own bodies, &c.

We have seen that cold, when not of too great intensity, tended to strengthen the body by increasing the faculty of producing heat; and farther, that with the progressive rise of the temperature in spring and summer the energy of this faculty diminished. This is what takes place with regard to those constitutions that are in the most favourable relation with the climate. Let us now examine the nature of those constitutions that do not adapt themselves thoroughly to the changes of the seasons, and see what the consequences are with regard to them. Let us begin with the relation of these to the cold season of the year. It might be presumed *à priori* that those constitutions that have a very limited capacity of engendering heat will not accommodate themselves well to the cold of winter. Their limited powers of producing heat will not enable them to repair the continually increasing loss of it arising from the depression of the external temperature. They consequently suffer in a greater or less degree from cold, perhaps not to any great extent in the first instance, as we shall have occasion to explain by-and-by, but still in some measure; and there are certain degrees of uneasiness and inconvenience that may be regarded as being still within the limits of health. There is even a certain, and that a pretty wide latitude in which the body may vary without trespassing on the line of disease. The uneasiness may only be experienced from time to time, and not even be always very manifestly referable to its proper cause. In other words the sensation may be something quite different from that ordinarily induced by cold; just as it sometimes happens that among weak constitutions the necessity of taking food is not always proclaimed by the feeling of hunger, but occasionally by some other distressing or painful sensation, with regard to the true nature of which experience alone can enlighten us. In such a low state of the calorific power, the faculty seems to lose strength still further, owing to the simple persistence of the same degree of cold, and still more from the ulterior depression of the temperature, in the manner we have seen when speaking of hybernating animals. This diminution in the temperature of the air sometimes occasions among weakly subjects morbid reaction, the principal features of which have already been explained. From all that precedes, the constitutions that will be the most apt to suffer from exposure to cold will be those of the earliest times of life observed in man and the warm-blooded tribes generally, since it is at this epoch that they produce the least heat; and as a corollary from this, we should infer that the mortality in early life ought to be greater during the winter season in this and other countries similarly circumstanced. It became a matter of peculiar interest to verify this inference from the experiments and reasonings of which we have just rendered an account. Messrs. Villermé and Milne Edwards accordingly undertook the necessary inquiries, entering upon extensive statistical researches with reference to the mortality of children in the different seasons of the year in France, and found that the mortality of infants from their birth to the age of three months was generally the greatest in those departments of which the winters were the most severe. For a similar reason, the natives of very warm climates who visit countries whose winters are excessively cold, run great risks of not being able to produce heat enough to compensate the loss they sustain from exposure to the low atmospheric changes, and thus of becoming obnoxious to disease and death in consequence. Those that have elasticity enough of constitution to meet this unwonted demand upon their calorific powers, experience an increase in the energy of the functions upon which the production of heat depends, by which they are brought into harmony with the climate. Others who are less robustly constituted complain loudly of the cold, languish, and finally perish if they do not find means of escaping from the destructive tendency of the cold.

What happens, in as far as these different constitutions are concerned, when the change of season is the opposite of that we have just discussed? when the progress is from the colder to the hotter period of the year? The constitutions that have just been particularly mentioned, it is obvious, will find themselves benefited by the change; they are continually supplied with larger proportions of heat of which they were especially in want. But robust constitutions, in which the calorific faculty is largely developed, will they not be in an opposite position, unless the energy of the faculty in question diminishes in proportion as the external temperature increases? This in fact is what of necessity happens to those in whom the power of accommodation is defective. For when the calorific faculty continues in full force, when the temperature of the surrounding atmosphere is high, there is an excess of heat proceeding from within as well as from without; and if the body does not suffer in the first instance, which it is apt to do, it before long feels the deteriorating influence of this additional excitement, which then superinduces a series of morbid phenomena of various degrees of intensity according to circumstances. All this is observed to occur in the most distinct manner among the natives of cold climates who come to reside in very hot countries. The most robust are even observed to be the most apt to suffer from the change, and the effect is so decided, that few escape some derangement of health, occasioned solely by the influence of the high temperature. When the affection appears in the acute form, after recovery, the new comer is said to be seasoned. The constitution appears to have suffered a favourable change, which consists essentially in a decrease of the faculty to produce heat. In fact it is often only by a process of this kind that the calorific power can be brought into harmony with the new circumstances in which it is placed.

Something of the same kind even takes place in the constitutions of the inhabitants of the countries which have two very different temperatures during the two halves of the year. Here, however, the change of constitution generally passes insensibly or nearly so, the transition being both less in itself, and the natives being accustomed to the difference. Let us just remark that we have here another instance of the *vis medicatrix naturæ*, the tendency of which at all events is salutary, but of which the violence of effect by exceeding the proper limit frequently becomes fatal. We even perceive here that nature has two processes at her command, by which she adapts us to changes of external circumstances; the one is gradual and insensible, the other is sudden and violent.

From repeated observation, and from experiments upon the effects of exposure to high temperatures, it is easy to infer the general character of the disease in its simplest form, which the natives of cold climates will be likely to contract in hot countries. As a high temperature of the air accelerates the breathing and excites the circulation, it may arouse these functions to such a pitch, that the condition becomes truly pathological, and the disease which results is continued fever with excessive heat of surface in those countries where the external conditions are subject to little variety.

There are other phenomena accompanying changes of climate that are referable rather to the state of health than to any morbid condition that bears upon the sensations. It is a general remark that natives of the warmer regions of the earth, of a good natural constitution, when they visit countries within the temperate zone, suffer little from the effects of cold the first winter; on the contrary, they seem to live very much at their ease, except in extreme cases. Let us see if we can explain this fact with the assistance of the principles established above. If the natives of warmer climates come during the summer to temperate countries, they experience a change of no great amount indeed, and which, in the generality of cases, is not obvious. The heat grows less and less intense, declining gradually; freshness or coolness succeeds; then comes moderate, and at last severe cold. Well-constituted individuals, therefore, and they may be assumed as the majority, will experience the general influence of a gradual cooling process; that is to say, their faculty of producing heat will increase, whence will result a feeling of warmth and of comfort. But this faculty has its limits of increase, which in fact lie within narrower bounds than in the case of well-constituted natives of temperate climates. They are consequently apt at length to fall short of the mark, and so to remain, in regard to calorification, under the standard necessary to the economy. Whenever the progression of which we have spoken ceases, which happens in the course of the second winter, these individuals begin to experience the uneasiness which results from its deficiency. It is easy to confirm and render manifest the justice of the above deduction by means of a simple yet curious experiment. If a person having warm hands will keep one plunged for some time in water near the freezing point, it becomes chilled of course, but reaction will be observed soon to take place, and the hand will become red. If it be now taken out of the water and wiped dry, the individual being all the while in a cool atmosphere, at 10° or 12° c., the hand will by-and-by begin to glow, and the feeling in it will be that of a temperature considerably above the heat of the other hand;—judging by the feeling alone the hand seems hotter than the other; tried by the thermometer however, it will be found to be cooler; or if it be applied to the other, it will at once be discovered to be below the temperature of the hand that was not chilled.

Let us follow the effects upon common sensation produced by a change of climate of an opposite kind. When the inhabitants of cold countries visit the hotter regions of the globe, how do they contrive to endure the heat in the first instance? Experience has often shown that when they are of the same race, they endure it at first with even greater ease than the natives themselves, and that they brave with greater hardihood and less suffering the utmost ardour of the sun. This capacity of resistance, however, has its term, and those who possess it gradually lose it, as has been shown in a former passage of this article. The native of the colder clime is more robust, and his nervous system, less impressible, resists painful sensations in a greater degree, and is not overwhelmed by the first effects of noxious influences. This conclusion is also susceptible of demonstration by the way of direct experiment. If during summer a frog be completely immersed in a small quantity of water at the ordinary temperature of this season of the year, and the same experiment be repeated during winter with water heated to the summer pitch, the animal will live much longer in the latter than in the former instance. The nervous system of the animal, by the continued action of the cold of the autumn and winter, has been rendered much more capable of resisting noxious influences, as we have had occasion to see already. It is on the same principle that the Finlander, according to the account of Acerbi, can endure a bath at a much higher temperature than it could be borne by a native of a warm or more temperate climate.

Effects of various other causes of modification in external agents.

The effects of external heat and cold on the sensations and on the system in general are not altogether dependent on degrees of temperature. Even at the same degree atmospheric effects are often very different, being principally influenced by the state of dryness or moisture, and by that of motion or rest, of the air. Speaking generally, media exert modifying influences other than those comprised in their temperature upon the phenomena of animal heat. Evaporation is a powerful cause of cooling, which increases in the same measure as the evaporation. In the summer season, consequently, during a state of the weather in which the temperature is the same, but the hygrometric condition different, the heat of the body will be higher in moist than in dry air. In the same way we observe all the effects of excessive temperature upon the body to be much more intense with a moist than with a dry atmosphere. In the climate of northern France or England it would be impossible to stand a vapour-bath at a temperature between 40° and 50° c. (104° to 122° F.) for more than ten or twelve minutes; but with a perfectly dry state of the air it is possible to bear a temperature twice, or more than twice as high during the same space of time. M. Delaroche found that he could not remain in a vapour-bath raised in the course of eight minutes from 37°,5 to 51°,25 c. (100° to 125° F.) for more than ten minutes and a half, although the bath fell one degree. M. Berger was compelled to make his escape within twelve minutes and a half from a vapour-bath the temperature of which had risen rapidly from 41°,25 to 53°,75 c. (106° to 129° F.). Both of these experimenters felt themselves become weak and unstable on their legs, and were affected with vertigo, thirst, &c. The weakness and thirst continued through the remainder of the day. But in the course of Dr. Dobson's experiments, a young man continued for twenty minutes in a dry-air stove, the temperature of which was 98°,88 c. (210° F.), within a degree or two, consequently, of the ordinary boiling temperature of water. His pulse, which usually beat 75 times in a minute, now beat 164 times. This, however, is by no means the degree of heat that can be and that has been endured. M. Berger for five minutes bore a temperature of 109°,48 c.; and Sir Charles Blagden went still further, having exposed his body during eight minutes to the contact of dry air heated up to the extraordinary pitch of 115°,55 and 127°,7 c. (240° and 260° F.). In assigning 40° or 50° c. (104° or 122° F.) for the limits of moist temperature that can be borne by the inhabitants of these countries, we are perfectly aware that in other latitudes it can be greatly exceeded. Thus Acerbi, in his journey to the North Cape, informs us that the Finnish peasantry remain for half an hour or more in a vapour-bath, the temperature of which finally rises to 70° and even 75° c. (158° and 167° F.). We have already given the reason of this difference of constitution.

Experimental philosophers have not yet tried the precise comparative cooling effects of dry air and of watery vapour; but all are agreed that the powers of the moist atmosphere are by far the most considerable. To measure the comparative effects upon the economy the following experiments were instituted. In equal spaces, the one filled with air at the point of extreme humidity, the other with extremely dry air, were placed young birds of the same age, which were as yet incapable of maintaining their temperature at its proper height when taken out of the nest. It was found that they lost temperature nearly in the same proportion in the same space of time when the air was either at the point of extreme humidity or of great dryness. Therefore moist air tends to cool at least as much as dry air by evaporation. It cools both by the abstraction of heat and by its action on the nervous system. Its action on the nervous system is of a debilitating nature, and therefore tends to diminish the power of generating heat. The *sensation* of cold was evidently greater in the moist air, as was shown by the shivering of the animal. There can be no doubt that the action of vapour in this case is complicated by a physical influence in the one instance, and by a peculiar physiological effect on the nervous system in the other; for it is well ascertained that water, as contrasted with air, has a debilitating effect upon the economy. General experience comes in support of these results; men have ever agreed that moist and cold states of the atmosphere and humid and cold climates were more difficult to be borne than those of an opposite character. Such climes in fact are in themselves extremely insalubrious. By their peculiar effects on the economy they tend greatly to lessen the power of producing heat, and they also engender intermittent fevers, among other morbid conditions. According to the state of the economy and the degree of the external temperature, watery vapour tends to refrigerate still more in winter, and to add to the heat in summer.

The state of the atmosphere in regard to motion or rest modifies to a great extent the effects of a given temperature upon the body. Refrigeration by simple contact increases in amount with the rate of motion of the air. The same law holds good in regard to evaporation, and indeed this process always complicates the results proceeding from simple contact. The cause of refrigeration in this case is consequently double. It is easy, therefore, to imagine how powerful a cause of cooling a cold wind must be. But observation can alone give any adequate idea of the extent of its influence in this respect. Mr. Fisher, one of the surgeons in the expedition under the command of Sir Edward Parry to the Polar Seas, has given us an account of its extraordinary effects. In the frozen regions around the arctic circle, the hardy voyagers under Capt. Sir E. Parry found that they could stand a cold adequate to freeze mercury when the air was perfectly calm, much more easily than a temperature nearly 50° F. higher when it blew. The air in motion in this case, therefore, produced a sensation of cold that was equal to such a depression of temperature as is indicated by a fall of 50° of the scale of F.—a most prodigious difference.

Sudden transitions of temperature also exert a great influence independently of any limits; in the first place, because the intenseness of the sensation of cold or of heat is in proportion to the suddenness of the abstraction, or of the communication of heat; and again, because the faculty of adaptation to different degrees of external temperature is not acquired all at once, but is only attained in a certain lapse of time, and by gradual modifications in the constitution. We therefore see that those countries of which the temperature is very high in the day, but very low in the night, are subject to diseases that seem to belong more peculiarly to cold and moist latitudes, or to marshy lands where *malaria* prevails. But the transition from hot to cold is not limited to the suddenness of the thermal depression; it extends to the refrigeration by the action of the wind. This is another among the many reasons why in the latitudes of England, France, &c. spring is a more dangerous season than autumn. There are, however, certain cases of sudden transition that are useful and salutary, as for instance, when the heat of the body is excessive, and is doing mischief, whether it be induced by an elevated external temperature, or proceeds from the violent and involuntary action of our organs. Then refrigeration even of the most sudden kind, provided it be restrained within proper limits, becomes beneficial. It is thus that the affusion of cold water produces such excellent effects in cases of extreme excitement, and where the temperature is really above the natural standard. This process is even to be regarded as one of the most brilliant triumphs of modern medicine. It is much to be regretted that recourse is not had to it more frequently. It is evident that the proper time for the use of this powerful means is that in which congestion has not yet passed into obstinate engorgement, that is to say, in the beginning of the disease, in which by allaying excitement congestion is diminished. The favourable moment for using the cold affusion is that in which the skin is hot and dry, which is also the period of the highest excitation. The experiments upon the effects of baths, quoted above, tend also to show the propriety of the practice; in citing these, we mentioned that the diminution of temperature produced in the body lasted for hours, and that the reaction consequent upon the use of the bath did not carry the temperature higher than the pitch it possessed at starting. It is obvious that the effects of the cold affusion are to be derived from the principles previously established; since we have referred the production of heat to two general conditions of the economy, one of which is the state of the nervous system. Now the affusion of cold water acts directly upon this system. There is another powerful method of tempering animal heat, which flows from the other general condition, upon which the production of heat depends, viz. the state of the blood. We have seen above that the respective proportions of the serous mass of the blood and of its red globules exert an important influence; that in the class of vertebrate animals which produce smaller quantities of heat, the proportion of the serum was in the inverse ratio of the faculty of calorification. Whence it follows, that in cases of excessive heat of body, to reduce the quantity of red globules would prove an effectual mode of reducing the temperature. Now this is precisely what is done by bloodletting. The effect, however, in this way is not instantaneous. The first influence of bloodletting is simply to lessen the quantity of the blood, and this is the extent to which ideas of the influence of the abstraction of blood are generally confined. There is, however, a consecutive influence, which is at the least as important, and which proves much more lasting. As the person who has been let blood confines himself at the same time to low diet, and principally to liquids, it is obvious that the blood is recruited in its quantity principally by additions of watery particles, without any notable or even sensible addition of globules. The blood is therefore altered essentially in its constitution; the proportion of its component fluid and solid elements is changed, and this in direct proportion to the extent and frequency of the venesections. The consequence of this is a diminution of temperature, unless other causes oppose such an effect.

Bloodletting, it must be observed, is not the sole means of accomplishing such a change in the constitution of the blood. We can produce a similar effect by exciting one or all of the secretions which are thrown off by the body. Secretion is performed at the cost of the blood, which supplies both of its elements

—the solid and the fluid part. The more the secretion eliminated abounds in solid parts or matters formed at the cost of the solid constituents of the blood, the more is the blood impoverished in these elements—the more is its mass of globules diminished. Absorption then begins, as in the preceding case, to make up the quantity of circulating fluid; and if this faculty have only fluids to work upon, it is evident that, as in the case of bloodletting, the blood will become more serous than before. The perspiration and the alvine secretions act in this manner, and nature makes use of these, especially of the former, to temper the burning heat of paroxysms of fever. Art but imitates nature in the treatment of acute diseases; she strives to procure action of the skin, and especially action of the bowels. The use of diaphoretics and purgatives is therefore plainly borne out by the principles which have been laid down. The alvine secretions are those especially that carry off the largest proportion of solid matters from the blood, and which therefore, when excited, prove the most permanently efficient in keeping down the temperature of the body. There is another important reason for preferring the intestinal canal to the skin as the means, in the generality of instances, of reducing temperature in the treatment of disease, which ought not to be lost sight of: this is, that we can excite the intestinal evacuations to a great extent without arousing the circulating system in almost any degree; very different from what occurs when we attempt to unload the vessels by the way of the cutaneous exhalants, in which it is generally impossible to produce abundant diaphoresis without arousing the heart and arteries to unwonted action as a preliminary. Purgative medicines, therefore, next to the direct abstraction of blood, are the most potent means of tempering the heat of the body by modifying the constitution of the blood. Nothing that influences the economy can have an effect in one direction only. It were foreign to our purpose, however, to enter upon any other than that which bears immediately upon our subject.

There is another natural process analogous in its effects, which the preceding considerations place in a new point of view. This is the influence of diet and regimen. Low diet does not act merely in preventing the excitement which always follows the ingestion of solid food; it further alters the constitution of the blood. This fluid, receiving a more scanty supply of solid matters, continues nevertheless to supply the natural secretions as before, and consequently very speedily undergoes by this alone a diminution in the proportion of its globules, in the direct ratio of the duration of the system of spare diet. Low diet is therefore a means which acts in the same way as bloodletting and purging, with this difference however, that it is slower in its operation, and in the first instance less marked in its effects. This, therefore, is the slowest and least efficacious of the immediate means of reducing temperature when employed alone, although its conjunction is indispensable to the success of any of the others.

Of all these means, one only is the proper effect of art, namely, the application of cold; the others are processes of the same *natura medicatrix*, and processes which we merely imitate. These act directly in modifying the constitution of the blood, and thus definitively influence the nervous system. The other exerts its influence directly on the nervous system, in calming the excitement or violent action which it has engendered in the sanguiferous system, and those that depend on it.

The application of heat becomes necessary in morbid states the reverse of those that have just been discussed. The proper employment of this means depends especially on two general principles bearing upon animal heat, which we have considered above. 1st, The one is, that the economy has the capacity of bearing heat in the same proportion as the function of respiration is extended. In those cases in which this function is limited, or, what comes to the same thing, where any part that requires an accession of heat is indifferently supplied with arterial blood, it is necessary to be extremely cautious in its application. 2nd, The other, that the effects of external heat are not confined to the simple interval during which it is applied, but remain after it has been removed, and even increase the faculty of producing heat. The application of warmth is therefore not merely palliative or supplementary of lost heat; it has further a directly remedial influence, which may even be excited in excess. When the lesion of the calorific faculty has been great, without much or any organic lesion, other means of greater force than those usually resorted to by art, or employed by nature in such circumstances, must be called in to assist. Art has happily discovered what seems the most effectual means of winding up the nervous system, and enabling the calorific faculty to be re-established in its normal condition. This means is quinia, the first of tonics. This powerful medicine is consequently never administered in acute diseases until all violence of action has ceased, and the functions have resumed their habitual rythm. We find that the action of this medicine is exerted directly upon the nervous system from this, that it seems to have no effect on the secretions, or when it does influence these, we are convinced by the trifling amount of the effect, that it is not through them that the cure is accomplished. As it acts during the intermission, by restoring the normal production of heat, we have no reason to expect the phenomena which characterize the fit—the shivering, &c.; and then the violent reaction which we have in the hot stage becomes useless, and in fact is no longer observed.

Confirmation of the general results.

We have thus passed in review the principal phenomena of animal heat, reducing or approximating these at all times to the most simple conditions. These conditions themselves are, in the first place, assumed from comparisons of the organization of the two grand groups or series into which the animal kingdom is divided with reference to heat—the cold-blooded animals, and the warm-blooded animals. In this review we have avoided all hypothesis, confining ourselves to the severe method of deduction, always starting from well-authenticated facts, and even confirming each step in advance by new data equally indisputable. The harmony which reigns in this comprehensive whole, which embraces the different classes of animals and man, not only in the various modifications of health, but even of disease, in their relation to external agents, and the therapeutic processes of nature and of art, afford the surest confirmation of the reality of these relations. As the phenomena of animal heat are referable to two general conditions of the economy,—the state of the blood and that of the nervous system; and as we have only in the first instance deduced these from the comparison of natural facts, although we have confirmed them by new observations and particular experiments, one may be desirous of seeing them confirmed by experiments of a more general bearing. To the reasonableness of this wish we yield assent the more willingly, as the results we have to quote are deductions from some of the most admirable researches that have been instituted by physiologists;—I allude to the enquiries of Legallois, Sir Benjamin Brodie, and Dr. Chossat.

The first of these experimenters, by the employment of various means for impeding respiration, or limiting the consumption of air, found that *the refrigeration of animals is in the compound ratio of the difficulty experienced in breathing and of the quantity of oxygen consumed; so that when, in two experiments, the difficulty of breathing is the same, the greatest extent of cooling occurs in that in which the smallest quantity of oxygen is vitiated, and the contrary.* Now, the end of the process of respiration being to change the venous into arterial blood, this conclusion of Legallois confirms directly the one of the two principal conditions—THE STATE OF THE BLOOD, which we have laid down as influencing the production of heat among animals, and to the knowledge of which we had attained by induction.

The results of the direct experiments which we have still to quote also come powerfully in aid of our inferences concerning the other principal condition, which we have assumed from induction, influencing the production of animal heat: this is THE STATE OR ACTION OF THE NERVOUS SYSTEM.

Sir B. Brodie demonstrated by a series of the most ingeniously conceived and happily executed experiments, that when animals were decapitated and respiration was kept up by artificial means, so that the blood circulated as usual, and the process of change from the venous to the arterial state went on uninterruptedly, the ordinary quantity of carbonic acid being eliminated, all the while, that, nevertheless, the temperature fell rapidly, even more rapidly than when no artificial respiration was maintained.

Dr. Chossat completed these researches upon the nervous system in its relations with the production of heat, by demonstrating in a series of experiments the following very important fact, viz. *that the depression of animal heat is constantly in relation with lesions of the nervous system, whether these lesions implicate the cerebro-spinal system, or the system of the great sympathetic.*

We necessarily confine ourselves, in alluding to these admirable researches, to the most general results, and the conclusions flowing most immediately from the experiments instituted. We reserve a more particular mention of them for the proper place, namely, the article on RESPIRATION, to which we beg to refer. With regard to the opinions of writers generally, we shall be content to observe here, that they have for the most part regarded the single physiological condition which was the subject of their particular study as the only source of animal heat. The general result of their united labours, however, is, that there are two principal sources, the one depending on the arterial blood, the other on the energy of the nervous system,—a conclusion to which we have come by another way, by combining all the known facts that bear upon animal heat, and embracing the manifestations presented by the whole of the animal kingdom as well as the isolated phenomena exhibited by man, and this not in one but in every condition of existence, not only in the state of health but of disease likewise, not as beings independent of all things around them, but as living in intimate relationship with external agents.

OF THE PHYSICAL CAUSE OF ANIMAL HEAT.

With regard to the physical cause of animal heat, or to *its mode of production*, there was a time, which we have not yet left very far behind us, when natural philosophers and chemists imagined they possessed the secret, especially with reference to the mineral kingdom. They have now discovered their mistake; and as the evolution of heat is a mystery to them, it is not to be expected that it is less so to physiologists, as manifested in the domain which they cultivate in peculiar. The problem, in fact, becomes immensely complicated by a variety of phenomena when from the inorganic we ascend to the organic world. All that could be done has been accomplished; from the particular conditions of organization and of function upon which this effect seemed to depend, physiologists have risen to those that were the most general and comprehensive. This, in fact, was the end we proposed in commencing this article. That nothing may be omitted which can make the sketch more complete, and none of the great inquiries which have had animal heat for their object may be passed over in silence, we shall briefly cite the more important of those in which the mode of production of animal heat is discussed, always reserving to ourselves the opportunity of treating several of these more fully in our article on Respiration.

Lavoisier, from his labours on combustion, which laid the foundation of the chemical doctrines of the age that has just elapsed, conceived the ingenious idea of explaining the phenomena of animal heat by the combustion of the carbon and hydrogen of the blood by the oxygen of the air in the process of respiration, and the experiments which he instituted upon this point along with the illustrious La Place appeared to confirm his idea. Still it was found impossible to give an account of the production of the whole heat engendered by animals. All that Lavoisier and La Place inferred was, that the heat evolved by an animal was *almost entirely* produced by the combustion which occurs in respiration. As the calorific power was measured in one animal, and the consumption of oxygen in another, it is evident that the inference, vitiated in its elements, became much less precise than it would otherwise have been.

This consideration as well as others induced M. Dulong, who is as well versed in mechanical philosophy as in chemistry, to take up this subject again. After numerous experiments, conducted with every precaution that could secure accuracy of result, he found that the heat disengaged by the fixation of the oxygen in the act of respiration was not equal to the whole of that which was produced by an animal. This inquiry (which however stood in no need of confirmation) has been confirmed by the analogous inquiries of M. Despretz, who arrived at the same numerical results. The hypothesis in question, therefore, gives no solution of the problem.

Bibliography.—*Martine*, Essay on the generation of Animal Heat, in Essays Med. and Philos. Lond. 1740. *Haller*, De generat. caloris, &c. Goett. 1741. *Stevenson*, Essay on the cause of Animal Heat, &c. Med. Essays and Obs. vol. 5. *Mortimer*, Letter concerning the Nat. Heat of Animals, Phil. Trans. 1745. *Braun*, De calore animalium, Nov. Comm. Petrop. t. 13. *Duncan*, Hypotheses of the cause of Animal Heat, Med. and Phil. Com. vol. 6. Experts. &c. Min. of Society for Philos. Experts. p. 157. *Martin (A.R.)*, Various Papers on Animal Heat in the Svenska Vetensk. Akad. Handlingar for the years 1764 and 1766. *Hunter*, Experts. on the power of producing Heat, and on the Heat of Vegetables and Animals, Phil. Trans. 1775-1778, and in Animal Economy. *Crawford (D.J.M.)*, De Calore Animali, Edinb. Exprts. and Obs. on Animal Heat, Phil. Trans. 1786, separately, 2d ed. 1788. *Leslie*, Philos. Inquiry into Animal Heat, Lond. 1778. *Rigby*, Essay on the Theory of the Prod. of Animal Heat, Lond. 1785. *Delaroche et Berger*, Memoire, &c. in Journ. de Physique, t. 71. *Brodie*, in Croonian Lecture, Phil. Trans. 1811. *Davy*, An Acc. of some Experts. on Animal Heat, Phil. Trans. 1814. *Legallois*, Mém. sur la chaleur animale, Ann. de Chimie, t. iv. *Earle*, Influence of the nervous system in regulating Heat, Med. Chir. Trans. vol. vii. *Chossat*, Influence du Systéme Nerveux sur la Chaleur Animale, Thèse, Paris, 1820. *Dulong*, De la Chaleur Animale, Journ. de Physiol. t. 3. *Despretz (Rich.)*, Exper. sur la Chaleur Anim. Ann. de Chimie, t. 26. *Home*, Influence of the Nerves in producing Animal Heat, Phil. Trans. v. 115. *Collard de Martigny*, De l'Influence de la Circulation, &c. sur la Chaleur du Sang, Journ. Complem. t. xliii. Vide also Journ. Complem. t. xxvi. The general works on Physiology, particularly those of Rudolphi and Tiedemann. *Czermack*, On the Temperature of Reptiles, in Zeitschr. für Physik, &c. Bd. 3. *Berthold*, Neue versuche uber die Temperature, &c. Gotting. 1835. Transl. in Ann. d'Anatomie, &c. Mai 1838. *Newport*, Temp. of Insects, Phil. Trans. 1837. *Becquerel & Breschet*, Mém. sur la Chaleur Animale, in Ann. des Sciences, Nat. Seconde Série, t. 3, 4, & 9.

(W. F. Edwards.)

HERMAPHRODITISM, or Hermaphrodism;* *Hermaphrodisia; androgynisme, gynandrisme; hermaphroditisme*, &c., of the French; *ermaphrodismo* of the Italians; *Zwitterbildung* of the Germans, &c.

Many different definitions of hermaphroditism, and almost an equal number of different classifications of the malformations usually comprehended under it, have been proposed by the various authors, ancient and modern, who have directed their attention to this subject. Without stopping to discuss the merits or errors of these definitions and classifications, and without inquiring, as some have done, into the propriety of the word itself, we shall content ourselves with stating that under it, as a convenient generic term, we purpose in the present article to include an account—1st, of some varieties of malformation in which the genital organs and general sexual configuration of one sex approach, from imperfect or abnormal developement, to those of the opposite; and 2d, of other varieties of malformation, in which there actually coexist upon the body of the same individual more or fewer of the genital organs and distinctive sexual characters both of the male and female.

To separate from one another, by as strong a line as possible, the two distinct varieties of hermaphroditic malformation marked out in this definition, we shall divide hermaphroditic malformations, considered as a class, into the two orders of *Spurious* and *True*; the spurious comprehending such malformations of the genital organs of one sex as make these organs approximate in appearance and form to those of the opposite sexual type; and the order, again, of true hermaphroditism including under it all cases in which there is an actual mixture or blending together, upon the same individual, of more or fewer of both the male and female organs.

Spurious hermaphroditism may occur either in the male or female; that is, there may, from malformation of the external sexual organ, be an appearance of hermaphroditism in persons actually of the female sex, or from a similar cause there may be an appearance of hermaphroditism in persons actually of the male sex. The differences derived from the diversity of sex in which spurious hermaphroditism occurs, and the particular varieties of malformation in each sex which may give rise to it, will serve as

* From the well-known mythological fable of the union into one, of the bodies of Hermaphroditos (the son of Ερμης, *Mercury*, and Αφροδιτη, *Venus*,) and the nymph Salmacis. See Ovid's Metamorphoses, lib. iv. fab. 8.

bases on which we shall found some further subdivisions of this order.

True hermaphroditism, as above defined, comprehends also, as shall be afterwards more particularly shewn, several very distinct varieties of malformation. If we conceive for a moment all the reproductive organs to be placed on a vertical plane, (as we may suppose them to be, though not with strict correctness, in the human body when in the erect posture,) we shall find that the principal of these varieties may be all referred to three sets of cases:—1st, those in which, if we drew a vertical median line through this supposed plane, the two lateral halves will be seen to present organs differing in this respect, that they belong to opposite sexual types; 2d, others in which, if we bisect the same plane by a transverse horizontal line, there exist organs of a different sex in the upper from what are present in the lower segment; or, in other words, the internal genital organs belong to one sex, and the external to another. In the two preceding classes of cases there is not necessarily, as we shall afterwards more fully point out, any malformation by *duplicity* in the sexual apparatus of the malformed individual; there is only one set of sexual organs present, but in some parts these organs are formed upon the male, and in others upon the female type. In the 3d and remaining set of cases, however, there is really present to a greater or less, though most generally only to a very partial extent, a double set of sexual organs, having opposite sexual characters, so that upon the same body, and usually upon the same side, or upon the same vertical line in our supposed plane, we find coexisting two or more of the analogous organs of the two sexes. In accordance with this view, we shall consider the cases of true hermaphroditic malformation under the three corresponding divisions of, 1st, *lateral;* 2d, *transverse;* and 3d, *vertical*, or, more properly, *double* or *complex hermaphroditism;* and each of these genera will admit of some further convenient subdivisions. But the mode in which we propose to classify and consider the subject will probably be at once more accurately gathered from the following table, than from any more lengthened remarks upon it in the present place.

Classification of hermaphroditic malformations.

- Hermaphroditism
  - Spurious
    - In the Female
      - From excessive development of the clitoris, &c.
      - From prolapsus of the uterus.
    - In the Male..
      - From extroversion of the urinary bladder.
      - From adhesion of the penis to the scrotum.
      - From hypospadic fissure of the urethra, &c.
  - True ..
    - Lateral......
      - Testis on the right, and ovary on the left side.
      - Testis on the left, and ovary on the right side.
    - Transverse ..
      - External sexual organs female, internal male.
      - External sexual organs male, internal female.
    - Vertical or Double ..
      - Ovaries and an imperfect uterus with male vesiculæ seminales, and rudiments of vasa deferentia.
      - Testicles, vasa deferentia, and vesiculæ seminales, with an imperfect female uterus and its appendages.
      - Ovaries and testicles coexisting on one or both sides, &c.

In commenting upon and illustrating the different varieties of hermaphroditism in the particular order in which they are placed in the above table, we shall, we believe, by following that order, be able to take a graduated, and, at the same time, a correct and comprehensive view of the subject, beginning with the more simple, and ending with the more complex and complete species of hermaphroditic malformation, as seen in the primary sexual characters, or the structure of the genital parts themselves. We shall then consider at some length the curious and important physiological subject of hermaphroditism as manifested in the secondary sexual characters of the system. After having done so, we shall endeavour to show how far the diversified forms of hermaphroditic malformation can be explained upon our present knowledge of the laws of developement; point out the actual anatomical and physiological degree of sexual duplicity which is liable to occur, and the numerous fallacies with which the determination of this question in individual cases is surrounded; and lastly, in conclusion, we shall offer some general observations upon the causes, &c., of this class of abnormal formations.

1. SPURIOUS HERMAPHRODITISM.

A. *In the female.*—There are two circumstances in the conformation of the genital organs of the female, the existence of each of which has occasionally given rise to doubts and errors with regard to the true sex of the individual on whom they were found—namely, 1st, a preternaturally large size of the clitoris; and 2d, a prolapsus of the uterus; the enlarged clitoris in the one case, and the protruded uterus in the other, having been repeatedly mistaken for the male penis.

1. *Abnormal developement or magnitude of the clitoris.*—In the earlier months of intrauterine life, the clitoris of the human female is nearly, if not altogether, equal in size to the penis of the male fœtus; and at birth it is still relatively of very considerable dimensions. From that period, however, it ceases to grow in an equal ratio with the other external genital parts, so that at puberty it is, as a general law, found not to exceed six or eight lines in length. But in some exceptional instances the clitoris is observed to retain up to adult age more or less of that greater proportionate degree of developement which it presented in the embryo of the third and fourth month, thus exhibiting in a persistent form the transitory type of structure belonging to the earlier stages of fœtal life. In some instances where this occurs, the resemblance of the external female to the external male parts is occasionally considerably increased by the apparent absence of the nymphæ. Osiander* endeavoured to show that at the third or fourth month of fœtal life the nymphæ are very imperfect, and so very small as not to be easily observed. Meckel,† however, has pointed out that these organs are not in reality of a small size at that time, but they are liable to escape observation from the folds of skin of which they consist, making, at the period alluded to, a perfectly continuous membrane with the prepuce of the clitoris, and forming indeed, in their origin, only one common mass with this latter body. When the ulterior changes, therefore, which these parts ought to undergo in the natural course of developement in the latter stages of fœtal existence, are suspended or arrested from about the end of the third month, there may not only coexist with the enlarged clitoris an apparent want of nymphæ, but the resemblance of the female to the male parts may be still further increased by the persistance of the original intimate connexion of the nymphæ with the prepuce and body of the clitoris, and by the consequently continuous coating of integuments, as well as the greater size and firmness of this organ.

Excessive size of the clitoris would seem to be much less common among the natives of cold and temperate than among those of warm countries. The frequency of it in the climate of Arabia may be surmised from the fact of directions having been left by Albucasis and other surgeons of that country for the amputation of the organ; an operation which Ætius and Paulus Eginetus describe as practised among the Egyptians. According to the more

* Abhandlungen über die Scheidenklappe, in Denkwurdigkeiten für die Heilkunde, Bd. ii. p. 4-6.

† Manuel d'Anat. Gén. tom. iii. p. 666.

modern observations of Niebuhr* and Sonnini,† circumcision would seem to be still practised upon the females of that country.

This variety of conformation of the female parts appears to have been well known to the ancient Greeks, and several of their authors have mentioned the women so constituted under the names of τριβαδις and ιταιριστριαι, a class in which the celebrated poetess Sappho (*mascula Sappho*) is well known to have been included. Martial, Tertullian, and other Roman authors have noticed the same malformation, (*fricatrices, confricatrices,*) and alluded to the depravity to which it led.‡

* Beschreibung von Arabien, s. 77.

† Voyage dans la Haute et Basse Egypte, tom. ii. p. 37.

‡ Mart. Epigr. lib. i. ep. 91.; see also lib. viii. ep. 66. The frequency of this crime in the ancient gentile world may be inferred from the pointed manner in which the Apostle Paul alludes to it, Romans, chap. i. 26. In Greece it was in some places forbidden by law, and in others, as in Crete, tolerated by the state. Seneca, in his 95th ep., when speaking of the depravity of the women of his own age, remarks, "non mutata fœminarum natura, sed vita est. . . . Libidine vero, nec maribus quidem cedunt pati natæ. Dii illas deæque male perdant, adeo perversum commentæ genus impudicitiæ viros ineunt." Op. Om. Genev. 1665, p. 787. Clemens Alexandrinus, in his Pædagogus, exposes the same vice: "et contra naturam fœminæ, viros agunt (ανδριζονται) et nubunt et etenim uxores ducunt." Also Athenæus, Deipnosoph. lib. xiii. p. 605. Justin Martyr, in his Second Apology, makes a still broader accusation. This author lived in the second century, and in declaiming against the vices of that licentious age, he alleges that multitudes of boys, females, and hermaphrodites (*androgyni ambigui sexus*) "nefandi piaculi gratiâ per nationem omnem prostant." Op. Om. Col. 1686, p. 70. See also Marcus Antoninus, De Seipso, ed. Gatakeri, Cambr. 1652, lib. iii., note at the end by Gataker. On the extent, among the ancients, of the vices above alluded to, see Meiner's Geschichte des Verfalls der Sitten und der Staatsverfassung der Roemer, Leipzig, 1791; Neander's Denkwurdigkeiten, Bd. i. s. 143; Professor Tholuck's, of Halle, Exposition of St. Paul's Epistle to the Romans, in the Edinburgh Biblical Cabinet, vol. v. p. 102, and in an Essay on the licentious vices, &c., of the ancients, translated into Robinson's American Biblical Repository, vol. ii. p. 441. In the essay last referred to, Tholuck incidentally mentions (p. 422,) that the deity Mitra (Mithras of the ancient Persians) was hermaphrodite. For our own part we are inclined to believe that many of the idols of the heathenish mythology of Asia could be traced to the deification of various monstrosities in man and quadrupeds. (See the figures of these idols *passim* in C. Coleman's Mythology of the Hindus, Lond. 1832; and E. Upham's History and Doctrine of Budhism, Lond. 1829.) It perhaps is not unworthy of notice that the Jewish Talmudists, taking the Hebrew noun in the Pentateuch answering to man in its individual and not in its collective sense, considered, from Genesis, chap. i. v. 21, that our original progenitor was hermaphrodite. (See Jus Talmud. Cod. Erwin. c. 2; Heidegg. Hist. Patriarch, t. i. 128; C. Bauhin De Monstrorum Natura, &c., lib. i. c. 24; and Arnaud's Mémoire, p. 249.) It is further interesting to remark that Plato, in his Symposion, introduces Aristophanes as holding the same opinion. "The ancient nature," he observes, "of men was not as it now is, but very different; for then he was androgynous both in form and

The dimensions which the clitoris occasionally presents are such as to render it, in respect of size alone, not unlike the male penis. It is not unfrequently found of two or three inches in length, but sometimes it is seen five and six inches long. Dr. Clark frequently found the organ an inch long, and thick in proportion, among the Ibbo and Mandingo women.*

Haller † and Arnaud ‡ have collected numerous instances of preternatural size of the clitoris. The former author alludes, among others, to two cases in which the organ was stated to have been seven inches in length; and to another, mentioned by Chabart, in which it was alleged to have been twelve inches,—a size which we can only conceive to have been the result of disease.

When the female clitoris is increased greatly in size, it is not wonderful that it should be sometimes mistaken for the male penis,—the female organ in the Mammalia naturally differing from the male only in regard to its smaller dimensions, its not being perforated by the urethra, and its wanting the corpus spongiosum,—a peculiarity or defect of structure that exists as the natural type of formation in the penis of male reptiles. In the human subject the organs are composed internally of the same kind of erectile tissue, and when we descend in the animal scale, and examine their relations in the males and females of the same species, we find some still more striking analogical peculiarities of structure. Thus, in several of the Carnivora and Rodentia, as in the lioness, cat, racoon, bear, marmot, &c. the clitoris contains a small bone like that belonging to the penis of the males of the same species; and amongst the Monotremata and Marsupiata the clitoris of the female, like the penis of the male, is surmounted by a bifid glans. In a species of lemur (*Loris gracilis* or *Stenops tardigradus*), the clitoris is of a very large size; and the urethra, as first pointed out by Daubenton,§ runs forward and opens at its anterior extremity between the branches of its glans, imitating, in this point of structure, the penis of the male among the Mammalia.

In the human subject the mere enlargement of the clitoris alone has seldom of itself given rise to errors with regard to the sex of the individual, except in young children; but it has frequently happened that along with it other minor malformations have coexisted, so as to render the sexual distinction much more ambiguous. In women possessing this peculiarity of structure we sometimes observe, for instance, the clitoris not only resembling the penis in size, but it has an indentation at the point of the glans, imitating the orifice of the urethra; and occasionally the glans is actually perforated to a certain extent backwards, or the body of the clitoris is drilled more or less imperfectly with a canal like that of the male urethra. In other instances the canal and orifice of the female vagina are, by an excess of development in the median line of the body, much contracted or nearly shut up, the vulva being closed by a strong membrane or hymen, and the labia cohering so as to give the parts a near resemblance to the united or closed perinæum and scrotum of the male. Further, in one or two very rare cases which have been put upon record, the ovaries and Fallopian tubes seem to have descended through the inguinal rings into the labia, thus giving an appearance of the presence of testicles; and a fallacy seems to have occurred in some cases from the presence of roundish masses of fat in this situation simulating more or less the same male organs.

Besides, it often happens in those women who present more or fewer of these peculiarities of conformation in the external genital parts, that the general or secondary sexual characters of the female are wanting, or developed in a slighter degree than natural, owing probably to the malformations of the external organs being often combined with some coexisting anomalies in those more important internal reproductive organs, the healthy structure and action of which at the time of puberty appear to exercise so great an influence on the development of the peculiar general conformation and moral character of the female. Thus the features are sometimes hard, the figure and gait rather masculine, the mammæ slightly developed, the voice is deep-toned, and the chin and upper lip are occasionally covered with a quantity of hair. In fact, in some marked cases the whole external character approaches to that of the male, or, more properly speaking, occupies a kind of neutral ground between that of the two sexes. Some of the more striking examples of this first variety of spurious hermaphroditism in the female will sufficiently illustrate the above remarks.

Dr. Ramsbotham * has briefly described the genital parts of an infant, that was christened and looked upon as a boy, until dissection after

name," (ανδρογυνεν και ειδος και ονομα.) Probably from the licentious purposes alluded to by Justin Martyr, or from the weak and imbecile character of hermaphrodite individuals, the word ανδρογυνος came in latter times to signify effeminate and luxurious. The ancient lexicographer Hesychius gives it this meaning; and Theodoret, in his Therap., speaks of Bacchus as being licentious, effeminate, and androgynous—(γυννις ων, και θηλυδριας, και ανδρογυνος.)

* Home's Comp. Anat. vol. iii. p. 317. On the peculiarities of the external genital organs in various African tribes, see a learned paper by Prof. Müller in his Archiv fuer Anatomie for 1834. Ht. iv. s. 319., with ample references to the observations and opinions of Levaillant, Barrow, Peron, Lesner, Lichtenstein, Burchell, Somerville, &c. See also Otto, in his Neue Seltene Beobachtungen zur Anatomie, p. 135, shewing the very prominent external female parts of different African tribes to consist differently, 1, of enlarged nymphæ, 2, of enlarged labia, and 3, of the enlarged clitoris.

† El. Phys. tom. vii. part ii. p. 81, 82.

‡ Dissertation sur les Hermaphrodites, p. 372. See also Homberg, De Excrescentiâ Clitoridis nimia, Jena, 1671; Tronchin, De Clitoride, Lugd. 1736; and Plonequet's Literatura Medica, art. Clitoris Magna, tom. i. p. 299.

§ Audibert, Histoire Nat. des Singes, tab. ii. fig. 8.

* Medical Gazette, xiii. p. 184.

death shewed that the sex was actually female. The uterus and other female organs (*fig.* 287, *c c c*) were present and apparently naturally

Fig. 287.

formed; but the clitoris (*b*) was fully as large, and in appearance closely resembled the penis of a male of the same age. At its anterior extremity there was a sulcus (*a*), which was not the entrance of the urethra, but terminated in a cul-de-sac.

Columbus* and De Graaf† give two similar examples of the same form of spurious hermaphroditism in young children, in which the true sex was only fully ascertained by dissection after death. In relation to the clitoris in the case described by Columbus, that author states that this organ was furnished with two muscles only, and not with four, as in the perfect male.

In a reputed hermaphrodite woman, Gallay‡ found after death the clitoris to be three and a half inches long, and three inches and four lines in circumference. The glans and prepuce were well developed. The urethra ran as in man through the body of the penis and its glans. The labia, nymphæ, vagina, &c. were natural, and the internal female organs, the ovaries, Fallopian tubes, and uterus, are described as scirrhous. This woman had been married, but never had any children; her catamenia, however, had been very regular. She had a considerable quantity of hair upon her face, and her voice was harsh and masculine.

In a child of two years of age, Schneider,§ on dissection after death, could find neither the labia externa nor interna, nor any trace of the ordinary cleft between them. The clitoris was an inch and a half long, and externally resembled most perfectly a male penis furnished with a glans and prepuce; but it was imperforate, having only at its anterior extremity a small spot marking the situation of the opening of the urethra in the male. Some lines below there was an opening by which the urine was evacuated. This opening formed the entrance to the vagina, which was found of the usual length, and with the characteristic rugæ. The canal of the urethra was found entering its roof, but in such a manner that the urine was always evacuated very slowly and by drops only from the external opening. All the internal female sexual organs were natural.

* De Re Anatomica, lib. xv. p. 493.

† Op. Om. cap. iii. xv. or, De mulierum organis gen. inserv. with a plate.

‡ Arnaud, l. c. p. 309.

§ Jahrbücher der Staatsarzneikunde, (1809), s. 193.

M. Beclard* has left us a very detailed and interesting description of an example of spurious hermaphroditism referable to the present variety, and exhibited at Paris in 1814. The subject of the case, Marie Madeline Lefort, was at that time sixteen years of age. The proportions of the trunk and members, and of the shoulders and pelvis, and the conformation and dimensions of this last part of the body, were all masculine; the volume of the larynx also, and the tone of the voice were those of an adolescent male; a beard was appearing on the upper lip, chin, and region of the parotids; some hairs were growing in the areola around the nipple; and the mammæ were of a moderate size. The inferior extremities were furnished with an abundance of long hard hairs. The symphysis pubis was elongated as in man; the mons veneris rounded, and the labia externa were covered with hair. The clitoris was 10½ (?) inches (27 centimetres) in length when at rest, but somewhat more when erect; its glans was imperforate, and covered in three-fourths of its circumference with a mobile prepuce. The body of this enlarged clitoris was furnished inferiorly with an imperfect canal, which produced a depression in it, instead of that prominence of this part which exists in the male penis. This canal was pierced along its under surface and median line by five small holes capable of admitting a small stylet; and one or more similar apertures seemed to exist in it after it reached backwards within the vagina. The labia were narrow and short, and the vulva or sulcus between them was superficial, being blocked up by a dense membrane, which, under the pressure of the finger, felt as if stretched towards the anus over a cavity. At its anterior part, or below the clitoris, there was an opening capable of admitting a sound of moderate size, and this sound could be made to pass backwards behind the membrane closing the vulva, which, when felt between the point of the instrument and the finger, seemed about twice as thick as the skin. The urine was passed by this opening, and also, according to the report of the individual herself, through the cribriform holes in the canal extending along the inferior surface of the urethra. By the same opening the menstrual fluid escaped, as Beclard ascertained on one occasion by personal examination. She had menstruated regularly from the age of eight years, considered herself a female, and preferred the society of men.

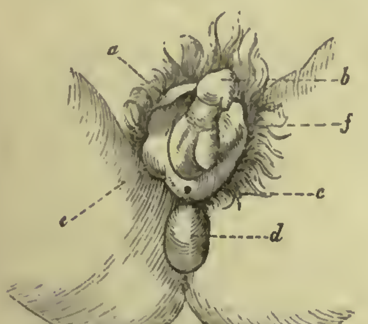
In this interesting case we have present all the secondary sexual characters of the male,

* Bulletins de la Faculté for 1815, p. 273.

with some of the female genital organs developed in so excessive a degree as to approach in several points the more perfect structure of them in man. The impossibility, however, as mentioned by Beclard, of finding any bodies like testicles in the labia or in the course of the inguinal canals, and more particularly the well-ascertained fact of the individual menstruating, can leave no doubt as to the nature of her sex. The perforation of the enlarged clitoris with the imperfect urethra is interesting, when compared with the peculiarities that we have formerly alluded to, of this part in the female Loris, as pointing out, what we have so often occasion to observe in human monstrosities, a type of structure assumed by a malformed organ similar to the normal type of structure of the same organ, in some of the inferior animals.

Arnaud* has represented and described at great length an interesting example of hermaphroditic malformation that seems referable to the head of spurious hermaphroditism in the female, although there are two circumstances in the history of the case which have led some authors to doubt the accuracy of this opinion; and the opportunity that was afforded of ascertaining the true structure of the parts after death was unfortunately lost through carelessness and neglect. The subject of the malformation, aged 35, passed in society for a female, and came to Arnaud complaining of a small tumour (*fig.* 288, *e*) in the right groin, which

Fig. 288.



had incommoded her much during her whole life. On examining this body, Arnaud was led to believe that it was a testicle, and he found a similar tumour (*f*) situated nearer the inguinal ring on the left side. The bags that contained them represented very exactly the labia externa. The clitoris (*a*) was two inches and nine lines in length, and placed between the labia at their upper angle. The glans (*b*) was well formed, and though imperforate at its extremity, it presented a small depression which ran backwards along the whole inferior border of the clitoris, indicating the situation of a collapsed urethral canal, that seemed pervious for some length at its posterior part, as it became distended when the patient evacuated the bladder. The orifice (*c*), however, from which the urine actually flowed, occupied the situation in which it exists in the perfectly formed female. There was not any vaginal opening, and the individual menstruated per anum. At each menstrual period a tumour (*d*) always appeared in the perinæum, which gradually increased in size, becoming, in the course of three or four days, as large as a small hen's egg. When the perinæal tumour had reached this size, blood began to flow from the anus, although no hæmorrhoids or other disease of the bowel was present. At these periods the individual had often experienced very alarming symptoms, and in order to avert these, Arnaud was induced to make an opening into the soft yielding space at which the perinæal tumour above alluded to appeared; and at a considerable depth he found a cavity two inches in circumference, and about two and a half in breadth, having projecting into it at one point an eminence which was supposed from its situation to be possibly the os uteri. At the next period the menstrual fluid came entirely by the artificial perinæal opening, and the usual severe attendant symptoms did not supervene. From inattention, however, to the use of the tent, the opening was allowed to become completely shut, so that at the sixth return of the menses they flowed again by the anus, and were accompanied by the old train of severe symptoms. The individual lived for several years afterwards. Her conformation of body was remarkable. Her skin was rough, thick, and swarthy; she had a soft black beard on her face; her voice was coarse and masculine; her chest narrow; her mammæ were flat and small; her arms lean and muscular; her hands large, and her fingers of very considerable length and strength. The form, in fact, of the upper part of her body was masculine, but in the lower part the female conformation predominated. The pelvis was wide and large, the os pubis very elevated, the buttocks large, the thighs and legs round, and the feet small.

In this remarkable instance, if we do not go so far as to conceive the coexistence of some of the internal organs of both sexes, we must, from the well-ascertained fact of the menstrual evacuations, allow the person at least to have been a female. In that case we can only suppose the tumours in the labia to be the ovaries descended into that situation; and to the same excess of development which has produced this effect, we may attribute the closure of the vaginal orifice, and the formation of the imperfect urethral canal in the body of the clitoris.

Spurious hermaphroditism from preternatural enlargement of the clitoris has been recognised among some of the lower animals. Rudolphi* has noticed a mare of this kind that had a clitoris so large as almost to shut up the entrance into the vagina. Lecoq† has detailed

* Dissertation sur les Hermaphrodites, p. 265, pl. x.

* Rudolphi's Bemerkungen auf einer Reise, &c. Bd. i. s. 79. See a case also figured by Ruysch in his Thesaurus Anat. lib. viii. no. 53.

† Journ. Prat. de Méd. Vét. 1827, p. 103.

the case of a calf which Gurlt* believes to belong to the present head. Neither testicles nor scrotum were observed externally, and the penis or enlarged clitoris, which occupied its normal situation, was apparently perforated by the urethra, and crooked upwards so as to throw the urine in that direction. Mery † shewed by dissection the true sex of a monkey, the length of whose clitoris had deceived some observers with regard to the true sex of the animal. The enlarged clitoris was furrowed on its inferior surface. The clitoris of the female Quadrumana is, as shall be afterwards more particularly mentioned, relatively larger than in the human subject, and retains in a greater degree the size and type of structure of this organ in the embryo.

We may here further mention that, as pointed out by Blumenbach,‡ the clitoris and orifice of the urethra are placed at some distance from the vagina and in front of it, in the rat, mouse, hamster, &c. This normal structure has sometimes been mistaken for an hermaphroditic malformation.§

2. *From prolapsus of the uterus.*—It may at first appear strange that this occurrence should ever lead to any difficulty in ascertaining the sex of the individual, though not only non-professional observers but even the most intelligent medical men have occasionally been so far misled by the similarity of the protruded organ to the male penis, as to mistake a female for a male. Of this circumstance some curious illustrations are on record.

M. Veay, physician at Toulouse, has inserted in the Philosophical Transactions of London, vol. xvi. p. 282, a brief account of the case of Marguerite Malause or Malaure, who was entered as a female patient in the Toulouse Hospital in 1686. Her trunk, face, &c. presented the general configuration of a female, but in the situation of the vulva there was a body eight inches in length when on its fullest stretch, and resembling a perfectly formed male penis in all respects, except in not being provided with a prepuce. Through the canal perforating this body she was alleged to evacuate her urine, and from its orifice M. Veay had himself an opportunity of seeing the menstrual fluid flow. After being examined by several physicians she was pronounced to be more male than female, and ordered by the civil authorities to exchange the name of Marguerite for that of Arnaud, and to wear male attire. In 1693 she visited Paris in her male habiliments, and reputed herself endowed with the powers of both sexes. The Parisian physicians and surgeons who examined her seem all to have accorded in opinion with the faculty of Toulouse, until M. Saviard|| saw her and detected the supposed penis to be merely the prolapsed uterus. He reduced the protruded organ, and cured the patient. Upon the enigma of her hermaphroditism being thus solved, she was permitted by the king, at her own request, to assume again her female name and dress.

Sir E. Home* detected a case of reputed hermaphroditism of the same description as the last, in a French woman of twenty-five years of age, who exhibited herself in London, and pretended to have the powers of a male. The cervix uteri was uncommonly narrow, and projected several inches beyond the external opening of the vagina. The everted mucous surface of the vagina had, from constant exposure, lost its natural appearance and resembled the external skin of the penis. The orifice of the os tincæ had been mistaken for the orifice of the urethra. The prolapsus had been observed at an early age, and had increased as the woman grew up.

Valentin† mentions another analogous instance of sexual ambiguity produced by a prolapsus of the uterus. In this case the husband mistook the displaced organ for the penis, and accused his wife of having "cum sexu virili necquicquam commune."

A case quoted at great length by Arnaud‡ from Duval, of reputed hermaphroditism in a person that was brought up as a woman, and married at twenty-one years of age as a male, but who was shortly afterwards divorced and imprisoned, and ordered again by the Court of Rouen to assume the dress of a woman, appears to us to belong very probably to the present division of our subject, the reputed penis being described as placed *within* the vagina. The recorded details of the case, however, are not so precise as to leave us without doubt in regard to its real nature.

In cases such as those now mentioned, in which the prolapsed uterus, or, more properly speaking, the prolapsed uterus and vagina have been mistaken for the penis, it appears probable that the neck of the uterus must have been preternaturally long and narrow, otherwise it would be difficult to account for the apparent small diameter and great length of the prolapsed organ. Among Professor Thomson's collection of anatomical drawings of diseased structures there is one of an uterus containing in its body a fibro-calcareous tumour, and having a neck of three inches in length. M. Cruveilhier§ has represented a similarly diseased uterus with a neck of between five and six inches. An organ shaped in this manner, whether from congenital malformation or acquired disease, would, when prolapsed for some time, represent, we conceive, a body resembling in form and size those observed in Saviard's and Home's cases. The prolapsus arising from a protrusion of an ordinary shaped uterus is generally of a greater diameter and roundness.

This second species of spurious female hermaphroditism is not observed among the lower animals.

B. *Spurious hermaphroditism in the male.*—

* Lehrbuch der Pathol. Anat. Bd. ii. s. 193.
† Hist. de l'Acad. (1686) tom. i. p. 345.
‡ Comp. Anat. p. 335.
§ Doebel, in Nov. Liter. Maris Balthici (1698), p. 238.
|| Recueil d'Observations Chirurgicales, p. 150.

* Comp. Anat. vol. iii. p. 318.
† Pandectæ Medico-Legales, t. i. p. 38, Casus xii.
‡ Mém. sur les Hermaphr. p. 314-18.
§ Anat. Pathol. liv. xiii. Pl. iv.

Malformed males have been more often mistaken for females than the reverse. The varieties of malformation in persons actually male, that are liable to lead to mistakes with regard to their true sex, appear to be, 1st, extrophy or extroversion of the urinary bladder; 2d, adhesion of the inferior surface of the penis to the scrotum; and 3d, and principally, fissure of the inferior part of the urethra and of the scrotum and perinæum.

1. *Extroversion of the urinary bladder.*—For a full description of this malformation we must refer to the articles BLADDER and MONSTROSITY. This malformation is known to occur more frequently in the male than in the female, and when present in the former it has occasionally given rise to a supposition of hermaphroditism, the red fungous mass formed by the mucous membrane of the protruded posterior wall of the bladder, and situated above the pubis, having been mistaken for the female vulva,—an error which has probably been the more readily committed from the uterus and seminal ducts, and sometimes also, as in an instance described by A. Fraenkel,* a part of the intestinal canal opening upon the surface of the exposed portion of bladder. In some instances of this malformation occurring in man, the external male sexual organs are very imperfectly formed, or can scarcely be said to be at all present. In other cases the scrotum is of the natural form, with the two testicles in it; and the penis is of considerable size, though almost always fissured on its upper surface from the epispadic or open state of the urethra.

An example of supposed hermaphroditic malformation briefly described by Rueffe,† which seems referable to this variety will be sufficient to illustrate it. "In the year 1519 an hermaphrodite or androgynus," he remarks, "was born at Zurich, perfectly formed from the umbilicus upwards, but having at this part a red mass of flesh, beneath which were the female genitals, and also under and in their normal situation those of the male."

2. *Adhesion of the inferior surface of the penis to the scrotum by a band of integuments.*—This state of parts has occasionally given rise to the idea of hermaphroditism, the penis being so bound down as not to admit of erection, and the urine passing in a direction downwards, so as to imitate the flow of it from the female parts.

In a boy of seven years of age regarding whom Brand ‡ was consulted, the penis was confined in this manner to the scrotum by abnormal adhesions. He had been baptized and reared as a girl, but by a slight incision the adherent organ was liberated, and the parents were convinced of the mistake that they had committed in regard to the sex of their child. The difficulty of determining the true sex of the boy was increased by the testicles not having descended into the scrotum.

Wrisberg* mentions two similar instances in persons of the respective ages of nineteen and forty-six. He relieved the adherent penis in the first case by operation.

3. *Fissure of the inferior part of the urethra, perinæum, &c.*—This species of malformation, which has perhaps more frequently than any other given rise to the idea of the person affected with it being the subject of hermaphroditism, evidently consists in an arrest of the development of the external male sexual parts.

At an early stage of the development of the embryo, the various central sexual organs are, like all the other single organs situated on the median line of the body, found to be composed of two separate and similar halves, divided from each other by a vertical fissure, which, after the originally blind extremity of the intestinal canal has opened upon the perinæum, forms a common aperture or cloaca for the intestinal canal, and also for the urinary and genital apparatus, both of which are, in their primary origin, prolongations from the lower part of that canal. After a time, (about the second month in the human embryo,) the opposite sides of this cloaca gradually approximate, and throw out two corresponding folds, which by their union constitute a septum that separates the rectum from the canal or portion of the fissure, that still remains common to the urinary and generative organs; and, in the same way, by two similar and more anterior folds, the urethra of the female, and the pelvic portion of that of the male is subsequently produced. After this in the female the process of median reunion does not proceed further, and the primary perinæal fissure remains, forming the vulva and vagina. In the male, however, the development, when normal, goes on to a greater extent, and the sides of the opening become so far united as ultimately to leave only the comparatively contracted canal of the urethra to serve as a common passage for both the internal urinary and genital organs; and the situation of the line of junction of the opposite sides of the original perinæal cleft remains still marked out in the adult, by the raphé existing in the median line of the scrotum. The two lateral parts of the female clitoris unite together into one solid body, having on its under surface a slight groove or channel, indicative of the line of conjunction of its two component parts; and the urethra is left to open at the root of this imperforated organ. In the male, on the contrary, the two primitive halves of the penis, consolidated together at an early stage along the course of their upper surfaces, come, in the progress of development, to unite inferiorly in such a manner with one another as to form a tubular prolongation of the pelvic portion of the canal of the urethra, which is gradually extended forwards along the body of the penis and ultimately through its glans.

Many of the malformations to which the

* De Organorum Generationis Deform. Rarissimâ, Berlin, 1825, with a plate.

† De Conceptu et Generatione Hominis, p. 44.

‡ Case of a boy who had been mistaken for a girl. London, 1788.

* Comment. Med. &c. Arg. p. 534.

male genital organs are liable may be traced to stoppages in the above process of development, the character of the malformation depending upon the period of the development at which the arrest takes place, and varying consequently in degree from the existence of a cloaca or permanent primitive fissure common to the intestinal, urinary, and generative organs,* to that want of closure, to a greater or less extent in different instances, of the inferior surface of the canal of the urethra in the body of the penis, or in its glans, which is generally known under the name of *hypospadias*. When the development of the male organs is arrested, immediately after the two septa respectively separating the canals of the intestine and urethra from the original perinæal cleft are formed, and consequently when this perinæal fissure and that running along the inferior surface of the penis are still open, the external genital parts often come to present at birth, and during the continuance of life, a striking resemblance to the conformation of the external organs of the female, and the resemblance is frequently rendered greater by the coexistence of other malformations of the male organs. In these cases the imperfect and undeveloped penis is generally of small size, and, at the same time, from being imperforate, may readily be mistaken for the clitoris; the two halves of the divided scrotum have the appearance of the two labia externa; the two labia externa or nymphæ are sometimes represented by the lateral divisions of the penis forming two folds, which run backwarks along the internal surfaces of the split scrotum; and the cleft in the perinæum corresponds in situation and direction, and occasionally also in size and form, with the canal of the vagina; this cleft is generally lined also by a red mucous membrane that is kept, like the natural female parts, constantly moistened by the secretions of the follicles with which it is provided; its mucous membrane occasionally presents irregular elevations imperfectly representing the carunculæ myrtiformes; and, further, the opening of the urethra at the root of the diminutive and imperforate penis serves still more to assimilate the malformed parts to the natural conformation of the female organs. In a number of cases, however, the apparent analogy to the female parts is rendered less striking by the perinæal cleft being small or altogether absent, the urethral orifice at the root of the penis often forming the only opening leading to the internal urinary and generative parts, and the halves of the scrotum in such instances being frequently more or less perfectly united. Generally the seminal ducts, and sometimes also the ducts of Cowper's glands, are seen opening on the surface of the urethra or supposed vaginal canal, at a short distance from its external orifice.

In males malformed in the manner described, the testicles are seldom found in the divided scrotum at birth, but commonly they descend into it through the inguinal rings towards the period of puberty; and in several instances on record, in which the sex of the individual had been mistaken for that of a female, the tumours formed in the groin at that time by the organs in their descent have been erroneously regarded and treated as hernial protrusions. At the same time it occasionally happens that with the descent of the testicles, and the arrival of puberty, the diminutive penis enlarges in size, and the individual assumes more or less fully the habits and attributes of the male. In several instances on record this change has, under venereal excitation, appeared to occur suddenly, and persons formerly reputed female have thus unexpectedly found themselves provided with an erectile male penis. These various changes are occasionally postponed for a considerable period beyond the usual term of puberty.

In a few rare instances one testicle only descends through the inguinal ring, and occasionally they both remain throughout life within the abdomen, in or near the situation in which they are originally developed, imitating in this abnormal state the normal position of the same organs in many of the males among the lower animals. In a number of instances in which the testicles are thus retained within the cavity of the abdomen, they are found small and imperfectly developed, and from the want of their usual physiological influence upon the constitution, the whole physical and moral character of the malformed individual frequently presents a considerable approximation to that of the female, or, as we should perhaps more justly express it, never attains the perfection of the male, but preserves that kind of common or neutral state exhibited by the constitution of both sexes before the specific sexual characters of each are developed at the time of puberty.

Numerous curious examples of mistakes having been committed with regard to the sex of males affected with the above species of malformation have now been put on record, from the time at which Iphis, the daughter of Ligdus, king of Crete, was conceived to be changed into a man by the miraculous interference of Isis, down to the present day. Pliny, (lib. vii. chap. iv.) has noticed several cases; and in the treatise of Duval on hermaphrodites a number of additional instances are collected from Livy, Trallian, and others, some of them no doubt invested (as most of the details regarding hermaphrodites in the older authors are) in much misrepresentation and fable, but others bearing every mark of accuracy and authenticity. In more modern times the sexes of individuals have often been mistaken in consequence of this variety of malformation. Jean Chroker* relates, in apparently the most authentic manner, the case of Magdelain Mugnoz, a nun of the order of St. Dominique in the town of Ubeda, who was changed, as he supposes, into a male, seven years after having taken the vows.

* See on this malformation in the human subject (the normal form of structure in birds, &c.) Meckel on Kloakbildung in his Path. Anat. Bd. i. s. 693.

* Fax. Histor. cent. i. and Arnaud, Dissertation sur les Hermaphrodites, p. 200.

He was expelled the convent, assumed the male dress, and took the name of Francois. The sequel of the story, as told by Chruker, would seem to shew that his sexual desires became extremely strong, and he is said to have been ultimately condemned, whether justly or not, under an accusation of rape.

Portal* quotes from Tigeon the story of a person who was brought up as a female, and afterwards was considered to be suddenly changed by a surprising metamorphosis into a male, and in citing this case Dr. Hodgkin,† of London, mentions, on the authority of a friend, a recent instance of an equally sudden development of the male sex in a previously reputed female. Similar instances in which the proper sex of malformed males was unexpectedly discovered under the excitement of sexual passion at the period of puberty are mentioned by Paré, Tulpius, and others.

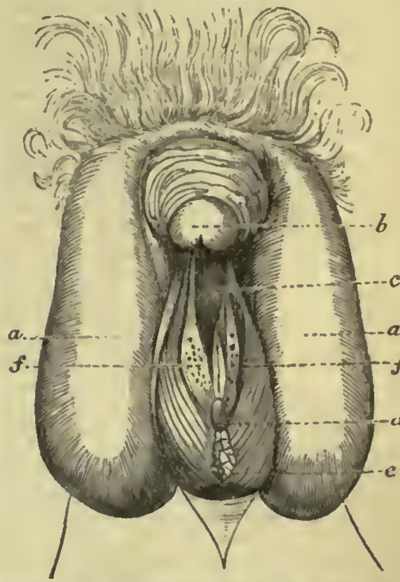
Schweikard‡ has recorded an instance of a person baptized and brought up as a female, and whose true sex was only at last disclosed by his requesting, at the age of forty-nine, permission to marry a young woman then pregnant by him. On examination it was discovered that the penis was slender and scarcely two inches long; the right testicle only had descended into the scrotum, and the urethra opened at the root of the penis, but its orifice was placed in such a manner that during micturition the urine was thrown along the groove or channel on the under surface of the penis, so as to appear to issue from its anterior extremity. The two halves of the scrotum were so far united that they left only a small oval opening between the anterior part of the raphé and the roots of the corpora cavernosa. In this opening the orifice of the urethra was situated.

Dr. Baillie§ has mentioned a case which appears to belong in all probability to the present division. The subject of it was twenty-four years of age. She had always passed in society as a woman, and came for consultation to the Nottingham Hospital on account of her menses never having appeared; a circumstance, however, that had in no way affected her health. The spurious vagina consisted of a cul-de-sac two inches in depth. The penis was of the size of the female clitoris, but there were no nymphæ. The labia were more pendulous than usual, and contained each of them a body resembling a testicle of a moderate size, with its cord. The look of the individual was remarkably masculine, with plain features, but no beard. The mammæ resembled those of a woman. The person had no desire or partiality for either sex.

Adelaide Preville, who had been married as a female, died in the Hôtel Dieu of Paris. In examining the body of this individual after death, Giraud* found that, except a perinæal cleft or false vagina consisting of a cul-de-sac placed between the bladder and rectum, nothing else resembling the female sexual apparatus could be detected, while all the organs belonging to the male sex were present

Otto† has described and represented (*fig*. 289)

Fig. 289.



a case of the present species of hermaphroditism in an individual whose history is remarkable. The person had lived ten years in the state of wedlock with three different men; but at the age of thirty-five an action of divorce was brought against her by her third husband, accusing her of being affected with some disease of the sexual parts that rendered the connubial act on his part extremely difficult and painful. After some difference of opinion between the two medical men to whose professional examination the wife was submitted, it was at last considered that she was in reality a male, and the case came at last under the investigation of the members of the Royal Medical College of Silesia, who confirmed this opinion. The imperforated penis (*b*) was one inch and a half in length; the perinæal fissure (*c*) forming the false vagina was, at the posterior part of its orifice, bounded by a distinct frænulum, but was of a size sufficient to receive the glans of the husband for an inch and a half in depth. This cavity, as well as the internal surfaces of the two lobes (*a a*) of the divided scrotum, were lined with a vascular mucous membrane. At the bottom of it the round orifice of the urethra (*d*) was seen to open; and at the same

* Hist. de l'Anat. tom. ii. p. 52.

† Catalogue of Guy's Hospital Museum, part ii. sect. xi.

‡ Hufeland's Journal der Prak. Heilkunde. Bd. xvii. No. 18.

§ Morbid Anatomy, p. 410, 2d edit.

* Recueil Period. de la Soc. de Méd. tom. ii. p. 315, or Moureau's Hist. Nat. de la Femme, t. i. p. 243, (with a figure of the parts.)

† Neue Seltene Beobachtungen zur Anatomie, &c. p. 123.

point a hard mass could be felt, probably consisting of the prostate gland; and more upwards and outwards, nearly in the natural situation of the bulb, was seen the split urethra (c) with a row of three considerably sized openings (*f f*), which, under pressure and irritation of the genital parts, gave out several drops of a transparent mucous fluid. Otto considers these openings as the extremities of the ducts of the prostate and Cowper's glands, and of the seminal canals. The right half of the scrotum contained a small testicle about the size of that of a boy of ten years of age; the left testicle lay likewise external to the abdominal ring, and was still softer and smaller than the right. Both were furnished with spermatic cords. The general configuration of the individual was strong, muscular, and meagre; the beard was thin and soft, and the face, mammæ, thorax, pelvis, and extremities were evidently masculine.

Along with the preceding instances we are inclined to classify the case of Maria Nonzia, as detailed by Julien and Soules.* This individual was born in Corsica in 1695, was twice married as a female, and at last divorced in 1739 by her second husband, after having lived sixteen years in wedlock. The penis was two inches in length, but imperforate, and the meatus urinarius was placed at its root. Two bodies, like ordinary sized testicles, and furnished with spermatic cords, were felt in the divided scrotum; and there was a narrow false vagina or perinæal canal one inch and three lines in depth, and crossed at its upper extremity by two small traversing membraneous bridles. The character and appearance of the person were masculine; the visage was bearded; the mammæ were as fully developed as in the adult woman, but the nipples were each surrounded with hair.

So far as the preceding details go, they seem amply sufficient to justify us in considering Maria Nonzia as a malformed male; and we are still inclined to take this view of the case, notwithstanding the statement inserted in the report of Julien and Soules, that the menses were present as in other women. For not to insist upon the circumstance that the reporters do not shew that they made any minute or satisfactory inquiry into this alleged fact, and not improbably took it upon the mere word of the subject of the case, who was necessarily greatly interested in maintaining the reputed female character, it would be requisite, in any such paradoxical instance, to ascertain if the discharge actually agreed in character with the menstrual fluid, or was not pure blood, the result of an hæmorrhage from the genito-urinary passages, or from the rectum, where, as in other parts of the body, this form of disease frequently assumes a periodical type. We would be inclined to apply even still more strongly these remarks to the celebrated case of Hannah Wild, detailed by Dr. Sampson.† This person had evidently the male genital organs malformed in the manner mentioned with regard to the other cases included under the present section, and possessed all the secondary sexual peculiarities of the male; so that we can only receive with great doubt and distrust the alleged existence of the menstrual discharge, and the more so, as this is evidently stated on the report of the subject of the case alone, who, deriving a precarious subsistence from the exhibition of his malformations, had a deep interest in amplifying every circumstance that could enhance the public curiosity with respect to the reality of his hermaphroditic character.

* Observ. sur l'Hist. Nat. sur la Physique et sur la Peinture, tom. i. p. 18, with a plate.

† Ephem. Nat. Curios. Dec. i. an. iii. p. 323.

At the same time, however, it must be remarked that in some instances of spurious hermaphroditism, it is found extremely difficult or even impossible during life to determine with precision the true or predominant sex of the malformed individual; and in regard to several well-known cases on record, we find on this point the most discrepant opinions offered by different authors. Thus while Morand,* Arnaud,† and Delius‡ described Michel-Anne Drouart as a male; Guyot,§ Ferrein,‖ and Caldani¶ maintained that this person was a female; and Mertrud** regarded the individual as an example of a real hermaphrodite.

A useful lesson of caution to us against our forming too decided and dogmatic an opinion in cases in which the sexual conformation appears in any marked degree doubtful, has lately been offered in the instance of Maria-Dorothée Duriée, or, as this individual was named in the latter years of his life, Charles Durge. While Metzger†† considered this person as a specimen of that kind of equivocal sexual formation to which the designation of hermaphroditism is truly applicable, Hufeland,‡‡ Mursinna,§§ Gall, Brookes,‖‖ and others¶¶ declared the sex of Duriée to be in reality female; and Stark,*** Mertens,††† and the Members of the Faculty of Medicine at Paris ‡‡‡ were equally positive in regarding the individual as merely a malformed male. The dissection of the body of Duriée by Professor Mayer has, as we shall afterwards state more in detail, shewn the sexual conformation of this individual to consist of a true mixture of both the male and female organs.

* Mém. de l'Acad. des Sc. 1750, p. 165.

† Dissert. sur les Hermaphr. p. 298.

‡ Frank, Sammlung. Th. viii. s. 398.

§ Mém. de l'Acad. des Sc. 1756, p. 71.

‖ Ib. 1767, p. 205.

¶ Mem. della Societa Itsliana, t. vii. p. 130.

** Arnaud, loc. cit. p. 298.

†† Gericht.-medic. Abhandlungen. Bd. i. s. 177.

‡‡ Journ. der Praktischen Heilkunde, Bd. xii. s. 170.

§§ Journ. für die Chirurgie, Arzneikunde, &c. Bd. i. s. 555.

‖‖ Medical Gazette for October, 1836.

¶¶ Von dem Neuangekommen. Hermaphrod. Berl. 1801.

*** Neuen Archiv. fur die Geburtshülfe. Bd. ii. s. 538.

††† Beschreibung der männlichen Geschlechtstheile von M. D. Durrier. Leipzig, 1802, with two plates.

‡‡‡ Med. Gaz. for October, 1836.

In attempting to determine the true sex in such doubtful instances of sexual formation as those which we have been now considering, we are inclined to attribute very little weight to the nature of the sexual desires of the malformed individual, as we have already found Adelaide Preville, the dissection of whose body shewed him to be in reality a man, living for some years before death in the capacity of a wife, and the same remark might be further illustrated by a reference to Otto's and other cases.

A species of spurious hermaphroditism similar in character to that which we have just described in man, is occasionally met with in the males of our domestic quadrupeds, and has been amply illustrated, as it occurs in these animals, by Professor Gurlt in his work on Veterinary Medicine. In instances of this malformation among the animals to which we refer, the hypospadic male penis has usually been found of a tortuous and winding form and of small size. In the cases in which the fissure of the parts extends through the scrotum, a false vagina is seldom formed, as in man, for the scrotum in most quadrupeds lies too remote from the perinæum, and consequently from the normal situation of the vagina, for this purpose; but in some examples this division appears to be carried upwards into the perinæum itself, leaving a vaginal-like opening, in which the urethra terminates. The testicles, as in man, are sometimes retained within the abdomen, and in other instances descend into the scrotum. They are frequently small in size. The mamma or udder seems to be often well developed.

This variety of hermaphroditic malformation has been met with in the horse by Penchenati;* in the he-goat by Haller;† and in the ram by the same author,‡ and by Wagner,§ Wepfer,‖ Stark,¶ Gurlt,** Kauw Boerhaave,†† and A. Cooper.‡‡ We have seen an excellent specimen of this malformation in the last-mentioned animal in the museum of Dr. Handyside of Edinburgh. In this instance the internal male organs are all perfect; the large testicles are situated in the halves of the split scrotum; the penis is small and imperforate, and a furrow running along its inferior surface is continued backwards and upwards along the perinæum to within a short distance from the anus, where it leads into a canal, into which the urinary bladder and seminal ducts open. This canal is evidently formed of the dilated pelvic portion of the male urethra; its orifice is comparatively contracted, but corresponds in situation with the vulva of the female. We have seen a second similar case in the ram in the possession of Professor Dick of the Veterinary School of Edinburgh.

There is another variety of malformation of the male parts occasionally found in quadrupeds, which is allied in its nature to the preceding. In this second species all the external male sexual organs are small; the short penis lies, when not in a state of erection, upon the posterior surface of the enlarged udder, and the imperfectly developed testicles are generally retained within the abdomen; or, if they have passed out of that cavity, they are found situated in the substance of the udder. The vasa deferentia, prostate, and Cowper's glands are usually of their normal size and appearance. This imperfect hermaphroditic formation appears to be not rare among horses, several instances of it in this animal having been now described by Arnaud,* Gohier,† Volmar,‡ Pallas,§ Virey,‖ and Gurlt.¶ Anselmo** and Lecoq†† have met with this variety of malformation in the bull; and Sandford ‡‡ has described an instance in the calf which seems referable to the same head. Gurlt§§ also notices the preparation of an analogous case in the calf, as preserved in the museum at Berlin.

II. TRUE HERMAPHRODITISM.

True hermaphroditism exists as the normal type of sexual conformation in several classes of the vegetable and animal kingdom. Almost all phanerogamic plants, with the exception of those included under the class Diœcia, are furnished with both male and female reproductive organs, placed either upon the same flower, or, as in the Linnæan class Monœcia, upon different flowers in the same individual. In the class Polygamia various exceptional genera are included, that present indiscriminately upon the same individual, or upon different individuals of the same species, male, female, and hermaphrodite flowers, and which thus form a kind of connecting link between the general hermaphroditic form of phanerogamic vegetables, and the unisexual type of the monœcious flowers, and the diœcious plants.

From anormalities in developement, these normal conditions of the sexual type in the different members of the vegetable kingdom are occasionally observed to be changed. Thus, among the Diœcia, individual plants are sometimes, in consequence of a true malformation, observed to assume an hermaphroditic type of structure; or, on the other hand, in hermaphroditic plants more or fewer flowers are occa-

* Mém. de l'Acad. de Turin. tom. v. p. 18.

† Comment. Soc. Reg. Sc. Gotting. tom. i. p. 2, tab. i.

‡ Ibid. p. 5, tab. ii.

§ Ephem. Nat. Curios. Cent. i. ii. p. 235.

‖ Miscell. Nat. Curios. Dec. i. An. iii. (1672,) p. 255.

¶ Ibid. Dec. iii. Ann. v. vi., p. 669.

** Lehrbuch, p. 193.

†† Nov. Comment. Acad. Petropolit. tom. i. (1750,) p. 315, tab. xi.

‡‡ Catalogue of Guy's Hospital Museum, No. 2546.

* Arnaud sur les Hermaphrodites, p. 282.

† Mém. et Observ. sur la Chir. et la Méd. Vet. tom. i. p. 18.

‡ Archiv. für Thierheilkunde, Bd. iii. s. 292.

§ Beschaft. der Gesellschaft naturforch. Freunde zu Berlin, Bd. iii. s. 296.

‖ Journal Compl. des Sc. Méd. tom. xv. p. 140.

¶ Lehrbuch der Path. Anat. Bd. ii. p. 189; and tab. viii. fig. 6.

** Mém. de l' Acad. des Sc. de Turin, tom. ix. p. 103. fig. 1-3.

†† Journ. Prat. de Méd. Vet. 1827, p. 102.

‡‡ Med. and Phys. Journal, vol. ii. p. 305, with two drawings.

§§ Loc. cit. p. 191.

sionally found unisexual, in consequence of the arrested developement of one order of their sexual organs; and again, though still more rarely, from an excess of evolution, a double set of male parts, or a double set of stamens, is seen developed on some of the individual flowers.

In the animal kingdom we find instances of a perfect hermaphroditic structure as the normal form of the sexual type in the Trematodes and Cestoides among the Entozoa, in the abranchial Annelida, in the Planaria, and in many of the Mollusca, particularly in the Pteropoda, and in several families among the Gasteropoda. In some of these animals that are thus naturally hermaphroditic, the fecundation of the female organs of the bisexual individual is accomplished by its own male organs; but in others, although the anatomical structure is strictly hermaphroditic, yet the union of two, or, as sometimes happens, of more individuals is necessary to complete the sexual act; and during it the female organs of each are respectively impregnated by the male organs of the other.

In the Nematodes and Acanthocephali among the Entozoa, and in the Cephalopoda and Pectinibranchiate Gasteropoda among the Mollusca, as well as in all symmetrically formed animals, or, in other words, in those whose bodies are composed of an union of two similar halves, as in Insects, and the Arachnida, Crustacea, and Vertebrata, the male and female organs of reproduction are placed each upon a different individual of the species, constituting the basis of distinction between the two sexes. In such animals a mixture of more or fewer of the reproductive organs of the two sexes upon the same individual appears occasionally as a result of abnormal formation; but the male and female organs that coexist in these cases are seldom or never so anatomically perfect as to enable the malformed being to exercise the proper physiological function of either or of both of the two sexes. This form of true hermaphroditism or abnormal mixture upon the same individual of the organs of the two sexes in the higher animals, has been termed *unnatural* or *monstrous*, in opposition to the natural hermaphroditism which exists as the normal type of sexual structure in some of the lower orders of animals, and in phanerogamic plants. The malformation itself is observed to differ greatly, both in nature and degree, in different cases, varying from the presence or superaddition of a single organ only of the opposite or non-predominant sex, up to the development and co-existence of almost all the several parts of the two sexes upon the same individual. In describing the malformation, we shall classify its various and diversified forms under the three general orders pointed out in our table, including, 1st, *lateral*; 2dly, *transverse*; and 3dly, *double* or *vertical hermaphroditism*.

A. *Lateral hermaphroditism.* — According to the opinion of many physiologists of the present day, the two lateral symmetrical halves of the body, and even the two halves of all its single mesial organs, are originally developed in a great degree independently of one another. Granting this point in the doctrine of eccentric developement, we can easily conceive how, in the same embryo, an ovary might be formed on one Wolffian body, and a testicle on the other; or, in other words, how female organs might be developed on one side, and male organs on the other. It is the existence of such an unsymmetrical type of sexual structure upon the two opposite sides of the body of the same individual, that constitutes the distinctive characteristic of lateral hermaphroditism.

Instances of this species of true hermaphroditic malformation have been observed in many different classes of animals, as well as in the human subject.

Individual examples are sometimes observed among insects, particularly among the Lepidoptera, in which all the different parts of the two sides or lateral halves of the body are formed after opposite sexual types. We shall afterwards have occasion to notice different examples of this form of lateral hermaphroditism as seen in the general conformation of the body, but may here state that in two or three instances such malformed insects have been carefully dissected, and found to present, in the anatomical structure of their sexual organs, a mixture of the organs of the male and female.

In a *Melitæa didymus* described by Klug,* the general external characters were those of the male, but the left eye, palpus, and antenna, and the left sexual fang, were smaller than in individuals belonging to this sex; and the left antenna was annulated with white and yellow at the apex, while the right was of one colour. On dissection, the various male sexual parts were present, and they had appended to them a free female ovary situated upon the left, and united to no other organ.

In a *Gastrophaga quercifolia* dissected by Schultz, and described by Rudolphi,† the left side appeared externally male, and the right female, with a distinct line of separation throughout the whole body. On dissection, Schultz discovered an ovarium upon the right side, and two testes upon the left. The oviduct of the ovary joined the canal of the vasa deferentia about two inches before its termination; and the spermatheca was connected with the common evacuating duct. The two testicles on the left side were placed one behind the other, and connected by a thin vessel. The spermatic duct belonging to one of the testicles immediately received, as in the Lepidoptera, the spiral vessel; further beyond, and on the opposite side, a second vessel, which appeared to consist of the rudimental spermatic duct of the other testicle, opened into it. The oviduct of the ovary joined the canal of the vasa deferentia about two inches before its termination in the penis, and a female spermatheca was connected with the common distended evacuating duct.‡

* Froriep's Notizen, vol. x. p. 183.

† Abhandlung. der Kœnig. Akad. zu Berlin für 1825, s. 55.

‡ See also drawings of the body and genital organs of an hermaphrodite *Sphinx populi* in Fischer's Oryctographie du Gouvernement de Moscou (Moscow, 1830.)

A well-marked example of lateral hermaphroditism among the Crustacea has been recorded by Dr. Nicholls.* In a lobster (*Astacus marinus*) he found on the right side of the body a female sexual aperture in its normal situation at the root of the third leg, and connected with a regularly formed oviduct, full of ova. On the left side of the animal there was a male sexual aperture placed, as usual, at the root of the fifth leg, and connected internally with an equally perfect testicle and spermatic cord. The general external conformation of the animal corresponded with its internal sexual structure, the right lateral half of the body presenting all the secondary characters and peculiarities of the female, and the left all those of the male; so that if split from head to tail, (to use Dr. Nicholls' mode of expression,) the animal would have been perfectly female on the right side, and perfectly male on the left.

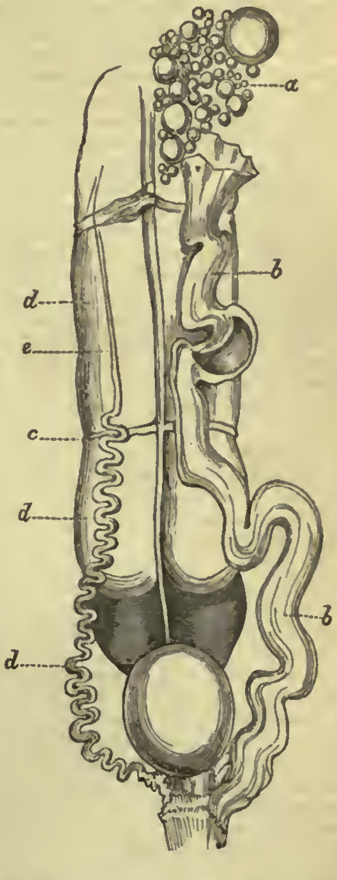
The investigations of Sir E. Home† led physiologists some years ago to believe that among Fishes lateral hermaphroditism constituted the natural type of sexual formation in the genera Myxine and Petromyzon; but the later and more accurate observations of Rathké‡ have shewn that these species are strictly bisexual, and that the opposite opinion had arisen from the kidneys of the female having been mistaken for the male testicles. Various instances, however, are on record of fishes, known to be normally bisexual, presenting from abnormal developement a lateral hermaphroditic structure, or a roe on one side, and a milt on the other. Such an hermaphroditic malformation has been met with in the genera *Salmo*,§ *Gadus*,|| and *Cyprinus*,¶ and in the *Merlangus vulgaris*,** *Acipenser huso*,†† and *Esox lucius*.‡‡

Of lateral hermaphroditism in Birds, we have one instance recorded by Bechstein,* in a chicken that had a testicle on the right side of the body, and an imperfect reniform ovary on the left. The external appearance of the bird presented a mixture of the characters of the two sexes.

Rudolphi has referred to a second and more ancient example of lateral hermaphroditism in the hen, mentioned by Heide.† The case, entitled by the author "galli qui putabatur hermaphroditus anatome rudis," is so imperfectly detailed as not to be entitled to much attention.

We have ourselves been fortunate enough to meet with two domestic fowls that presented in their sexual organization examples of lateral hermaphroditism. In the first of these cases (*fig.* 290) the female sexual organs were placed on the left side of the body, and the ovary (*a*) and oviduct (*b*) were in all respects apparently naturally formed. On the right side, a male vas deferens (*d*), of about half the normal length,

Fig. 290.



* Phil. Trans. for 1730, no. 413, vol. xxxvi. p. 290, with drawings of the animal, and of its reproductive organs.

† Phil. Trans. for 1823. Art. xii.

‡ Bemerkungen ueber den Innern Bau der Pricke, s. 119. See also additional observations by the same author in Müller's Archiv fur Anatomie, &c. for 1836. Heft. ii. s. 171. The older error of Cavolini, who supposed that he had detected two ovaries and two testicles in the *Perca marina* and *Labrus channa*, (Sulla Generazione dei Peschi et dei Granchi, Nap. 1787,) had been previously shewn by Rudolphi to depend upon his having mistaken undeveloped portions of the ovaries for testicles. (Schweigger's Skeletlose Thiere. s. 204; and Abhandlungen. Konig. Akad. der Wissenschaft zu Berlin, 1825. p. 48.)

§ Commercium Litter. Norim. 1734. Hebd. 39.

|| Pipping, Vetensk. Akad. nya Handl. (1800.) Bd. xxi. s. 33. tab. i. fig. 1. Leuwenhoeck, Experim. et Contempl. p. 150. Eph. Nat. Cur. Dec. i. Ann. i. obs. 125. Du Hamel, Traité des Poissons, Part ii. p. 130.

¶ Alischer, Breslau. Sammlung. 1720, p. 645; Morand, Mém. de l'Acad. des Sc. 1737. p. 72. Schwalbe, Commer. Lit. Norimb. 1734. p. 305.

** Marchant, Mém. de l'Acad. des Sc. 1737. p. 12. Baster, Opusc. Subcesiva, tom. i. p. 138.

†† Pallas, Reise durch Russe, &c. Theil. ii. s. 341.

‡‡ Reaumur, Mém. de l'Acad. 1737. p. 51. Starke, Eph. Nat. Cur. Dec. iii. ann. vii. and viii. obs. 109.

* Naturgeschichte der Voegel, &c. Bd. ii. s. 1219, (1807).

† Anatome Mytuli: subjecta est Centuria Obser. Amster. 1684, p. 193, obs. 95.

ran up from the cloaca to opposite the origin of the iliac vessels (*c*), and during this part of its course was bent into those short transverse zig-zag folds which characterise the structure of this part in the common cock. (See article Aves, vol. i. p. 354.) When it reached the middle third of the kidney (*d d*), it lost this particular form, became membranous (*e*), and after proceeding upwards for about an inch, in the common course of the canal, at last disappeared. The convoluted or contorted portion ran over a space of about two and a half inches, and if unrolled would have extended three or four times that length. Its canal was about the usual size of the same part in the perfect cock, and perhaps at some parts even more dilated. Its cavity was filled with a whitish seminal-looking albuminous fluid, which at first prevented a mercurial injection from readily passing through it. There was not any apparent vestige of a testicle. The fowl that was the subject of this malformation possessed in an imperfect degree the plumage, comb, spurs, and general appearance of the cock, and when young was considered to be a male until the time it commenced to lay eggs, which it did very constantly, except during the moulting season, up to the time of its death. Its eggs were remarked to be very large. They had repeatedly been tried to be hatched, but always without success. The bird itself was never known to incubate. It was peculiar in its habits in so far that in the barn-yard it did not associate with the other poultry, and at night roosted separately from them. It crowed regularly, especially in the morning, and often attempted copulation with the hens.

In the second case, the ovaries and oviduct on the left side of the body were, as in the former example, natural in themselves; but in the mesometry of the oviduct, a tube of the size of the male vas deferens was found. This tube, like the normal vas deferens, was thrown into the distinctive angular folds. It ran for about an inch and a half through the upper portion of the mesometry, was blind at either extremity, and admitted of being injected with quicksilver. On the right side, there was also a male vas deferens, marked with the characteristic angular folds. The contorted portion of this canal only stretched in this instance to about an inch above the cloaca; but the folds were even stronger than in the first case, and the tube itself was rather more dilated. Above or anterior to this convoluted part, the tube became straight and membraneous, and ran up in this form for about two inches in its usual track over the abdominal surface of the kidney; but there was not at its upper extremity any trace of a testicle. This bird presented during life, in a very slight degree only, the appearance of a cock, its comb and spurs being even less developed than in the previous case. It shewed the same solitary habits in the poultry-yard. It layed eggs regularly. On three different occasions I had a number of them submitted to incubation, but in none of them was a chick produced.

In the Quadruped, Schlump* has mentioned an instance of lateral hermaphroditic malformation. In a young calf he found on the left side, under the kidney, a small testicle having attached to it a vas deferens, which was connected with the peritonæum towards the abdominal ring of the same side, and there became lost in the cellular texture of the part. An ovary and Fallopian tube, with an uterus consisting of a single horn only, were connected to the right side of the loins by a ligament. The neck of the uterus lost itself in the cellular substance beneath the rectum, and there was no vagina. The external organs were male, but imperfectly formed. The udder occupied the place of the scrotum.

In the human subject several different instances of sexual malformation have now been met with referable to the head of lateral hermaphroditism. In these cases, along with a testicle on one side, and an ovary on the other, there has generally co-existed a more or less perfectly formed uterus. The external parts have differed in their sexual characters, in some instances being female, in others male, and in others again of a neutral or indeterminate type.

In man, and in the higher quadrupeds, we have not unfrequently exhibited to us a slight tendency to this unsymmetrical type of sexual structure constituting true lateral hermaphroditism in the testicle of one side only descending, whilst the other, in consequence of imperfect development, remains within the inguinal ring. In the single unsymmetrical ovary of most female birds and some fishes,† we see a still nearer approach to the state; and it is worthy of remark, that among birds at least, the single ovary is always placed upon the left side. In lateral hermaphrodites in the human subject, the left side also appears to be that on which we most frequently meet with the female type of the sexual organs. We shall divide the following cases according to the particular sides which were respectively male and female in them.

1. *Ovary on left side, and testes on the right.*— *a.* M. Sue met, in 1746, with an instance of lateral hermaphroditism in the human subject, in a young person of thirteen or fourteen years of age, whose case was the subject of a Thesis sustained by M. Morand.‡ Of the interual

* Archiv. fuer die Thierheilkunde, Bd. ii. Hft. ii. s. 204.

† In the early embryo of birds, the ovaries are originally double, as pointed out by Emmert, (see Reil's Archiv for 1811;) and as was previously known to Wolff and Hochsteller, (Anat. Phil. tom. i. p. 349.)

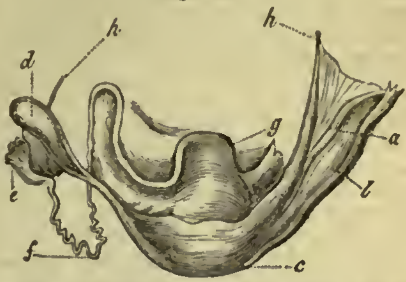
‡ De Hermaphroditis, Paris, 1749. This, according to Arnaud, (p. 323,) is the same case of lateral hermaphroditism with that described by Lecat. If so, the latter author, (probably from drawing his description from memory, and not, as Morand seems to have done, from the parts placed before him,) has stated that along with the testicle and vas deferens on the one side, there existed a vesicula seminalis, and that both sides were provided with round ligaments, the one on the male side forming probably one of the two tubes described by Morand as arising from the testicle.

genital organs, there existed on the *left* side a very distinct ovary, a round ligament which ran outwards to the groin of the same side, and a well-formed Fallopian tube with its usual fimbriated extremity. The other extremity of the Fallopian tube terminated in the fundus of the uterus, which occupied its usual situation between the bladder and rectum. On the *right* side, again, there was a slender elongated testicle, which had moved forwards to the corresponding inguinal canal, but had not proceeded so far as to pass out of the abdominal cavity. On the superior part of the testicle was a body resembling the epididymis, and the testicle itself sent off two tubes, which afterwards united into one immediately before their insertion into the uterus. The *external* genital organs were those of a hypospadic male, and during life the person had been always looked upon as belonging to the male sex. The perinæal canal or vagina terminated, between the scrotum and root of the imperforate penis, in a very small opening, which was common to it and to the meatus urinarius.

b. In 1754,* a young person of about eighteen years of age died in the Hôtel Dieu of Paris; and in dissecting his body, the anatomist, Varole, found the reproductive organs malformed in the following manner. On the *right* side the scrotum contained a testicle, and the vas deferens arising from it opened, not as usual into the neck, but into the middle of the external border of the corresponding vesicula seminalis. On the *left* side the scrotum was empty; and internally on this side there were found an ovary, a Fallopian tube with its fimbriated extremity, a small oval uterus without a neck and somewhat flattened, and a broad and round ligament, the last of which ran outwards, and was lost in the cellular tissue of the left half of the scrotum. The vesicula seminalis on the right, and the imperfect uterus on the left side, communicated by a canal of an inch and a half in length. The external organs were male; but the penis was very small, had no corpus spongiosum, and was imperforate for half an inch at its anterior extremity. The mammæ were as large as in women of the same age. The individual had been regarded during life as a male.

c. In 1825 the late Professor Rudolphi† detailed to the Academy of Sciences at Berlin the case of an infant who was reported to have died seven days after birth, and whose sexual organs exhibited the following interesting instance of lateral hermaphroditic conformation. On the left side were discovered an ovary (*fig*. 291, *a*), without a distinct broad ligament,

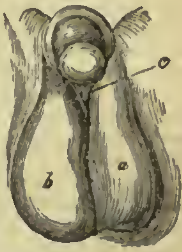
Fig. 291.



Uterus (c) turned downwards and forwards to show its posterior surface and connections, &c.

and a Fallopian tube (*b*), which communicated with the superior and left portion of an uterus (*c*). The left side of the scrotum (*fig*. 292, *a*), was empty; the right (*b*) contained a testicle (*fig*. 291, *d*) furnished with an epididymis (*e*) and tortuous vas deferens (*f*). Below the uterus there was a hard flattened ovoid body (*fig*. 291, *g*, and *fig*. 293, *b*), which, when divided was found to consist of a cavity with thick parietes, and was considered by Rudolphi as the prostate gland in a rudimentary state.

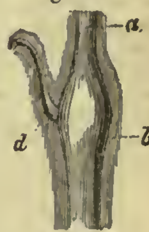
Fig. 292.



External organs.

The mouth of the uterus (*fig*. 293, *a*) terminated below in the parietes of this ovoid body, and on the right the vas deferens (*d*) penetrated into its substance, but without opening into its cavity. At the inferior part of the uterus there was a true vagina (*fig*. 293, *c*), which terminated in a cul-de-sac. The anus, rectum, and other organs were natural. The external sexual parts were male, but the penis was divided inferiorly (*fig*. 292, *c*). The testicle and ovary were supplied with the two usual spermatic arteries (*fig*. 291, *h h*).

Fig. 293.



Os uteri, vagina, prostate, and vas deferens.

d. Under the present section of lateral hermaphroditism, we may also, according to Mayer's report, include the celebrated case of Marie Derrier, or Charles Doerge.* This person was baptised and brought up as a female, but at forty years of age was persuaded to change his name and dress to those of a man. We have already alluded to the great diversity of opinion which was entertained by the medical men of

Meckel (Reil's Archiv. Bd. xi. s. 322,) considers Morand's and Lecat's as two different cases, and points out that what is described as the male side in the one, was the female in the other, and *vice versa*. It is, perhaps, not unworthy of remark, that in the coloured plate accompanying the translation of Morand's case by Gautier, the male and female sides have been reversed from an error in the engraving; and this circumstance may have contributed to mislead Lecat in his description, provided he happened to look to this notice of the case.

* Mém. de la Soc. Méd. de Paris, tom. iv. p. 342.

† Abhandlung. Konig. Akad. der Wissenschaft. zu Berlin für 1825, s. 60.

* Gazette Méd. de Paris (1836), no. 39. Lancet, v. i. for 1836-7, p. 140; or London Medical Gazette for October 29, 1836.

Europe in regard to the true sex of this individual. Even the different parts of his body were at one time referred to the male type, and at another time, and by other persons, to the female. The pelvis was the only part that was generally considered as decidedly female, yet the inspection of the body after death by Professor Mayer shewed that even in this respect all were in error.

Of the female sexual organs there existed an uterus, vagina, two Fallopian tubes, and an ovary ; and of the male, a testicle, and prostate gland and penis. The uterus was placed in its normal situation between the urinary bladder and rectum, but with its fundus directed in some degree to the left. The organ was extremely narrow, and two and a half inches in length. The cavity of its cervix presented on its inner surface some slight folds, but would scarcely admit a quill ; the cavity of its fundus was nearly half an inch across. The small canals of two Fallopian tubes opened into the fundus uteri. Their abdominal extremities were shut, but the corpora fimbriata were present. Near the extremity of the right Fallopian tube, which was four inches and four lines in length, a small flattened almond-shaped body was placed, which on examination proved to be distinctly a testicle. It was completely enveloped in peritonæum, and received a cord composed of muscular fibres, and of a spermatic vein and artery. Its internal structure was yellow and filamentous, like that of the testicle, and its seminiferous tubes could be easily separated. The left Fallopian tube was an inch shorter than the right; and a little outside and behind its abdominal extremity another small flattened body was found inclosed in the peritonæum. It resembled an ovary rather than a testicle. Its tissue was composed of small granules conglomerated together. The penis was two inches and nine lines in length, and was for the greater part concealed underneath the mons veneris. During life it was capable of erection, and was then elongated to more than three inches. The prepuce covered only half the glans. There was not any corpus spongiosum. A fossa or groove, representing an urethral canal divided inferiorly, ran along the under surface of the penis. The two folds of skin forming the sides of the groove separated from each other posteriorly, and might be compared to nymphæ. Towards the root of the penis, by uniting inferiorly with a puckering of the skin of the labia majora or divided halves of the scrotum, they formed a circular orifice not larger than a quill, having some bodies, supposed to be vestiges of the carunculæ myrtiformes, at its lower edge, and leading to a short vestibule, or common canal, into which the urethra, surrounded by a firm but small prostate, entered from above, and the vagina, encircled at its entrance by a vascular ring of varicose veins, opened from below. The vagina was two inches and eight lines in length, and only ten lines at its greatest breadth. Its inner surface was somewhat wrinkled anteriorly, but smooth behind. It terminated above in a kind of spongy isthmus representing the blind orifice of the uterus, and from four to six lines in length. The diameters and form of the pelvis were, on dissection, found to be most evidently masculine.

The general character of Doerge was a mixture of the male and female type. When between twenty and thirty, he had been examined by different medical men in Germany, France, and England, and, as we have already mentioned, the most contradictory opinions were offered upon his real sex. The breasts were not much developed, and there was no distinct mammary glandular structure. His stature was small (five feet). As he had advanced in age, his voice had become more firm and grave, and a slight trace of beard had appeared; but his head and face presented the aspect of that of an old woman. His neck was short, and the thyroid cartilage did not project much : his chest was fat and full. During the last few years of his life he was subject to epistaxis and hæmorrhoids, but did not present any trace of sanguineous discharge from the genital organs,—a phenomenon which was alleged to have manifested itself three times during his twentieth year.

The right hemispheres of the cerebrum and cerebellum, particularly that of the latter, were smaller and less developed than the left, and the left side of the occiput was externally more prominent than the right. He is stated by Professor Mayer to have shewn a certain predilection for females, without, however, feeling any sexual desire.

2. *Testicle on the left, and ovary on the right side.*—An instance of malformation of the reproductive organs minutely described by Maret,* and which is in all its more essential anatomical points an example of lateral hermaphroditism, may be included under this head.

a. The subject of the case (Hubert Jean Pierre) died in the hospital at Dijon in 1767, at the age of seventeen. On the left side a perfect testicle was discovered with its usual spermatic vessels, vas deferens, and vesicula seminalis, all occupying the natural situation in which they are placed in the male adult. The vesicula seminalis contained a fluid of the colour and consistence of semen. On the *right* side an oblong cystic tumour was found lying in the iliac fossa, and stretching outwards into the inguinal region. On opening it a quantity of reddish limpid fluid escaped, and then the solid contents of the tumour were seen to consist of a somewhat flattened body, that gave off from the upper part from its right side a short Fallopian tube; and at the fimbriated extremity of this tube an ovary of the natural size, consistence, and figure, was situated. The roundish shaped body to which the tube was attached was about an inch and a half in its greatest, and an inch in its smallest diameter. It contained in its centre a small cavity continuous with that of the tube,—a circumstance, which, along with the structure of its walls, left little doubt that the body itself was an imperfectly formed uterus. No other opening except that of the tube could be traced into its cavity. Its external surface

* Mém. de l'Acad. de Dijon, t. ii. p. 157.

was attached to the ovary by a kind of ligament. On this same side of the body (the right) there existed also a vesicula seminalis, but smaller and more shrivelled than that on the left. It gave off a vas deferens, which became gradually smaller as it was traced backwards, and at last disappeared altogether without being connected with any structure resembling a testicle. In regard to the external organs of generation, the penis was four inches long and imperforate, but in all other respects perfectly formed. It possessed a corpus spongiosum, which does not exist in the female clitoris. On raising the penis, it was observed to cover a large fissure, the sides of which resembled the labia of a female. In the left labium or left half of the scrotum the testicle already alluded to was placed, but there was none in the right. When the labia were separated, two red spongy bodies were seen, resembling the nymphæ in appearance, and seemingly consisting of the sides of the split urethra. Between these bodies and at their upper part, the urethra opened as in the female; while below there was a very narrow aperture covered by a semilunar membrane, and presenting on one side of its entrance a small excrescence somewhat resembling in figure a caruncula myrtiformis. This orifice led into a membranous canal or cul-de-sac an inch in depth, and half an inch in diameter. On the lower part of this canal the verumontanum and orifices of the seminal ducts of both sides were discovered.

During life Pierre had been considered a male, but was not known to have shown any partiality for the female sex. His countenance was more delicate than what we ordinarily see in the male sex. There was no beard on the face; the larynx was not enlarged as in man; and the mammæ, each of which was furnished with a very large areola, were of a moderate size and roundish form. The configuration of the lower part of the body was more decidedly masculine, and there was none of that enlargement of the buttocks and projection of the thighs, from the increased width of the pelvis, which is observable in young females.

In this case we have on the *left* side of the body male sexual organs, consisting of a perfect testicle, vas deferens, and vesicula seminalis. On the *right* side, again, we have a female ovary and Fallopian tube with a rudimentary uterus, together with an imperfect male vesicula seminalis and vas deferens.

Arnaud mentions a very imperfect form of lateral hermaphroditism as having been recognised by M. Boudou, surgeon to the Hôtel-Dieu of Paris, on the person of a monk who died in that hospital in 1726. The external genital parts were those of a hypospadic male. In one of the halves of the scrotum a testicle was found; the other was empty. The seminal canals and vesiculæ seminales on the side on which the perfect testicle existed were natural in their course and situation. Those of the opposite side lost themselves between the bladder and rectum in a small body, which, in M. Boudou's opinion, was a shrunk uterus.*

Among the preceding cases of lateral hermaphroditism in the human subject, there are four in which the left side, and one only in which the right was the female. In the last instance quoted from Boudou the respective sides on which the male and female organs were placed are not stated by Arnaud.

B. *Transverse hermaphroditism.*—In the variety of hermaphroditic malformation which we have last considered, we have found upon the same individual the reproductive organs of one side disagreeing in their sexual type from those of the other. In the present division we have a similar sexual antagonism following a different direction; for supposing the internal sexual apparatus to be divided from the external by a transverse line, we have, in transverse hermaphroditism, on each side of this partition, organs of an opposite sexual type: in other words, the organs of reproduction (in the more correct sense of the word) or the internal sexual organs do not, in the present species of hermaphroditism, correspond in type with the organs of copulation, or the external sexual parts,—a circumstance the occasional occurrence of which tends to shew that these two portions of the generative apparatus are in some degree independent of one another in their normal development and existence, and consequently also in their abnormal formations.

Transverse hermaphroditism varies in its character according to the relative positions occupied by the co-existing male and female organs; the external organs, or all those exterior to the supposed transverse line, being sometimes female, and the internal male, and *vice versâ*.

1. *Transverse hermaphroditism with the external sexual organs of the female type.*—In the cases included under this division, the external genital organs consist of a clitoris, vagina, and uterus; the uterus is often rudimentary, and sometimes altogether absent and replaced by the male vesiculæ seminales. The male internal organs are the testicles, generally small and imperfectly developed, and placed either within or without the abdomen, with vasa deferentia terminating in the uterus and vagina.

This variety of sexual malformation has been repeatedly observed among our domestic quadrupeds, particularly among black cattle. Mr. John Hunter, in an essay read before the Royal Society in 1779, and published in their Transactions,† and in his Observations on the Animal Economy, shewed that, (as had been long known among agriculturists,) when among black cattle the cow brings forth twin calves, one of them a male, and the other apparently a female, the male is a perfect bull calf, but the female, while it has all the external marks of a cow-calf, as the teats and udder, is still, with a few exceptions, imperfectly formed in its

* Arnaud, loc. cit. p. 283.

† Vol. lxix.

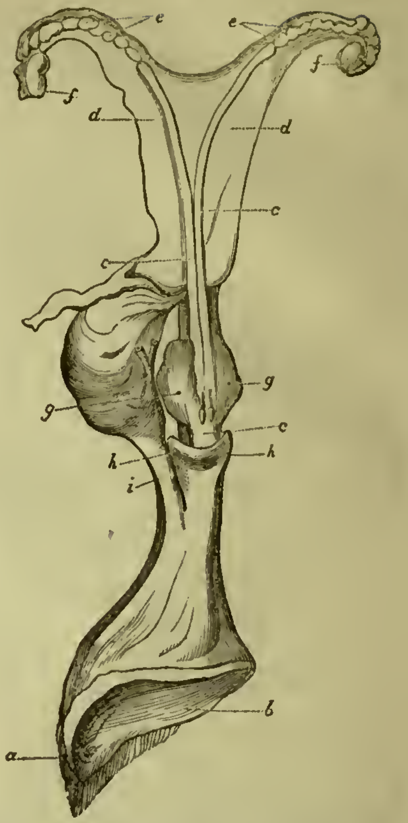
internal sexual organs, and very generally presents a mixture of the organs of the two sexes in various degrees. Such hermaphroditic twin cattle have long been distinguisbed in this country under the name of *free-martins.* In some exceptional cases only have they been observed capable of breeding; and generally they shew no sexual desire for the bull, or the bull for them. In appearance they resemble the ox or spayed heifer, and have a similar, or still greater disposition to become fat under the use of good food.

In the paper to which we have referred, Mr. Hunter has described the dissection of three free-martins: and one of these seems to belong to our present division of female transverse hermaphroditism. The clitoris and external parts appear to have been strictly of the female type, and there was a small udder with four teats. The vagina terminated in a blind end a little beyond the opening of the urethra, and from this point the vagina and uterus were impervious. The uterus at its superior part divided into two horns, and at the terminations of these horns, not ovaria, but bodies resembling the male testicles were found. These bodies had not a perfect internal structure like that of testicles, but resembled these organs in so far that, 1st, they were nearly as large as the male testes, and much larger than the female ovaries; 2nd, they were supplied with tortuous spermatic arteries like those of the bull or rigdil; and 3d, cremaster muscles passed up to them, as in rigdils, from the abdominal rings. There were two small vesiculæ seminales placed behind between the bladder and uterus, with their ducts opening into the vagina. Nothing, according to Mr. Hunter, similar to the vasa deferentia was present; but Gurlt is inclined to believe that the parts which Mr. Hunter has described as the horns of the uterus were really the deferent vessels.

Professor Gurlt* has himself given, from a preparation in the Museum of the Berlin Veterinary School, the accompanying sketch of the malformed sexual organs of a five-year old free-martin, (*fig.* 294,) which presents to us an illustration of Mr. Hunter's supposed mistake, at the same time that it affords a well-marked example of transverse hermaphroditism. The detail of the anatomical peculiarities of the case has been unfortunately omitted by the author, but from the short explanations appended to the drawing, it appears that the clitoris (*a*) and external pudenda (*b*) were perfectly feminine, and that the vagina, short and funnel-shaped, terminated at its superior contracted extremity in two vasa deferentia (c c c), which were carried upwards in a duplicature of peritonæum (*d d*) resembling the broad ligament, until they joined the unrolled and lengthened epididymes (*e e*) of two small testicles (*f f*) placed in the position of the ovaries. Near the junction of the vagina and vasa deferentia bodies resembling the male vesiculæ seminales

* Lehrbuch der Pathol. Anat. d. Saug. Th. Bd. ii. S. 186.

Fig. 294.



(*g g*) and Cowper's glands (*h h*) were situated, and the urethral canal (*i*) opened into the vagina and was shorter than it usually is in the cow.

We have found upon a free-martin cow a state of the sexual apparatus very much resembling that figured in the above case by Professor Gurlt. The two vasa deferentia, as they ran in the duplicature of the peritonæum, had very much the appearance and shape of an imperfectly developed uterus. The vesiculæ seminales were large; the vasa deferentia were quite impervious throughout their whole course; and the bodies placed at their abdominal extremities were large, but of so indeterminate a structure as not to enable us to pronounce them to be either true testicles or ovaries.

M. Geoffroy St. Hilaire published in 1834 a very distinct case of an hermaphroditic goat which had two male testicles and epididymes with a two-horned uterus and female external parts.* M. Isidore St. Hilaire† mentions a nearly analogous case in the same animal, and quotes a third from Bomare which was observed upon a deer.‡

* Nouv. Ann. du Museum d'Hist. Nat. t. ii. p. 141.

† Histoire des Anomalies, t. ii. p. 128.

‡ Journ. de Phys. t. vi. p. 501.

To the present division of transverse hermaphroditic malformation with external female and internal male organs, we may probably also refer the case of the hermaphrodite dog detailed by Sir E. Home,* and three instances in the sheep described by Ruysch,† Herholdt,‡ and Gurlt.§ In all these instances imperfectly developed testicles were situated either within the abdomen or without it upon the udder, at the same time that the external parts exhibited in a more or less marked degree the peculiarities of the female sex; the vagina was, however, narrower, and the clitoris more developed than in the perfectly formed female; and in the dog mentioned by Home, this latter organ was very large, being three quarters of an inch long, and half an inch broad, but still it could not properly be considered as an imperfect penis, since the bone, which forms the distinguishing mark of that organ in the dog, was wanting.

Few well-marked instances of transverse hermaphroditism with external female organs have been hitherto described as observed in the human subject, unless we regard as an approach to it the numerous cases, already referred to, of spurious hermaphroditic malformation in the male from hypospadic division of the urethra, scrotum, and perinæum.

a. In his essay on hermaphroditism, however, Steghlehner‖ has detailed at great length the particulars of a case belonging to the present variety, which he met with on the body of a woman who died of phthisis at the age of twenty-three. The external sexual organs were all of the female type and in general well formed, though the clitoris and nymphæ were perhaps smaller than natural, and the orificium vaginæ was rather contracted and half shut up by a hymen. The fossa navicularis was very distinct, and the vagina normally situated, but extremely short and narrow. Its internal surface presented an appearance of transverse and longitudinal rugæ, but its upper extremity formed a blind sac, and no traces could be found beyond it of the uterus, nor indeed any vestiges whatever of the other internal female organs, the ovaries and Fallopian tubes. On more minute examination a testicle with its spermatic cord was found in each inguinal region, placed outside the external ring, and surrounded with their cremaster muscles and vaginal coats. The testicles were flaccid and small, but their internal structure and that of their epididymes was natural; and the slender pervious vasa deferentia arising from them entered the abdomen, descended into the pelvis, and were joined behind the urinary bladder by two vesiculæ seminales of considerable size. Their common ejaculatory ducts opened into the vagina. The form of the thorax and pelvis, and of the body in general, was feminine; and the mammæ and nipples were well developed, but the larynx was rather more protuberant than in females, and the voice approached in tone to that of a man. There had never been any menstrual discharge, but the periodical molimina indicative of its appearance were said to have been observed regularly. There were some hæmorrhoidal tumours situated around the anus.

b. If possible a still more perfect example of the present variety of transverse hermaphroditism in the human subject has lately been observed at Naples. The malformation occurred in the person of an individual Maria E. Arsano, who died at the age of eighty in one of the pauper charities at Naples, and who had passed through life as a female and been married as such. No suspicion of the malformation existed during life, and it was only at first accidentally discovered in preparing the dead body for demonstration in the anatomical theatre of Professor Ricco, who afterwards carefully dissected the malformed parts in company with Professors Sorrentino and Grosetti. We have taken the following account and sketches from Ricco's published description of the case.*

The external organs of generation were those of the female in their natural or normal state, consisting of the mons veneris with a scanty quantity of hair (*fig.* 295, *a*); of the labia ex-

Fig. 295.

terna (*fig.* 295 & 296, *b b*) naturally formed, and the nymphæ (*fig.* 295 & 296, *d d*); of the clitoris (*fig.* 295 & 296, *c*), which was perfectly imperforate, and of the ordinary size of the same organ in the adult female; of the orifice of the urethra (*fig.* 295 & 296, *e*) situated below the clitoris; and of the os vaginæ (*fig.* 295 & 296, *f*), which was of the usual size and diameter. Altogether the aperture of the vulva was natural. The canal of the urethra was of the usual length, as seen at *u* in the section

* Phil. Trans. for 1795, p. 157. Comp. Anat. iii. 323.

† Thesaur. Anat. viii. n. c. iii. tab. 115.

‡ Viborg's Sammlungs fuer Thierartze (1797.) s. 25.

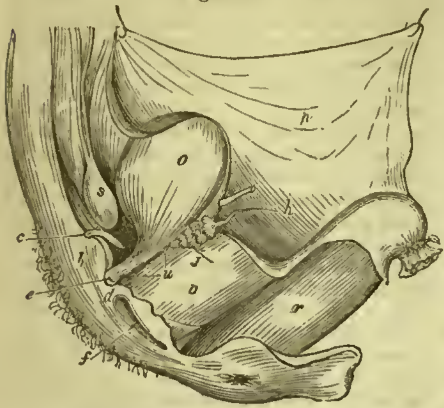
§ Lehrbuch, &c. Bd. ii. s. 186. tab. ix. 2. and xxii. s. 2.

‖ Tract. de Hermaphr. naturâ, p. 120.

* Cenno Storico su di un Neutro-Uomo, p. 5, 7.

of the pelvis represented in *fig.* 296, in which *s* marks the divided symphysis pubis, and *p* the

Fig. 296.



peritonæum. The os vaginæ shewed no vestiges of the membrane of the hymen, or, in other words, was without carunculæ myrtiformes. The canal of the vagina *(fig.* 296, *v)* was about two inches long, but without rugæ, and it terminated internally in a completely blind extremity or cul-de-sac. The uterus was entirely wanting, as were also the Fallopian tubes and uterine ligaments.

The internal organs of reproduction were, on the other hand, completely male. The two testicles *(fig.* 295, *g g)* were situated in the region of the pubis, and were scarcely clear of the inguinal rings. They were of the usual ovoid figure, and natural in size. They had internally the structure of the tubuli seminiferi, but it was not well developed. The spermatic cords were quite normal both in regard to their composition and the origin and course of their bloodvessels. The right spermatic artery *(fig.* 295, *l)* arose, as usual, from the renal, and the corresponding vein (*m*), after forming the pampiniform plexus (*k*), opened into the vena cava inferior; while on the left side the artery (*l*) arose from the aorta, and the vein (*m*) terminated in the left emulgent. The epididymes of the testes were also of the usual vermiform figure, and the corresponding vasa deferentia *(fig.* 295 & 296 *h h)* coursed towards their vesiculæ seminales *(fig.* 296, *j)*, and terminated in an attenuated membranous expansion without any external aperture or ducti ejaculatorii. The vesiculæ seminales (see the left one *j* in *fig.* 296) were placed between the urinary bladder (*o*) and rectum (*r*); they were smaller and more shrunk than those of the adult male, though certainly they preserved their naturally oblong form. Their internal hollow or tubular structure was indistinct. The prostate gland was not present. The urinary bladder (*o*) and ureters (*n n*), the rectum (*r*), and the other intestinal viscera, with the abdominal bloodvessels (*s*, the aorta, *t*, the vena cava, *fig.* 295) seem to have been all quite natural.

The head of the above individual was of the usual size, the neck long, and the stature ordinary. The periphery of the thorax was so expanded as almost to equal that of the male, notwithstanding the presence of well pronounced mammæ. The face, although entirely free from hair, had yet neither the expression of that of a female nor of a male, but shewed more of that mixed character which is seen in the eunuch. The pelvis was altogether that of a male in its form and dimensions, and the limbs were perfectly masculine. According to information collected after death, the voice was deep, and the temperament strong and firm. Though there was never any menstruation, yet, from being constantly employed in domestic occupation, the mental character was feminine, and the married state had been willingly entered into.

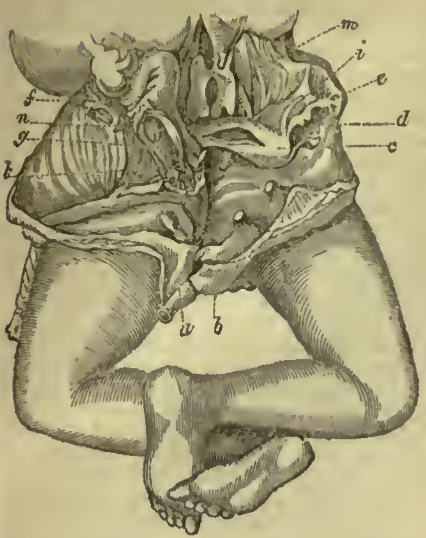
2. *Transverse hermaphroditism with the external sexual organs of the male type.*—The male organs that are present consist of the penis, which is provided with a regular formed prepuce, glans, corpora cavernosa, and corpus spongiosum, with the urethra perforating it, and of the prostate gland, verumontanum, &c. The co-existing female organs are the ovaries, the Fallopian tubes with their infundibula, and the uterus.

We are not aware of any recorded instances of this variety of hermaphroditic malformation among the lower animals. We have already, under the head of spurious hermaphroditism in the female from enlargement of the clitoris, &c., mentioned several cases, in which, from excessive developement, the external organs in women had assumed some of the characters of the corresponding parts in man; but the two following cases described by Professors Eschricht of Copenhagen, and Bouillaud of Paris, present instances of malformation in which the more exterior sexual organs were all formed upon the male, and the internal upon the female type.

a. The subject of the case described by Eschricht* was a twin child that died very shortly after birth, and in whom the external sexual organs were of the male type, and the internal female. The penis *(fig.* 297, *a)* and scrotum (*b*) were well developed, but the usual raphé seen upon the latter was absent. The urethral canal of the glans and body of the penis was pervious throughout, and admitted of a sound being easily passed into the bladder. The glans was remarkably thin and slender. The prepuce could be easily pushed back. No testicles could be felt in the scrotum, and internally there was an uterus with Fallopian tubes and ovaries. The uterus (*c*) was about an inch in length, and had the general form presented by this organ in female infants. It contained a cavity marked with rugæ, but had no orifice inferiorly, nor any vagina attached to it. Its blind or imperforate neck was firmly attached to the posterior walls of the urinary bladder (*g*), while its fundus was directed very obliquely downwards and over to the left side. From the left side of the fundus of the uterus a twisted Fallopian tube (*d*) proceeded, having

* Müller's Archiv fuer Anatomie, &c. 1836, Heft ii.

Fig. 297.



well developed fimbriæ (*e*) at its abdominal extremity, and the broad ligament or fold of peritonæum along which it ran contained an oblong soft body (*i*), (which Eschricht considered as distinctly an ovary,) and a round ligament that took its course through the inguinal canal of the same side. On the right side an ovary (*k*) and Fallopian tube (*f*) were likewise discovered, but they were displaced and separated from the body of the uterus. The ovary lay in the iliac region, and above it and towards its outer side was placed the fimbriated extremity of the corresponding Fallopian tube. The tube presented towards this extremity a vesicular swelling of the size of a small pea, which admitted of being inflated and filled with quicksilver through a small opening between the fimbriæ. Below this it was impervious, and apparently diverged off into two prolongations, one of which (the round ligament) passed down into the inguinal canal, and the other crossed over with a fold of peritonæum to where the rectum and urinary bladder were preternaturally connected together. Professor Jacobson suggested that this latter part was a rudiment of the right half or horn of the uterus. It may perhaps, however, be more properly regarded as the commencement of the right Fallopian tube, and in this case it would, if continued onwards, have been joined to the neck of the uterus,—an arrangement which would be quite in accordance with the usual deep and displaced origin of one of the tubes in instances of congenital obliquity of the uterus.

The child was malformed in other respects also. The anus was imperforate, and the rectum (*n*) opened into the urinary bladder, which was very contracted. The kidneys (*m*) were irregularly formed, and lay near the promontory of the sacrum. There was an accessory spleen, and the formation of the heart and large vessels was abnormal. The other twin child was well formed and lived.

b. The case of transverse hermaphroditism observed by Bouillaud* was even still better marked than that of Eschricht. Valmont, the individual who was the subject of it, died in one of the hospitals of Paris of the epidemic cholera. He was a hatter by trade, and had been married as a male. No further particulars of his history or habits could be obtained. The following was found by MM. Manec and Bouillaud to be the state of the external and internal sexual organs.

Externally there was a penis (*fig*. 298) of a

Fig. 298.

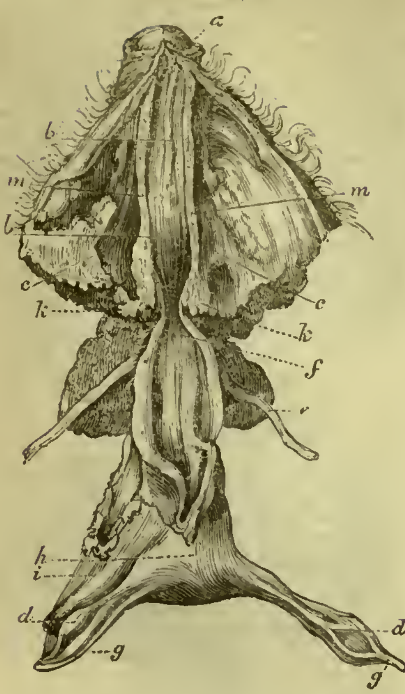
medium size, terminating in a regularly formed glans (*a*), and furnished with a prepuce (*b*).

The urethra (*fig*. 299, *b b*) opened on the inferior side of the glans (*fig*. 298 & 299, *a*). In its course from this point backwards to the bladder, it perfectly resembled the urethra of the male, and was surrounded at its origin by a well-formed prostate gland (*fig*. 299, *k k*). Cowper's glands were also present (*fig*. 298, *d*). The verumontanum or caput gallinaginis was distinct, as well as the orifices of the prostatic follicles; but the usual openings of the seminal canals could not be found. The corpus spongiosum urethræ (*fig*. 298, *g*) and the corpora cavernosa (*fig*. 299, *m m*) were as well developed as in the perfect male subject. The scrotum was small, and did not contain any testicles; it presented on its middle a line or raphé extending from the prepuce to the anus, and which was harder and better marked than it usually is upon male subjects. The various muscles of the male perinæum (*fig*. 298, *c c*) were present, and very perfectly formed. The constrictores urinæ muscles (*e*) were particularly long and thick.

In the cavity of the pelvis two ovaries (*fig*. 299, *d d*), similar in form and structure, according to M. Manec, to those of a girl of fifteen or sixteen years of age, or (to adopt

* Journ. Hebdom. de Méd., tom. x. p. 466. "Exposition Raisonnée d'un cas de nouvelle et singulière variété d'hermaphrodisme observée chez l'homme."

Fig. 299.



M. Bouillaud's statement) two bodies in some sort fibrous, and perhaps intermediate in their structure between ovaries and testicles, were found along with two Fallopian tubes (*fig.* 299, *g g*), having each a fimbriated extremity at one end, and opening by the other into the cavity of an uterus (*h*) which occupied the usual situation of that organ in the female, and opened inferiorly into a kind of vagina (*e*). The internal surface of the uterus showed the usual arborescent wrinkles of this organ in the unimpregnated state; the os tincæ was regularly formed; the vagina was about two inches long, and of a middle size, and presented internally numerous ridges, such as are met with in virgins. This canal, when opposite the neck of the bladder at *f*, became much contracted, and was continued downwards in the form of a small tube to the membraneous portion of the urethra, into which it entered by a narrow orifice. The broad ligaments of the uterus were normally formed; the round ligaments passed through the inguinal canal accompanied each by an artery larger than that of the corresponding one in the female sex.

The external appearance and form of Valmont are described by M. Bouillaud as having been intermediate between those of the male and female sex. The stature was short; the mammary glands and nipples were well developed; the face was bearded; but the general physiognomy was still delicate. The body was fat; the hands and feet were small; the pelvis was shallow; and the haunches were wider than in a well-formed man.

C. *Double or vertical hermaphroditism.*—In the two divisions or orders of true hermaphroditism which have been already considered, we have seen re-united upon the body of the same individual more or fewer of the organs of the two sexes, but so arranged as not necessarily at least to present the occurrence of actual duplicity in any of the corresponding male and female parts. In both lateral and transverse hermaphroditism the type of the sexual apparatus is in fact *single* in so far that it consists, in almost all cases, in the presence at one part of an organ or organs differing in sexual type from those that are present at other parts, without there necessarily co-existing at any one point the two corresponding male and female organs. In the present or third variety, however, of true hermaphroditism, we come to a tendency to actual sexual duplicity, in the co-existence of two or more of the analogous organs of the two sexes upon the same side, or in the same vertical line of the body. For, supposing we viewed, either from before or behind, the reproductive organs belonging to the two sexes all stretched out upon the same erect plane, so that their corresponding organs should be exactly superimposed upon one another,—as the two female ovaries upon the two male testicles, the Fallopian tubes upon the vasa deferentia, the uterus upon the vesiculæ seminales and prostate gland, &c.,—we should find in vertical or double hermaphroditism more or fewer of those analogous organs of the two sexes that were thus placed upon one another, and that consequently lay in the same vertical line, or upon the same side of the body, co-existing together at the same time upon the same individual.

Double, vertical, or complex hermaphroditism differs much in variety and degree in different cases, from the imperfect repetition of two only of the corresponding organs of the male and female upon the same body, to the reunion or co-existence of almost all the genital organs of both sexes upon one individual.

For the purpose of contrasting and collecting together as much as possible the more analogous cases, we shall arrange the instances of double hermaphroditism under three genera or divisions; the *first* including cases in which there co-existed a female uterus and male vesiculæ seminales, with a general female type; the *second*, those in which a female *uterus*, occasionally provided with Fallopian tubes, was added to an organization that was in other respects essentially male; and the *third* comprehending all examples in which ovaries and testicles are alleged to have been repeated together upon one or both sides of the body. Other divisions of double hermaphroditism may become necessary under the accumulation of new varieties of cases, but we believe it will be possible to arrange all the instances hitherto recorded under one or other of the above divisions. In classifying and describing these instances we shall in the meanwhile offer no observations on the probable anatomical mistakes that have been committed in the examination of individual cases. We reserve this important subject for special consideration under a separate head, where we shall endeavour to shew the numerous sources of error with which the observation of individual examples and varieties of complex hermaphroditism is beset.

1. *Male vesiculæ seminales, &c. superadded to organs of a female sexual type.*—In this first genus of double hermaphroditism we find two female ovaries, or bodies resembling ovaries, and an imperfect uterus co-existing with two male vesiculæ seminales, which are occasionally accompanied also with rudiments of the vasa deferentia. One of the free-martins described by Mr. Hunter* is referable to this variety of double hermaphroditism. The external genital organs and mammæ resembled those of the cow, but were smaller in size. The vagina, beyond the opening of the urethra into it, was, with the uterus itself, impervious. The imperfect uterus divided into two horns, at the end of which were the ovaria. On each side of the uterus there was an interrupted vas deferens broken off in several places; and between the bladder and vagina these vasa deferentia terminated in two vesiculæ seminales. The ducts from the vesiculæ and the vasa deferentia opened into the vagina. In this instance we have all the female organs present, but imperfect in their development; and at the same time there is superadded to them a tubular structure, formed, according to Mr. Hunter's opinion, of the male vesiculæ seminales and vasa deferentia.

We have met with a free-martin cow, in which upon dissection we found an arrangement of sexual parts very similar to that described in the preceding case. The uterus, however, though small, was pervious for a distance of some inches above the vagina; and at the abdominal end of each blind Fallopian tube there was a dilated sac of considerable size lined by peritonæum, and opening into the abdominal cavity by a small orifice. These sacs we considered as abortive attempts at the formation of the fimbriated extremities. The imperfect bodies which we considered as testicles were placed near the cavities which we mention, in the situation of the ovaries. They were small in size, and of an oblong shape. On a section being made of them, they shewed internally a kind of dense homogeneous yellow tissue, dotted or crossed with strongly marked white lines. The vasa deferentia could be traced along each side of the uterus in the form of broken dense cords. The vesiculæ seminales were large and partially hollow, and near them on each side there was an oblong body of considerable size, having the appearance of Cowper's glands. The tubes from them, and from the vesiculæ seminales, opened near the os tincæ into a vagina of nearly the usual size.

2. *An imperfect female uterus, &c. superadded to a sexual organization essentially male.*—In the cases included under this second division of double hermaphroditism there exist a male testicle, or testicles, vasa deferentia, and vesiculæ seminales, along with a female uterus. The uterus occupies its normal situation between the bladder and rectum. It is sometimes defectively developed, and of a membranous structure; and occasionally it is not provided with Fallopian tubes, or, in the quadruped, with cornua. The cavity of the uterus communicates with a vagina that either opens in its usual situation externally, or, as happens more frequently, joins the male urethra. In some cases the vagina is wanting, and the uterus opens directly into the canal of the urethra.

Several cases of sexual malformation in the ram, goat, and dog referable to this variety of double hermaphroditism have been described by different authors; and various analogous instances have now also been observed in the human subject.

In a lamb described and delineated by Mr. Thomas,* all the external parts were male, but the scrotum was divided or hypospadic. Internally there were two perfect male testicles in the situation of the ovaries, with their epididymes, vasa deferentia, and vesiculæ seminales; and a well-formed two-horned uterus furnished with its usual ligaments, and with Fallopian tubes that ran up and terminated in a tortuous convoluted manner upon the testicles. The body of the uterus possessed the common rugose structure, but the horns were lined by a smooth membrane without their usual glandular bodies internally. At the anterior extremity of the fundus uteri, a thick semilunar valve, which seemed to correspond to the os tincæ, passed across and hardly allowed a fine probe to be entered over its upper edge. The vagina scarcely existed, and formed only a short smooth pouch terminating below in a cul-de-sac. The male vesiculæ seminales and vasa deferentia entered the male urethra in their normal situation at the caput gallinaginis.

Gurlt† has described and delineated the sexual parts of a goat in which all the internal male genital organs, with the exception of Cowper's glands, were found (*fig.* 300). There was also present an uterus (*c*) provided with long but narrow and curved cornua (*f f*), that accompanied the vasa deferentia and testicles through the abdominal rings, and ended blind at the epididymes. The testicles lay externally upon the udder, which was of considerable size. The scrotum was absent; the penis (*g*) was short, tortuous, and imperforate; and there was a fissure in the perinæum into which the urethra (*h*) opened.

Stellati‡ has recorded an analogous case in the same animal. The male sexual organs

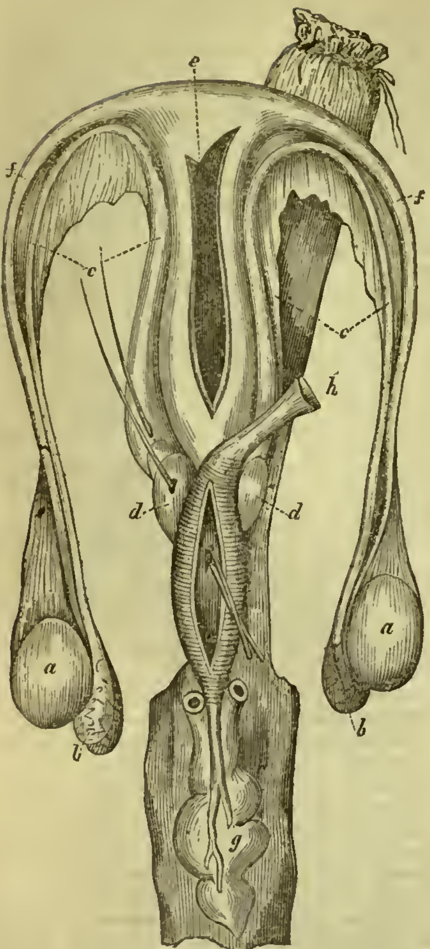
* See An. Econ. p. 64. Mr. Well's free-martin.

* London Med. and Phys. Journ. vol. ii. (1799), p. 1, with a good drawing of the malformed organs of generation.

† Lehrbuch der Pathol. Anat. Bd. ii. s. 195. pl. ix. fig. 1 & 2, and pl. xxii. fig. 3 & 4.

‡ Atti del Real Instit. d'Incoragg. alle Sc. Nat Naples, tom. iii. p. 380.

Fig. 300.



a a, the testicles; *b b*, epididymes; *c c*, vasa deferentia; *d d*, vesiculæ seminales.

were not entirely complete, and there were superadded to them a female vagina and an imperfectly developed uterus, the Fallopian tubes of which ran towards the inguinal rings, and terminated with them upon the epididymes of the testicles.

Another instance of hermaphroditic malformation in the goat, detailed at great length by Meckel,* seems also in its principal points justly referable to the present division of cases, although there was at the same time a tendency, in the unequal size of the two cornua uteri, &c., to a degree of lateral hermaphroditism.

Professor Mayer, of Bonn,† has detailed at length the dissection of three hermaphroditic goats, in all of which the conformation of the sexual parts resembled in its more essential parts the preceding cases of Thomas and Gurlt. In all the three instances there were found two male testicles with their epididymes, vasa deferentia, and vesiculæ seminales; and at the same time there was present a well-marked female two-horned uterus, with a vagina opening into the urethra. In the first case the large hollow cornua uteri terminated in blind extremities, and there were only very short impervious rudiments of the Fallopian tubes. In the second case, at the extremity of the right horn of the uterus, a blind appendicula was situated, formed by a vestige (according to Mayer) of the Fallopian tube; and from this a ligament was sent off to the corresponding testicle; a similar ligament, but no appendicula, existed on the left side. In the third case both Fallopian tubes were present, and each ended in a bursa formed by the lamina of the peritonæum, and partly surrounding the testicle and epididymes. In two of the instances the ejaculatory ducts seem to have opened into the urethra near the point at which the vagina terminated in it; and in one of the cases they opened into the canal of the vagina itself before it joined that of the urethra. All the external organs were male, but malformed in so far that the penis was short, and in two of the cases somewhat twisted; and the scrotum was either small or wanting.

The same author* has described the dissection of a dog, the sexual organs of which exhibited a similar variety of hermaphroditic malformation. The Fallopian tubes were pervious throughout in this instance, and at their further extremities opened upon the neighbouring cellular tissue. The body of the two-horned uterus was very small. On compressing the epididymes and vasa deferentia, a fluid resembling semen issued from the openings of the latter into the urethra. The external sexual parts were those of a hypospadic male.

Several cases of hermaphroditic malformation in the human subject, similar in their anatomical characters to the preceding, have been described by Columbus, Harvey, Petit, Ackermann, and Mayer.

a. In a person with external hypospadic male organs, Columbus† found two bodies like testicles in the situation of the ovaries, and larger in size than the latter female organs naturally are. From each of these testiform bodies two sets of tubes arose, one of which, like the male vasa deferentia, passed on to the root of the penis and opened into the urethra; while the other, like the female Fallopian tubes, were inserted into an uterus. The prostate gland was absent.

b. Harvey‡ has mentioned a very small hermaphroditic embryo, on which he found a two-horned uterus with two testicles of a very

* Reil's Archiv fuer die Physiologie, Bd. xi. s. 334-8.

† Icones Select. Præparat. Mus. Anat. Bonn. p. 17-20. tab. iv. fig. 5, and tab. v. figs. 1, 2, & 3.

* Ib. p. 16. tab. iv. fig. 3, external parts of generation; fig. 4, internal.

† De Re Anat. lib. xv.

‡ De Gen. Anim. Exerc. lxix. p. 304.

small size, and, near the diminutive penis, some traces of a prostate gland.

c. The observation of M. Petit,* of Namur, is still more complete. On the body of a soldier, aged twenty-two, who died of his wounds, and whose external organs appear to have presented no deviation from the male type except in the absence of the testicles from the scrotum, these bodies, with male vasa deferentia, vesiculæ seminales, and a prostate, were found to co-exist with female Fallopian tubes, and an uterus that was attached to the neck of the urinary bladder, and opened into the urethra between this neck and the prostate. The form of this imperfect uterus, M. Petit remarks, merited for it rather the name of a vagina than of an uterus, and it resembled more this organ in the female quadruped than in women. From the body of the uterus, at three inches from its entrance into the urethra, two Fallopian tubes arose. These tubes were perforated, and were three inches and a half long; their abdominal extremities were not loose and provided with fimbriæ, but were attached to a small soft body on each side, occupying nearly the natural situation of the ovaries, but having the substance or structure of the testicles, and provided with an epididymis and vas deferens. The vasa deferentia were each seven inches and a half long, and were attached to two long and rather slender vesiculæ seminales placed alongside of the uterus. The vesiculæ opened into the urethra by two ducts.

In a note appended to this case, M. Petit states that he had been consulted by a man who rendered blood by the penis regularly every month, without pain or any troublesome symptom. Perhaps, adds M. Petit, this man had also a concealed uterus. We have been informed, on credible authority, of two similar cases, the one in a young unmarried man of seventeen years of age, and the other in a person who had been married for several years without his wife having had any children. In both of these cases the discharge was in very considerable quantity, and perfectly regular in its monthly occurrence. Did it consist in a periodical hæmorrhage from the urinary bladder or passages only? or was it, as M. Petit seems to suppose in his instance, of a true menstrual character, and produced by the reproductive organs of the female existing internally, and communicating with the bladder or urethra?

d. Professor Ackermann,† of Jena, published in 1805 the following interesting case of the present variety of hermaphroditic malformation. It occurred in an infant that lived about six weeks after birth. On dissection, two testicles were found; one of them had descended into the scrotum or labium; the other had advanced no further than the groin. Both were perfectly formed, and had their usual appendages complete. In the natural situation of the female uterus, there was found a hollow pyriform organ, which, from its locality and connections, was supposed to be an uterus, though its coats were finer and thinner, and its cavity greater than naturally belongs to that viscus. Duplicatures of peritonæum, resembling the ligamenta lata, connected this imperfect uterus with the sides of the pelvis, and its cavity opened into a kind of short vagina, which soon united with the urethra, and formed one common canal with it (*vagina urethralis*). The vasa deferentia ran from the testicles towards the superior angles of the uterus, and penetrated into its substance at the points where the Fallopian tubes are usually placed. Without opening here, however, they passed onwards under the internal mucous-like membrane of the uterus and vagina, and at length terminated, by very small orifices, in the vagina urethralis. Immediately previous to entering the ligamenta lata, each vas deferens formed a number of convolutions, conglomerated into a mass resembling a vesicula seminalis.

e. Steghlener* has described at great length the case of an infant that survived only for half an hour after birth, and upon whose body he found perfect external male organs (*fig.* 301, *a b*), and internally two small elongated testicles (*c c*), with their epididymes (*g g*), the convolutions of their vasa deferentia (*b b*)

Fig. 301.

* Hist. de l'Acad. Roy. des Sc. for 1720, p. 38.
† Infantis androgyni historia et iconographia, Edinb. Med. and Surg. Journ. vol. iii. p. 202.

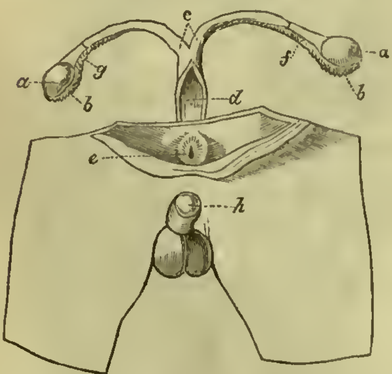
* De Hermaphr. Nat. p. 104.

distinctly marked. Between the rectum and bladder there was placed a very large pear-shaped bag or pouch (*f*), with firm, coriaceous, but not thick walls, and distended with fluid. This bag or imperfect cystoid uterus terminated inferiorly by a narrow neck, in a vagina that opened into the urethra, in the situation of the verumontanum, and was there dilated into a large bag or ampulla, occupying exactly the site of the prostate gland, and resembling this organ also in its form and position. The internal membrane of the uterus was collected at its neck into numerous valvular-like folds, and that of the vagina had also a rugous or plicated arrangement. From the fundus of the large sac of the uterus, and not from its angles, but from near its middle, two impervious solid ducts (Fallopian tubes, or rather vasa deferentia,) arose, and after a somewhat flexuous course reached the testicle (*c c*) lying in the superior part of the iliac fossæ. These ducts had attached to them at one or two points a number of small reddish nodules (*b b*), consisting, according to Steghlener, of glandular granules, and described by Ackermann in his case as vesiculæ seminales. The canal of the urethra was obliterated for a short distance towards the fossa navicularis, and the urinary bladder (*j*) and uterus (*i i*) were extremely distended, and the left kidney (*m*) was vesicular.

Mayer, in the work already referred to,* has described and delineated the following five cases of the present species of hermaphroditic malformation in the human subject, all of which he had himself met with and dissected.

f. In a fœtus of the fourth month, and affected with omphalocele and extroversion of the urinary bladder, he found male testicles (*fig.* 302,

Fig. 302.

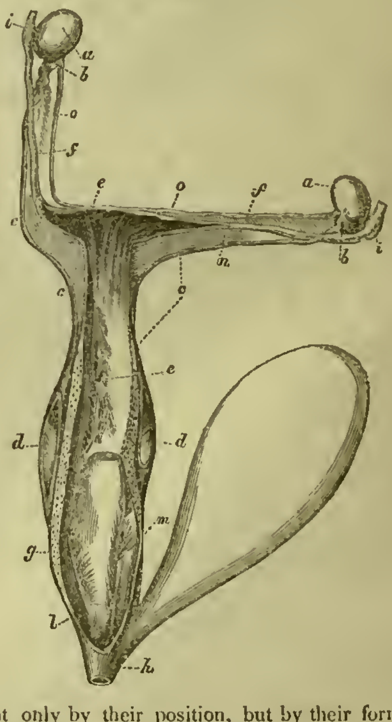


a a) with their epididymes (*b b*), and a two-horned uterus (*c*) terminating in a vagina (*d*), that opened into the posterior part of the urinary bladder (*e*). From the left testicle a contorted vas deferens (*f*) arose, and ran down to the vagina; the right vas deferens (*g*) was shorter, and became thread-like, and disappeared near the corresponding cornu of the uterus. A rudiment only of the left male vesicula seminalis was observable. The external organs were male; the glans penis (*h*) was imperforate.

g. In another fœtus of the sixth month,* there existed a perfect set of internal and external male sexual organs, viz., testicles, epididymes, vasa deferentia, and vesiculæ seminales, with a prostate gland and a normally formed penis and scrotum. But besides these, there was also present an imperfect female uterus, the body of which divided into two cornua, the right longer and incurvated, the left shorter and sacciform. The neck of the uterus was marked internally by its usual arborescent appearance; and it opened into a vagina that terminated in the urethra near the exit of the latter from the urinary bladder.

h. In a third case† of hermaphroditic malformation in an infant who died of convulsions when six months old, Mayer found the following blending of the organs of the two sexes. Of the internal male genital organs there were present two bodies at the inguinal rings that were evidently testicles, (*fig.* 303, *a, a*) as was proved

Fig. 303.



not only by their position, but by their form, coverings, connections, and internal structure, ("their substance," says Mayer, "being evidently composed of yellow canals"); their epididymes (*b b*) were also distinctly developed, and each of them sent off a vas deferens (*c c*), which

* Icones Select. &c. p. 8-16. See also Walther and Graefe's Journal der Chirurgie und Augenheilkunde, Bd. vii. Hft. 3, and Bd. viii. Hft. 2.

* Icones, p. 8. tab. ii. fig. 5.

† Icones, p. 9, tab. iii. fig. 1 and 2.

was furnished with a corresponding multilocular vesicula seminalis (*d d*). Of the internal female sexual organs there were found a perfectly developed uterus (*e e*), with its broad (*n n*) and round (*o o*) ligaments naturally formed and placed, and provided with two Fallopian tubes (*f f*) that followed the course of the testicles through the inguinal canals, and a vagina (*g*) which opened into the urethra (*h*) near its external orifice. The ejaculatory ducts of the male vesiculæ seminales opened into this vagina at *l* and *m*. The internal surface of the vagina was already beginning to present the appearance of its usual rugæ. The cavity of the uterus was triangular, and exhibited on the internal part of the cervix its characteristic plicated or arborescent structure. The Fallopian tubes were, at their uterine orifices, of a large caliber; their cavity afterwards became suddenly contracted, and then again dilated, and terminated at their ulterior extremities, where they lay in contact with the testicles at the external inguinal rings, in blind sacs (*i i*), without any very distinct appearance of fimbriæ. The external genital parts in this very interesting case were of a doubtful nature, being referable either to those of a hypospadic male, or of a female with a large clitoris, but without nymphæ, the meatus urinarius being in its normal situation, but leading behind to the cavities of both the urinary bladder and uterus. The circle of the pelvic bones was large.

i. The two other instances described by Mayer occurred in adult subjects, and the malformation in both of them differed from that found in the cases just now cited in this, that there was only one testicle present along with the imperfect uterus.

The subject of one of these cases* was a person who died at the age of eighteen, and whose external sexual organs were those of a hypospadic male, with a narrow perinæal canal or fissure. On dissection this perinæal canal was found to communicate anteriorly with the urethra, and posteriorly with a vagina of two inches and nine lines in length, and five or six lines in caliber. The anterior and posterior column of rugæ belonging to the vagina was only slightly marked. Its canal led to a large dilated uterus, the superior part of which was unfortunately cut away with some diseased viscera before the genital organs were examined; but, from the portion left, this organ seemed to resemble the uterus of quadrupeds in its oblong form, and in the thinness of its walls, which were composed of a cavernous fibro-vascular texture, and full of lacunæ. The usual arborescent appearance of the internal surface of the os uteri was very perfectly marked. Besides these female organs, there was a well-formed male prostate gland at the neck of the bladder; and behind the abdominal ring of the right side, a small roundish body, similar in form and texture to the testicle, and having the cremaster muscle adhering to its membranous involucrum. There were no traces of any similar organ on the left side. On both sides some portions of a canal were seen, but whether they were the remains of the vasa deferentia or Fallopian tubes was not ascertained on account of the previous mutilation of the uterus. On each side of the neck of the uterus there was placed a vesicula seminalis, provided with an ejaculatory duct that opened into the orifice of the vagina. The dimensions of the pelvis approached much nearer to those of the female than those of the male. In the secondary sexual characters of the individual, the female type was further recognised in the want of prominence in the larynx, in the slender form of the neck, and (according to Professor Mayer) in the rounded shape also of the heart, the smallness of the lungs, the oblong shape of the stomach, the large size of the liver, the narrowness of the forehead, and the conformation of the brain; while the individual approximated, on the other hand, to the male in the length and position of the inferior extremities, in the breadth of the thorax, the undeveloped state of the mammæ and the hairy condition of their papillæ, and in the existence of a slender beard upon the chin and cheeks.

j. In the second adult subject (a person of eighty years of age) Mayer* found, on the left side of the cavity of the abdomen, and near the inguinal ring, a small oval body exhibiting imperfectly in its internal structure the tubular texture of the male testicle, and having an appendix resembling the epididymis attached to it. From this testicle arose a vas deferens, which was joined in its course by a vesicula seminalis, and ended in an ejaculatory duct. On the opposite or right side a vesicula seminalis, having no continuous cavity, was present; but no vestige of a corresponding testicle, vas deferens, or ejaculatory duct could be discovered. The prostate gland was present, and regularly formed. In the cavity of the pelvis an uterus was found with parietes of moderate thickness, and of the usual cavernous texture; its cervix was marked internally with the appearance of the natural arborescent rugæ. Inferiorly it opened into a narrow membranous vagina, that received the right ejaculatory duct, then passed through the body of the prostate, and latterly joined the canal of the urethra. The fundus of the uterus could not be examined, as it had been removed in a previous stage of the dissection. The external parts were male and naturally formed, with the exception of the penis, which was shorter than usual, and had the canal of the urethra fissured inferiorly, and the meatus urinarius situated at its root. The individual was during life regarded as a male, but had all along remained in a state of celibacy. The general appearance of the face and body was that of an imperfectly marked male, but the pelvis was broad like that of a female.

3. *Co-existence of female ovaries and male testicles.*—This third division of complex or double hermaphroditism includes all those cases in which a male testicle and female ovary exist together either upon one side only, or upon

* Icones, p. 11. tab. iii. fig. 3 and 4.

* Icones, p. 15, tab. iv. fig. 1 and 2.

both sides of the body. With this arrangement, other malformations by duplicity of the sexual organs are generally combined; but these are so various in their character as not easily to admit of any useful generalization. In considering this third division of complex hermaphroditism, we shall mention, *first*, the cases in which *two* testicles and *one* ovary are stated to have co-existed; and *secondly*, those in which there have been supposed to be present *two* testicles and *two* ovaries.

Two testicles and one ovary.—The two dissections that we have previously detailed of lateral hermaphroditic insects, (see *Lateral Hermaphroditism*, p. 696,) shew that in these two cases this variety of sexual duplicity existed. It appears to have been observed also in two instances of hermaphroditic malformation in the quadruped, the histories of which have been described by Mascagni and Mayer.

In a bull, nine years of age, and which was provided with the usual external organs of the male, Mascagni found internally, on dissection, a prostrate gland and two perfect vesiculæ seminales, vasa deferentia, epididymes, and testicles. The testicles and epididymes were injected with mercury through the vasa deferentia. In addition there was discovered near the left testicle, and connected to it by peritonæum and bloodvessels, a body having the structure of the female ovary; and, in its normal situation, there existed a distended double uterus, containing from fifteen to sixteen pounds of a clear fluid. This uterus was furnished with two Fallopian tubes at its upper part, and terminated inferiorly in a vagina, which opened by a small orifice into the male urethra.*

In a goat dissected by Mayer,† he found two testes with their epididymes fully developed, and vasa deferentia and vesiculæ seminales. One of the testes was placed without and the other still remained within the abdominal cavity. At the same time there were present a large female vagina communicating with the urethra, and a double-horned uterus provided with two Fallopian tubes. One of these tubes terminated in a blind canal, but the other had placed at its abdominal extremity several vesicles, resembling, according to Mayer, Graafian vesicles, or an imperfect ovary. The vesiculæ seminales and (through regurgitation by the urethra and ejaculatory ducts) the cavities of the vagina and uterus, were filled with about four ounces of a whitish fluid, having the colour and odour of male semen. This fluid could not be found by the microscope to contain any seminal animalcules, but only simple and double Monades (*Monades termones et guttulas*). Bergmann, however, is alleged to have found it, on analysis, to contain the same chemical principle that characterizes human male semen.

Two testicles and two ovaries.—Various instances have now been published in which this sexual duplicity has been supposed to exist among cattle and other domestic quadrupeds, as well as in the human subject.

One of the free-martins* described by Mr. Hunter comes under this variety. In the case referred to, in the situation of the ovaries "were placed," to use Mr. Hunter's words, "both the ovaria and testicles,"—or, as Sir Everard Home, in alluding to this case, more justly expresses it, "an appearance like both testicles and ovaria was met with close together."† The two contiguous bodies were nearly of the same size, being each about as large as a small nutmeg. There were no Fallopian tubes running to the ovaries, but a horn of an imperfect uterus passed on to them on each side along the broad ligament. Pervious vasa deferentia were found; they did not, however, reach up completely to the testicle on either side, or form epididymes. The vesiculæ seminales were present, and much smaller than in the perfect bull. The external parts appear to have been those of the cow, but smaller than natural. The vagina passed on, as in the cow, to the opening of the urethra, and, after having received it and the orifices of the seminal ducts, it began to contract into a small canal, which ran upwards through the uterus to the place of division of that organ into its two horns.

Velpeau,‡ in his work on Midwifery, mentions that in an embryo calf, he had "found reunited the testicles and ovaries, the vasa deferentia, and uterus."

In an hermaphroditic foal-ass, Mr. Hunter§ found both what he considered to be two ovaries placed in the natural situation of these bodies, and two testicles lying in the inguinal rings in a process or theca of peritonæum similar to the tunica vaginalis communis in the male ass. No vasa deferentia or Fallopian tubes could be detected; but there was a double-horned uterus present, and from its broad ligaments, (to the edges of which the cornua uteri and ovaries were attached,) there passed down on either side into the inguinal rings a part similar to the round ligament in the female. The horns and fundus of the uterus were pervious; but its body and cervix, and the canal of the vagina from above the opening of the urethra into it, were imperforate. The external parts were similar to those of the female ass; but the clitoris, which was placed within the entrance of the vagina, was much larger than that of a perfectly formed female; it measured about five inches. The animal had two nipples.

Scriba has given an account‖ of an hermaphroditic sheep, in which two large testicles are stated to have been found in the scrotum, at the same time that there existed, in their normal situation, two moderately sized ovaries, and a small uterus furnished with two apparently closed Fallopian tubes. The external sexual parts appear to have been those of a

* Atti dell' Acad. delle Scienze di Siena, t. viii. p. 201.

† Icones, p. 20.

* An. Econ. p. 63-64, pl. ix.

† Comp. Anat. vol. iii. p. 322.

‡ Traité de l'Art des Accouchemens, t. i. p. 114.

§ An. Econ. p. 58.

‖ Schriften der Gesellschaft Naturforschender Freude zu Berlin, Bd. x. s. 367.

malformed male, the penis being short and impervious, the scrotum divided, and the urethra opening into a contracted perinæal fissure resembling the female vulva. This animal had often attempted connection with the female sheep.

Borkhausen* has described a very similar case in the same species of animal. Each half of the divided scrotum contained a testicle which was regularly formed, but greater in size than usual, and furnished with a large spermatic artery. The pelvis contained a normal uterus, which was smaller, however, than natural; it was provided with its usual ligaments. The Fallopian tubes were present but imperforate, and the two ovaries were full of vesicles and inclosed in a strong membrane. The vagina was natural and opened as in the female. Behind the divided scrotum the rudiment of an udder with four teats (instead of two) was situated. The male penis was also present, but diminutive and short; its erectores muscles were small, and the prostate gland indistinct. The urethra was single as it left the bladder, but it afterwards divided into two canals, the wider of which opened into the female vagina and vulva, and the narrower ran through the male penis. The urine passed in a full stream through the former canal, and only by drops through the latter. The animal is alleged to have attempted coition in both ways.

In 1829, an account of an hermaphroditic goat was published at Naples, which is said to have been provided with both female ovaries and male testicles.† The two ovaries occupied their usual situation; no Fallopian tubes were found; but there were present a double-horned uterus with blind cornua, and a vagina which opened externally, as in the female. In the neighbourhood of the ovaries, and more external than them, two small testicles were discovered, having two vasa deferentia arising from them. The vasa deferentia ran downwards to two corresponding vesiculæ seminales, that were placed alongside of the uterus. In the lower angle of the external pudenda, a body, resembling in length the male penis more than the female clitoris, was situated: it was, as we have already had frequently occasion to mention in regard to the penis in malformed male quadrupeds, of a very tortuous or convoluted form.

We have had an opportunity of examining an excellent preserved specimen of double hermaphroditism in the sow, referable to the present section, which was met with some years ago by Dr. Knox, and we have his permission to state here the following particulars of the case.

Among the internal female organs there is present a natural well-formed double uterus, provided with broad ligaments and two hollow cornua, each about six or seven inches in length. The fimbriated extremities are not distinctly marked, the female tubes appearing to end blind at their upper terminations, as they have often been observed to do in similar cases. The os uteri opens inferiorly into a vagina, which seems normal in its structure. At a short distance from the upper extremity of each horn of the uterus, two bodies of considerable magnitude are seen lying in close juxta-position. The smaller of these two bodies is on either side about the size and shape of a large almond; and though internally of an indeterminate amorphous structure, they are considered by Dr. Knox as answering to the two ovaries. The two larger bodies, which are placed *between* the supposed ovaries and the upper extremities of the cornua uteri, are most distinctly testicles, as shewn by their numerous tortuous seminiferous tubes, which have been successfully filled with a mercurial injection. They are of the full size of the organ in the adult male. The seminiferous tubes of each testicle terminate in a vas deferens, which was injected from them; and the two vasa deferentia run downwards through the ligamenta lata of the uterus, and terminate inferiorly in the upper part of the vagina, thus following the course of those natural canals in the female sow that we shall afterwards have occasion to allude to at greater length under the name of Gaertner's ducts, and which Dr Knox, from the evidence of the present case, believes to be in reality typical of the male vasa deferentia. There is no trace of vesiculæ seminales. Externally the vagina opened along with the urethra upon the perinæum, at a point lower than natural in the well-formed female. The clitoris in situation and size was nearly normal.

The animal at the time of death was fourteen months old; it was ferocious in its habits; and it had been in vain tried to be fattened. It had repeatedly shewn strong male propensities, and at the season of heat its vagina is said to have presented the usual injected appearance observed in the female sow.

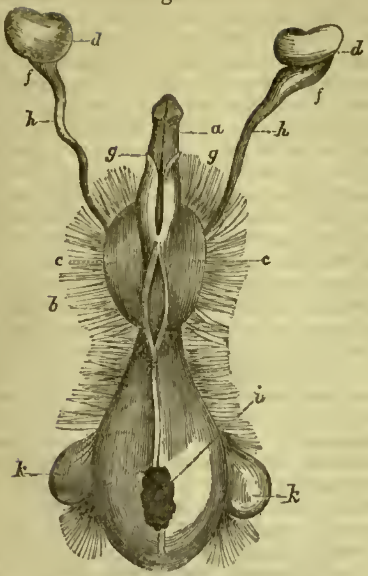
Dr. Harlan of Philadelphia* has lately described a still more perfect instance of double hermaphroditism than any of the preceding, which he met with in the body of a gibbon or orang outang, from the Island of Borneo (*Simia concolor*). This animal died of tubercular disease in Philadelphia in 1826, when it was considered to be under two years of age. Dr. Harlan gives the following account of its sexual formation. The penis (*fig.* 304, *a*) was about one inch in length, and subject to erections; it terminated in an imperforate glans; and a deep groove on its inferior surface served as a rudimentary urethra. This groove extended about two-thirds of the length of the penis, the remaining portion being covered with a thin articular diaphanous membrane, which extended also across the vulva (*b*), and closed the external orifice of the vagina. The vagina was rather large, and displayed transverse striæ. Traces of the nymphæ and labia externa were visible. The meatus urinarius opened beneath the pubis into the vagina, but the urine must have been directed along the groove of the penis by the

* Rheinisches Mag. zur Erweiterung der Naturkunde. Giessen 1793. Bd. i. s. 608.

† Brevi cenne su di un Neutro Capro; or, Gurlt's Pathologischen Anatomie, Bd. ii. s. 198.

* Med. and Phys. Researches, p. 19.

Fig. 304.

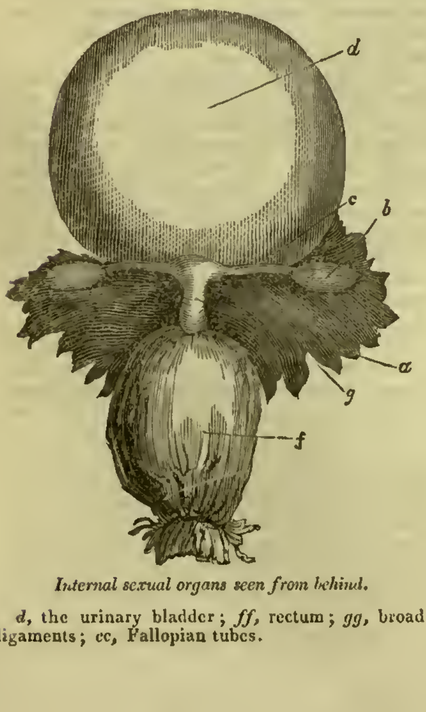


External sexual organs and testicles.

gg, the prepuce; *hh*, the vasa deferentia; *i*, the anus; *kk*, ischiatic protuberances.

membrane obstructing the orifice of the vulva. The os tincæ was surrounded by small globular glands. The orifice and neck of the uterus admitted a large probe into the cavity of that organ, which appeared perfect with all its appendages. The round and broad ligaments, together with well-developed ovaries (*fig.* 305, *b b*), were all found in situ. The scrotum

Fig. 305.



Internal sexual organs seen from behind.

d, the urinary bladder; *ff*, rectum; *gg*, broad ligaments; *cc*, Fallopian tubes.

(*fig.* 304, *c*) was divided, and consisted of a sac on each side of the labia externa, at the base of the penis, covered with hair. The testicles (*fig.* 304, *d d*) lay beneath the skin of the groin about two inches from the symphysis pubis, obliquely outwards and upwards: they appeared to be perfectly formed with the epididymis (*f f*), &c. The most accurate examination could not discover vesiculæ seminales; but an opening into the vagina, above the meatus urinarius, appeared to be the orifice of the vas deferens. In all other respects the male and female organs of generation were in this animal as completely perfected as could have been anticipated in so young an individual, and resembled those of other individuals of a similar age.

Two imperfect instances are on record of the co-existence of male testicles and female ovaries in the human subject.

a. The first of these cases is detailed by Schrell.* It occurred in an infant who died when nine months old. All the internal and external male organs were present and perfectly formed, with the exception of the prepuce of the penis, which seemed divided in front and rolled up. At the root of the large penis, was a small vulva or aperture capable of admitting a pea, and provided with bodies having an appearance of labia and nymphæ. This vulva led into a vagina that penetrated through the symphysis pubis, and terminated in a nipple-like body or imperfect uterus, to which, structures having a resemblance to the Fallopian tubes and ovaries were attached.

b. The other and still more doubtful case of the alleged existence of both testicles and ovaries in the human subject, was first published by Beclard.† The case was met with by M. Laumonier of Rouen, who injected and dissected the sexual parts, and deposited them in a dried state, along with a wax model representing them in their more recent condition, in the Museum of the School of Medicine at Paris. In the wax model two female ovaries with an uterus, vagina, external vulva, and large imperforate clitoris, are seen combined with two male testicles, the vasa deferentia of which terminate in the uterus at the place at which the round ligaments are normally situated; these ligaments themselves are wanting. The preparation of the dried sexual parts is far from being equally satisfactory, and, in its present imperfect condition at least, does not bear out by any means the complete double hermaphroditic structure delineated in the model.

III. HERMAPHRODITISM AS MANIFESTED IN THE GENERAL CONFORMATION OF THE BODY, AND IN THE SECONDARY SEXUAL CHARACTERS.

In the preceding observations we have principally confined ourselves to the description of hermaphroditic malformations as seen in the resemblance in appearance and structure of the

* Schenk's Medic. Chirurg. Archiv. Bd. i. s.

† Bullet. de la Fac. de Méd. 1815, p. 284; or, Dict. des Sc. Méd. xxi. p. 111.

external genital parts of one sex to those of the other, and in the different degrees and varieties of reunion or co existence of the reproductive organs of the two sexes upon the body of the same individual. Hermaphroditism, however, may appear not only in what are termed the *primary* sexual parts or characters, or, in other words, in the organs more immediately subservient to copulation and reproduction, but it may present itself also in the *secondary* sexual characters, or in those distinctive peculiarities of the sexes that are found in other individual parts and functions of the economy, as well as in the system at large. We have occasionally an opportunity of observing some tendency to an hermaphroditic type in the general system, without there being any very marked corresponding anormality in the sexual organs themselves, but it rarely happens that there exists any hermaphroditic malformation of the primary organs of generation, without there being connected with it more or less of an hermaphroditic type in the secondary sexual characters; and this circumstance often offers us, in individual doubtful cases, a new and perplexing source of fallacy in our attempts to determine the true or predominating sex of the malformed individual. Before, however, describing that variety of hermaphroditism which manifests itself in the general system and in the secondary sexual peculiarities, it will be necessary, in order to understand its nature and origin, to premise a few remarks on the dependence and relation of these secondary characters upon the normal and abnormal conditions of the primary sexual organs.

That the various secondary sexual peculiarities which become developed at the term of puberty are intimately dependent upon the changes that take place at the same period in the organism of the female ovaries and male testicles, seems proved by various considerations, particularly by the effect produced by original defective development and acquired disease in these parts, and by the total removal of them from the body by operation. In considering this point we shall speak first of the effects of the states of the ovaries upon the female constitution, and shall then consider those of the testicles upon the male.

When the usual development of the ovaries at the term of puberty does not take place, the secondary sexual characters which are naturally evolved in the female at that period do not present themselves; and this deficiency sometimes occasions an approach in various points to the male formation. Thus in a case recorded by Dr. Pears,* of a female who died of a pectoral affection at the age of twenty-nine, the ovaries on dissection were found rudimentary and indistinct, and the uterus and Fallopian tubes were present, but as little developed as before puberty. This individual had never menstruated nor shewed any signs, either mental or corporeal, of puberty. The mammæ and nipples were as little developed as those of the male subject. She had ceased to grow at ten years of age, and attained only the height of four feet six inches.

* Phil. Trans. for 1805, p. 225.

In another analogous instance observed by Renauldin,* scarcely any rudiments of the ovaries existed, and the body of the uterus was absent, but the external genital female organs were well formed. The individual who was the subject of this defective sexual development had never menstruated; the mammæ were not evolved; in stature she did not exceed three and a half French feet; and her intellect was imperfectly developed.

In reference to these and other similar instances that might be quoted,† it may be argued that they do not afford any direct evidence of the evolution of the sexual characters of the female depending upon that of the ovaries, as the arrestment in the development of both may be owing to some common cause which gives rise at the same time to the deficiency in the development of the genital organs, and to the stoppage of the evolution of the body in general. That the imperfection, however, in the organism of the ovaries may have acted in such cases as the more immediate cause or precedent of the imperfection or non-appearance of the secondary characters of the sex, seems to be rendered not improbable, in regard to some, if not to all the instances alluded to, by the fact that the removal of these organs before the period of puberty, as is seen in spayed female animals, entails, upon the individuals so treated, the same neutral state of the general organization as was observed in the above instances; or, in other words, we have direct evidence that the alleged effect is capable of being produced by the alleged cause; and further, when in cases of operation or disease after the period of puberty, both ovaries have happened to be destroyed, and their influence upon the system consequently lost, the distinctive secondary characteristics of the female have been observed also to disappear in a greater or less degree.

Thus in the well-known case recorded by Mr. Pott,‡ the catamenia became suppressed, the mammæ disappeared, and the body became thinner and more masculine, in a healthy and stout young woman of twenty-three years of age, whose two ovaries formed hernial tumours at the inguinal rings, and were, in consequence of their incapacitating the patient from work, both removed by operation.

Many facts seem to show that the act of menstruation most probably depends upon some periodical changes in the ovaries, if not, as Dr. Lee§ supposes, in the Graafian vesicles of these organs; and when the function becomes suddenly and permanently stopped in a

* Seances de l'Acad. Roy. de Méd. 28 Fevrier 1826, and Medical Repository for 1826, p. 78.

† Davis, in his Principles and Practice of Obstetric Medicine, p. 513, refers to several instances in point. We may mention that Dr. Haighton found that after the Fallopian tubes were divided in rabbits, the ovaries became gradually atrophied, and the sexual feelings were lost. Phil. Trans. for 1797, p. 173.

‡ Surgical Works, vol. iii. p. 329.

§ Article OVARY in Cyclo. of Pract. Med.

woman at the middle period of life, without any indications of the catamenial fluid being merely mechanically retained, we may perhaps suspect with reasonable probability the existence of a diseased state which has destroyed either successively or simultaneously the functions of both ovaries. In such a case the distinctive secondary peculiarities of the female sex come to give place to those of the male. Thus Vaulevier mentions an instance in which menstruation suddenly ceased in a young and apparently healthy woman; no general or local disease followed; but soon afterwards a perfect beard began to grow upon her face.* Again, in women who have passed the period of their menstrual and child-bearing life, and in whom consequently the functions and often the healthy structure of the ovaries are lost or destroyed, we have frequently an opportunity of observing a similar tendency towards an assumption of some of the peculiarities of the male; an increase of hair often appears upon the face, the mammæ diminish in size, the voice becomes stronger and deeper toned, the elegance of the female form and contour of body is lost, and frequently the mind exhibits a more determined and masculine cast. Women, both young and aged, with this tendency to the male character, are repeatedly alluded to by the Roman authors under the name of *viragines;* and Hippocrates† has left us the description of two well-marked instances.

Among the females of the lower animals a similar approach to the male character in the general system not unfrequently shows itself as an effect both of disease and malformation of the sexual organs, and also in consequence of the cessation of the powers of reproduction in the course of advanced age. Female deer are sometimes observed to become provided at puberty with the horns of the stag,‡ and such animals are generally observed to be barren,* probably in consequence either of a congenital or acquired morbid condition of their ovaries or other reproductive organs. In old age, also, after the term of their reproductive life has ceased, female deer sometimes acquire the horns of the male in a more or less perfect degree;† and Burdach alleges that roes sometimes become provided with short horns when they are kept from the male during the rutting season, and at the same time furnished with abundant nourishment.‡ Mehliss§ alludes to two cases in which a virilescent type was shewn principally in the hair of the female deer. In one of these instances the hair of the head, neck, and abdomen, the shape of the ears and extremities, and the odour of the animal, gave it the closest resemblance to the male, and it followed the other females as if urged by sexual desire.

This kind of acquired hermaphroditism in aged females has, however, been more frequently and carefully attended to as it occurs in Birds than as met with among the Mammalia, the change to virilescence in the former being more marked and striking than in the latter, owing to the great difference which generally exists between the plumage of the male and female.‖ When old female birds live for any considerable period after their ovaries have ceased to produce eggs, they are usually observed to assume gradually more or less of the plumage and voice, and sometimes the habits also of the male of their own species. This curious fact, first pointed out by Aristotle¶ in relation to the domestic fowl, has now been seen to occur in a number of other species of birds, but particularly among the Gallinaceæ. It has been in modern times remarked in the common fowl *(Phasianus gallus)* by Tucker, Butler, and Jameson; in the common pheasant *(P. colchicus)* by Hunter and Isidore St. Hilaire; in the golden pheasant *(P. pictus)* by Blumenbach and St. Hilaire; in the silver pheasant *(P. nychemerus)* by Bechstein and St. Hilaire; in the turkey *(Meleagris)* by Bechstein; in the pea-hen *(Pavo)* by Hunter and Jameson; and in the partridge *(Tetrao perdrix)* by Montagu and Yarrell. Among the Cursores it is mentioned as having occurred in the bustard *(Otis)* by Tiedemann, and in the American pelican *(Platalea aiaia)* by Catesby. In the order Palmipedæ it has been observed by Tiedemann and Rumball in the

* Journ. de Méd. tom. lxix. and Meckel in Reil's Arch. Bd. xi. s. 275. Meckel quotes other similar cases from Seger in Ephem. Nat. Cur. Dec. i. Ann. ix. and x. obs. 95; Vicat, sur la Plique Polonaise, in Murray's Pr. Bibl. Bd. i. s. 578; and Schurig's Parthenologia, p. 184. Burlin published an express treatise on the subject, De barba mulierum ex menstruorum suppressione, Altorf. 1664. See also Haller's Elem. Phys. tom. v. p. 32; Reuss, Repert. Comment. tom. x. p. 205; Eble, Die Lehre von den Haaren in der organischen Natur. Bd. ii. s. 222. Vien. 1831; and Mehliss, Ueber Virilescenz und Rejuvenescenz thierischer Körper. Leipz. 1838, who quotes several cases additional to those of Meckel.

† De Morb. Vulg. lib. vi. ss. 55, 56. "Abderus Phaetusa, Pythei conjunx, antea per juventam fœcunda erat; viro autem ejus exortante, diu articulos exorti sunt. Quæ ubi contigerunt, tum corpus virile, tum in universum hirsutum est redditum, barbaque est enata, et vox aspera reddita. Sed cum omnia quæ ad menses deducendos facerent tentassemus, non profluxerunt, verum haud ita multo post vita functa est. Idem quoque in Thaso Namysiæ, Gorgippi conjugi, contigit." Hippocr. Op. ed. Fœsii, p. 1201.

‡ Camden's Angl. Norm. (1603) p. 821. Langelot Eph. Nat. Cur. Dec. i. ann. ix and x. obs. 88. Ridinger's Abbild. Seltener Thiere Taf. 79, or Meckel in Reil's Archiv. für die Physiol. Bd. xi. p. 273.

* Wildungen, Taschenbuch für Forst- und Jagdfreunde, s. 17.

† Otto's Path. Anat. by South, p. 166, s. 123, n. 18, for list of cases.

‡ Phys. vol. i. § 183, p. 318.

§ Ueber Virilescenz Thierisch. Koerper; or British and Foreign Med. Review, vol. vi. p. 77.

‖ It occurs also more frequently among birds than among mammalia, from the former possessing only a single ovary.

¶ "Gallinæ, cum vicerint gallos, concurrunt maresque imitandi subagitare conantur. Attollitur etiam crista ipsis, simul et clunes (uropygium); adeo ut jam non facile diagnoscantur an fœminæ sint. Quibusdam etiam calcaria parva surriguntur." Hist. Animal. lib. ix. cap. 36.

domestic and wild duck *(Anas boscha)*. Among the Scansores it has been seen in the cuckoo *(Cuculus canorus)* by Payraudeau; and among the Passeres in the cotinga *(Ampelis)* by Dufresne; in the chaffinch *(Fringilla)* and *rougequeue (Motacilla)* by Prevost; and in the bunting *(Emberiza paradisæa* and *longicauda)* by Blumenbach.

This change of plumage in old female birds commences, according to M. Isidore St. Hilaire,* much sooner in some instances than in others; it may only begin to show itself several years after the bird has ceased to lay, though depending more or less directly upon this phenomenon, and sometimes it commences immediately after it. The change may be effected in a single season, though in general it is not complete for some years. When it is perfected, the female may display not only the variety of colours, but also the brilliancy of the male plumage, which it sometimes resembles even in its ornamental appendages, as in the acquisition of spurs, and, in the domestic fowls, of the comb and wattles of the cock. The voice of the bird is also very generally changed. Its female habits and instinct are likewise often lost; and, in some instances, it has been seen to assume in a great degree those of the male, and has even been observed to attempt coition with other females of its own species † In most of the female birds that have undergone this change, the ovary has been found entirely or partially degenerated, though in a few cases the morbid alteration is not very marked, eggs having even been present in the organ in one or two instances. In general, however, it is greatly diminished in size, or has become altogether atrophied; but the perfection of the change in the plumage does not seem to bear any direct ratio with the degree of morbid alteration and atrophy in the ovary.

That the changes towards the male type, described as occasionally occurring in old female birds, is directly dependent, not upon their age, but upon the state of the ovaries in them, seems still further proved by similar changes being sometimes observed in these females long previous to the natural cessation of the powers of reproduction, in consequence of their ovaries having become wasted or destroyed by disease. Greve,‡ in his Fragments of Comparative Anatomy and Physiology, states that hens whose ovaries are scirrhous crow sometimes like cocks, acquire tail-feathers resembling those of the male, and become furnished with large spurs. The same author mentions also the case of a duck, which, from being previously healthy, suddenly acquired the voice of the male, and on dissection its ovary was found hard, cartilaginous, and in part ossified.

Mr. Yarrell, in a paper read before the Royal Society in 1827,* has stated that in a number of instances he had observed young female pheasants with plumage more or less resembling the male, and in all of them he found on dissection the ovaries in a very morbid state, and the oviduct diseased throughout its whole length, with its canal obliterated at its upper part. He also shews that a similar effect upon the secondary sexual characters of the female bird is produced by the artificial division and removal of a small portion of their oviduct in the operation of making capons of female poultry; and he states that his investigations have led him to believe that in all animals bearing external characters indicative of the sex, these characters will undergo a change and exhibit an appearance intermediate between the perfect male and female, wherever the system is deprived of the influence of the true sexual organs, whether from original malformation, acquired disease, or artificial obliteration.†

From the frequency with which castration is performed, the effects of the testicles in evolving the general sexual peculiarities of the male have been more accurately ascertained than those of the ovaries upon the female constitution. These effects vary according to the age at which the removal of the testicles takes place. When an animal is castrated some time before it has reached the term of puberty, the distinctive characters of the male are in general never developed; and the total absence of these characters, together with the softness and relaxation of their tissues, the contour of their form, the tone of their voice, and their want of masculine energy and vigour, assimilate them more in appearance and habits to the female than to the male type. If the testicles are removed nearer the period of puberty, or at any time after that term has occurred, and

* Edinburgh Journ. of Philosoph. Science, (1826) p. 308.

† Rumball, in Home's Comparative Anatomy, vol. iii. p. 330, states having observed an old duck which had assumed the male plumage, attempt sexnal connection with another female. This may perhaps enable us to understand tho reputed cases of hermaphroditism in women, who, as related by Mollerus (Tract. de Hermaphr. cap. ii.) and Blancard, (Collect. Medico-Phys. cent. iii. obs. 80,) after having themselves borne children became addicted to intercourse with other females. Of coorse we cannot give our credence to tho alleged successful issue of such intercourse.

‡ Bruchstuecke sur vergleich. Anat. und Physiol. s. 45.

* Phil. Trans. for 1827, part ii. p. 268.

† On old or diseased female birds assnming the plumage, &c. of the male, sco J. Hunter, Observ. on the An. Econ. p. 75; E. Home, Lect. on Comp. Anat. vol. iii. p. 329; Mauduit, in Encycl. Method. Art. *Faisan*, tom. ii. p. 3; Butter, in Wernerian Soc. Mem. vol. iii. p. 183; Schneider's Notes, in his edition of the Emperor Frederick the Second's Treatise "De Arte Venandi cum Avibus;" Tucker's Ornithologia Damnoniensis; Catesby's Natural History of Carolina, &c. i. t. 1.; Bechstein, Naturgeschichte d. Deutschlands, bd. ii. § 116; Blumenbach, De anomalis et vitiosis quibusdam nisus formativi aberrationibos, p. 8; and Instit. of Physiology, p. 369; Payrandean, Bull. des Sc. Nat. t. xiii. p. 243; Tiedemann, Zoologie, vol. iii. p. 306; Geoff. St. Hilaire, Phil. Anat. tom. ii. p. 360; Isid. St. Hilaire, Mém. du Mus. d'Hist. Nat. tom. xii. p. 220; Annal. des Sc. Nat. t. vii. p. 336, or Edinburgh New Philosophical Journal for 1826, p. 302, with additional cases by Professor Jameson, p. 309; Kob, De mutatione sexus, p. 11. Berlin, 1823; Yarrell, Phil. Trans. for 1827, p. 268, with a drawing of the diseased ovaries, &c.

when the various male sexual peculiarities have been already developed, the effect is seldom so striking; the sexual instincts of the animal, and the energy of character which these instincts impart, are certainly more or less completely destroyed, and the tone of the voice is sometimes changed to that of puberty; but the general male characteristics of form, such as the beard in man, and the horns in the Ruminantia, most commonly continue to grow. In animals, such as the stag, which possess deciduous horns, the removal of the testicles during the rutting season causes the existing horns to be permanent; and if the operation is performed in an adult animal when out of heat, no new horns in general appear.* In the ox, the effect of castration upon the growth of the horns, even when performed before the time of puberty, is quite remarkable; for instead of having their development altogether stopped, or their size at least diminished by the operation, as occurs in the ram and stag, the volume of these appendages is even increased by the operation, the horns of the ox being generally larger but less strong than those of the entire bull. Castration in the boar causes, according to Greve,† the tusks to remain small, and prevents altogether the replacement of the teeth. This author also states that the same operation on the horse prevents the full development of the neck, renders the teeth smaller and slower in their growth, increases the growth of the hair, and the size of the horny protuberances on the inside of the legs. The prostate gland, he further alleges, as well as the vesiculæ seminales, become augmented as much as a third in their volume in consequence of the operation.‡

The removal of the testicles both before and after the period of puberty commonly gives rise to another singular effect,—to an increased deposition of fat over the body, as has already been mentioned in the article Adipose Tissue, and from this circumstance the general form of the body, and in man that of the mammæ, is sometimes modified in a degree that increases the resemblance to the opposite sex. In the sterile of both sexes in the human subject an unusual corpulency is not uncommon, and the same state is often met with in old persons, and particularly in females, after the period of their child-bearing life is past.

The nature of the effects produced by the existence and functional activity of the testicles and ovaries upon the development of the secondary sexual characters of the male and female, may be further illustrated by what occurs in the season of heat to animals such as the deer, sheep, birds, &c. that have periodical returns of the sexual propensity. At these periods all the distinctive general characters of the sexes become much more prominently developed, in conjunction with, and apparently in consequence of, the changes which have been ascertained by observation to occur at that time in the relative size and activity of the internal organs of generation. Thus with the return of the season of sexual instinct the dorsal crests and cutaneous ear-lobes of tritons enlarge; in Batrachian Reptiles the spongy inflations of the thumbs become increased in size; the various species of singing birds reacquire their vocal powers; and some, as the cuckoo and quail, appear capable of exercising their voice only at this period of the year. At the pairing season also the plumage of birds becomes brighter in tint, and in some instances is in other respects considerably changed, as in the male ruff *(Tringa pugnax)*, who then reassumes the tuft of feathers upon his head and neck, and the red tubercles upon his face that had fallen off during the moulting, and thus left him more nearly allied in appearance to the female during the winter. In reference to this subject, it appears to us interesting to remark, that in certain birds, as in the different species of the genus Fringilla, the male presents in winter a plumage very similar to that of the female,* and in the present inquiry it is important to connect this fact with the very diminutive size and inactive condition of the testicles of these birds at that season. (See Aves.)

From the remarks that we have now made upon the influence of the ovaries and testicles in developing the general sexual peculiarities of the female and male, it will be easy to conceive that when, in cases of malformation of the external genital organs giving rise to the idea of hermaphroditism, there is at the same time, as sometimes happens, a simultaneous want of development in the internal organs of reproduction, particularly in the ovaries and testicles, the general physical and moral peculiarities distinctive of the sex of the individual may be equally deficient, or have a tendency even to approach in more or fewer of their points to those of the opposite sexual type. In this way we may, it is obvious, have *general* or constitutional hermaphroditic characters, if they may be so termed, added to those already existing in the *special* organs of generation, and rendering more difficult and complicated the determination of the true sex of the malformed individual. Some cases of spurious hermaphroditism in the male published by Sir E. Home† may serve to illustrate this remark.

A marine soldier, aged twenty-three, was admitted a patient into the Royal Naval Hospital at Plymouth. He had been there only a few days, when a suspicion arose of his being a woman, which induced Sir Everard to examine into the circumstances. He proved to have no beard; his breasts were fully as large as those of a woman at that age; he was inclined to be corpulent; his skin was uncommonly soft for a man; his hands were fat and short, and his thighs and legs very much like those of a woman: the quantity of fat upon

* Buffon, Hist. Nat. tom. vi. p. 80.

† Bruchstuecke zur Vergl. Anat. und Physiol. p. 41.

‡ Loc. cit. p. 45.

* Stark's Elements of Nat. Hist. vol. i. p. 243.

† Comp. Anat. vol. iii. p. 320.

the os pubis resembled the mons veneris; and in addition he was weak in his intellect, and deficient in bodily strength. The external genital organs shewed him to be a male, but the penis was unusually small, as well as short, and not liable to erections; the testicles were not larger in size than they commonly are in the fœtal state; and he had never felt any passion for the opposite sex.

The following cases by the same author strongly illustrate this subject.* In a family of three children residing near Modbury in Devonshire, the second, a daughter, was a well-formed female, the eldest and youngest were both malformed males. The eldest was thirteen years of age. His mons veneris was loaded with fat; no penis could be said to be present, but there was a præputium a sixth of an inch long, and under it the meatus urinarius, but no vagina. There was an imperfect scrotum with a smooth surface, there being no raphé in the middle, but, in its place, an indented line; it contained two testicles, of the size that they are met with in the fœtus. His breasts were as large as those of a fat woman. He was four feet high, and of an uncommon bulk, his body round the waist being equal to that of a fat man, and his thighs and legs in proportion. He was very dull and heavy, and almost an idiot, but could walk and talk; he began to walk when a year and a half old. The younger brother was six years old, and uncommonly fat and large for his age. He was more an idiot than the other, not having sense enough to learn to walk although his limbs were not defective.

A case in a similar manner confirmatory of the preceding remarks is mentioned by Itard de Riez.† A young man, aged twenty-three, had no testes in the scrotum, a very small penis, not capable of erection, and a divided scrotum. He was in stature below the middle size. His skin was soft, smooth, and entirely free from hair, the place of the beard being supplied by a slight down. The voice was hoarse; the muscles were not well marked; the form of the chest resembled that of the female, and the pelvis was extremely broad and large. The intellectual faculties were very dull, and the sexual appetite was entirely wanting.

Renauldin, also, in the same work,‡ has recorded another case in point. In a soldier of twenty-four years of age, whose genital organs were extremely undeveloped, his penis being only of the size of a small tubercle, and his testicles not larger than small nuts, the pelvis was broad; the chest narrow; the face and body in general were not covered with hair, with the exception of a small quantity upon the pubis; the voice was feminine, and the mammary glands were as perfectly developed as in the adult female. The body of this individual was rather lean than otherwise. The mammæ had begun to enlarge when his body attained to its full stature at sixteen years of age. He had all the habits and sexual desires of the male sex.

* Ib. p. 320-21.

† Mémoires de la Société Méd. d'Emulation, tom. iii. p. 293-5.

‡ Tom. i. p. 241.

In quadrupeds as in man, when the testicles or ovaries are imperfectly formed, the secondary sexual peculiarities are frequently so defectively evolved as to offer a kind of hermaphroditic or neutral type in the general configuration and characters of the animal. Thus, the free-martin does not present an exact analogy in form either with the bull or cow, but exhibits a set of characters intermediate between both, and more nearly resembling those of the ox and of the spayed heifer. In size it resembles the castrated male and spayed female, being considerably larger than either the bull or the cow, and having horns very similar to those of the ox. Its bellow is similar to that of the ox, being more analogous to that of the cow than of the bull. Its flesh, like that of the ox and spayed heifer, is generally much finer in its fibre than the flesh of either the bull or cow, and is supposed to exceed even that of the ox and heifer in delicacy of flavour.*

The consideration of the various facts that we have now stated inclines us to believe that the natural history characters of any species of animal are certainly not to be sought for solely either in the system of the male or in that of the female; but, as Mr. Hunter pointed out, they are to be found in those properties that are common to both sexes, and which we have occasionally seen combined together by nature upon the bodies of an unnatural hermaphrodite; or evolved from the interference of art, upon a castrated male or spayed female. In assuming at the age of puberty the distinctive secondary peculiarities of his sex, the male, as far as regards these secondary peculiarities, evidently passes into a higher degree of development than the female, and leaves her more in possession of those characters that are common to the young of both sexes, and which he himself never loses, when his testicles are early removed. These and other facts connected with the evolution of both the primary and secondary peculiarities of the sexes further appear to us to shew that, physiologically at least, we ought to consider the male type of organization to be the more perfect as respects the individual, and the female the more perfect as respects the species. Hence we find that, when females are malformed in the sexual parts so as to resemble the male, the malformation is almost always one of excessive development, as enlargement of the clitoris, union of the labia, &c.; and, on the other hand, when the male organs are malformed in such a manner as to simulate the female, the abnormal appearance is generally capable of being traced to a defect of development, such as the want of closure of the perinæal fissure, and of the inferior part of the urethra, diminutive size of the penis, retention

* Hunter's Obs. on the An. Econ. p. 60.

of the testicles in the abdomen, &c. In the same way, when the female assumes the secondary characters of the male, it is either, first, when by original malformation its own ovaries and sexual organs are so defective in structure as not to be capable of taking a part in the function of reproduction, and of exercising that influence over the general organization which this faculty imparts to them; or, secondly, when in the course of age the ovaries have ceased to be capable of performing the action allotted to them in the reproductive process. In both of these cases we observe the powers of the female organization, now that its capabilities of performing its particular office in the continuation of the species are wanting or lost, expend themselves in perfecting its own individual system, and hence the animal gradually assumes more or fewer of those secondary sexual characters that belong to the male.

We do not consider it subversive of the preceding view to qualify it with the two following admissions,—1st, that, owing to the energies of the female system being so strongly and constantly directed towards the reproductive organs, and the accomplishment of those important functions which these organs have to perform in the economy of the species, the general characters of the species may be developed in her body in a degree *less* than they otherwise would be, or than actually constitutes the proper standard of the species; and, 2dly, in consequence of the peculiarities of the sexual functions of the female, some of the individual organs of her system, as the mammæ, are evolved in a degree *greater* than is consonant with the standard characters of the species. At the same time we would here remark that the occasional enlarged condition of the mammæ in hermaphrodites in whom the male sexual type of structure predominates, (as in the examples of spurious male hermaphrodites that have been quoted from Sir E. Home, and in other instances mentioned by Renauldin, Julien, Petit, Rullier, and others in the human subject, as well as in numerous cases among hermaphrodite quadrupeds,) would almost seem to shew that the full development of the mammary glands is a character proper to the species in general, rather than one peculiar to the female system alone. In males, also, who are perfect in their reproductive organs and functions, the mammæ are sometimes observed to be developed in so complete a manner as to be capable of secreting milk, forming what may be regarded as one of the slightest approaches towards hermaphroditic malformation in the male organization;* and the mammæ of the infants of both sexes not unfrequently contain a lactiform fluid at birth.

In some instances of hermaphroditic malformation the total form and configuration of the body have been alleged to present not only a general tendency towards the physical secondary characters of the opposite sex, or to exhibit in a permanent state the neutral condition existing before puberty, but different individual parts of it have been occasionally conceived to be developed after a different sexual type. Thus, for instance, we have already mentioned in regard to Hubert Jean Pierre, that the upper half of the body of this individual seemed formed after the female, and the lower half after the male type, the larynx and mammæ being quite feminine, the face shewing no appearance of beard, and the arms being delicate and finely rounded, while the pelvis was narrow, and the thighs were marked and angled as in man. In a case described by Schneider,* the reverse held true, the bust being male with a strong beard and large thorax, and the pelvis being large and distinctly female. A more mixed combination of the secondary sexual characters has been already described as existing in the cases detailed by Ricco, Mayer, Arnaud, Bouillaud, &c.

One side of the body has been sometimes observed to be apparently formed in one or more of its parts on a sexual type different from that of the same parts on the opposite side. Girald, in his Topography of Ireland,† mentions a reputed female, who had the right side of the face bearded like that of a man, and the left smooth like that of a woman. Mr. King ‡ has described an interesting instance of hermaphroditic malformation in an individual whose general character was masculine, but with the pelvis large and wide; the left testicle only had descended into the groin, and the mamma of this side was small comparatively to that of the opposite or right side.

In a hind mentioned by Mr. Hay,§ and which, he believed, had never produced any young, one of the ovaries on dissection after death was found to be scirrhous. The animal had one horn resembling that of a three years-old stag on the same side with the diseased ovary; there was no horn on the opposite side. Bomare‖ has given a similar case in the same

* The secretion of milk in the mammary glands of the male is occasionally observed amongst our domestic quadrupeds. See Gurlt's Pathologischen Anatomie der Haus-Saugthiere, Bd. ii. s. 188; Blumenbach in the Hanoversich Magazin for 1787; and Home in Comp. Anat. iii. p. 328. Among the recorded instances and observations upon it in man we may refer to Paullini, Cynographia, p. 52; Schacher, De Lacte Virorum et Virginum, Leipz. 1742; Sinnibaldus, Geneanthrop. tom. iv. p. 456; Alex. Benedictus, Anatom. Corp. Hum. lib. iii. p. 595; Winslow, Anatomy, vol. ii. p. 214; Deusing, De Lacte, p. 327; Kyper, Anthropologia, lib. i. p. 490; Buffon, Hist. Nat. tom. ii. p. 543; Bishop of Cork, Phil. Trans. vol. xli. p. 813; Humboldt, Personal Narrative, vol. iii. p. 57; Franklin, First Expedition to the Polar Seas, (London, 1823,) p. 157.

* Kopp's Jahrbuch der Staatsarzneikunde, Bd. x. s. 134.

† Topog. Hiberniæ, in Camden's Angl. &c. (1603), part ii. p. 724.

‡ London Med. Repository for 1820, vol. xiii. p. 87.

§ Linnæan Transactions, vol. iii. p. 356.

‖ Journ. de Phys. tom. vi. p. 506.

animal, where a single horn was present, situated also on the same side with the diseased and degenerated ovary; and Russell* states, as the result of his experiments on castration in the deer, that when he removed one testicle only from the animal, the horn on the opposite side was the more completely developed of the two. Azara † observed in two birds the right side of the tail to possess the characters of the male, and the left those of the female.

In the hermaphroditic lobster previously alluded to as described by Nicholls, the general external configuration of the body was, like that of the sexual organs, perfectly female on one side, and perfectly male on the other.

It is principally, however, among hermaphroditic insects that a difference of sexual type in the general conformation of the opposite sides of the body, and of its individual parts, has been observed; and this malformation is the more striking and easy of observation in this class of animals, on account of the great differences in colour, size, and form respectively presented by the antennæ, wings, and other parts of the body of the males and females of the same species.

Lateral hermaphroditism of the body in Insects has been most frequently observed by Entomologists amongst the class Lepidoptera. It has now been remarked in the following species:— in the *Argynnis paphia*, *Lycæna alexis*, *Saturnia pyri*, *Endromis versicolor*, and *Harpya vinula* (Ochsenheimer); in the *Gastrophaga medicaginis* and *Lycæna adonis* (Rudolphi); in the *Liparis dispar* (Schaefer, Ochsenheimer, and Rudolphi); in the *Saturnia Carpini* (Capieux, Ochsenheimer, and Rudolphi); in the *Gastrophaga quercifolia* (Hettlinger and Rudolphi); in the *Gastrophaga pini* (Scopoli); in the *Gastrophaga cratægi* (Esper); in the *Sphinx convolvuli* (Ernst); *Sphinx populi* (Fischer and Westwood); *Papilio polycaon* (Macleay); *Polyommatus alexis* (Entomolog. Mag. vol. iii. p. 304); *Bombyx castrensis* (Duval); in the *Argynnis paphia* (Allis); in the *Vanessa atalanta* (Schrank and Germar); and in the *Vanessa antiopha* and *Deilephila euphorbiæ* (Germar). Klug and Germar have recorded two instances of it among the Coleoptera, the former in the *Lucanus cervus*, and the latter in the *Melolontha vulgaris*; and Mr. Westwood mentions a third case in the large water-beetle *(Dyticus marginalis)*, as contained in Mr. Hope's collection, and has seen a fourth in the stag-beetle *(Lucanus cervus)*.

Out of twenty-nine recorded cases of lateral hermaphroditism in Insects, in which the sexual characters of each side are distinctly specified, we find that in seventeen instances the right side was male, and in twelve female. Burmeister alleges that in by far the majority of cases the right side is male, and the left female,—a statement in which Meckel coincides, while Westwood maintains the reverse. The cases we have ourselves collected are certainly numerically in favour of the former opinion, but the data are as yet so few, and the difference so trifling, as not to warrant us to come to any decided conclusion on this point.

In some instances we find among insects an imperfect lateral hermaphroditism consisting of some parts of one side, as of one or more of the wings, palpi, or antennæ being formed according to a different sexual type from the same parts of the opposite side, and from the general body of the animal. Thus in the Melitœa described and dissected by Klug (see *Lateral Hermaphroditism)* the general form of the insect was male, but the left eye, palpus, antenna, and left sexual fang were smaller than in individuals belonging to this sex; the left antenna was annulated with white and yellow at the apex, while the right was of one colour; the general form of the abdomen was male but somewhat thick, and the wings were all equal and male.

In a *Pontia duplidice* mentioned by Rudolphi, and which in its general external characters was female, the right anterior wing was formed after the male type, and the sexual organs also resembled those of the male.

Ochsenheimer mentions one *Gastrophaga quercus* with the body, and the antennæ and wings on the left side female, and the right wings male; and a second with the body and the right side female, and the left side and two antennæ male, the latter being brown and pectinated.

In this imperfect variety of lateral hermaphroditism, the malformed wing, antenna, or palpus is sometimes formed after one sexual type and coloured after another. In a male *Melitæa phœbe* noticed by Germar, the right wings and antenna were female in regard to size, but male in respect to colouring and markings. In a female *Deilephila galii*, he found the left antenna and palpus of the small size of the male, but agreeing in colouring and markings with the corresponding female parts on the right side. In a *Pontia cardamines*, which was male in all its other characters, Ochsenheimer observed the right superior wing marked as in the female, and he mentions another individual of the same species which had a female form with some male colours.

In another variety of insect hermaphroditism the sexual difference is sometimes, as we have already noticed in regard to the human subject, expressed not by a lateral, but by a longitudinal sexual antagonism, or, in other words, the anterior and posterior parts of the body are formed after the two opposite sexual types. Thus in a *Saturnia carpini* described by Ochsenheimer, the antennæ were male, the superior wings male in form, but coloured as in the female, and the posterior wings, with the exception of a reddish brown spot upon the left, were, with the body and other parts, female.

Lastly, in a third variety of external hermaphroditic conformation in Insects, we find the characters of the two sexes mixed up and crossed in different irregular combinations upon the body of the same individual. In a *Gastrophaga castrensis* described by Rudolphi, and where the male type predominated, with a tendency,

* Economy of Nature in Glandular Diseases.
† Kob's Dissert. de Mutatione Sexus, p. 19.

however, in all parts to the female form, the right antenna and the wings on the opposite or left side were distinctly female, while the left antenna and right wings were entirely male, the latter being only somewhat larger than in male insects, and the colours brighter than in the female. In a *Bombyx castrensis* alluded to by Westwood, the wings on the right side, and the antennæ and abdomen of the left, were those of a male, while the left wing, right antennæ, and right side of the abdomen were those of a female.

GENERAL SUMMARY WITH REGARD TO THE NATURE OF HERMAPHRODITIC MALFORMATIONS.

1. *Of the varieties of spurious hermaphroditism.*—On some of these varieties it is unnecessary for us to dwell here. The first species of spurious male hermaphroditism, or that arising from extroversion of the urinary bladder, is elaborately discussed elsewhere (see BLADDER); and two others, namely, the second female species consisting of prolapsus of the uterus, and the second male consisting of an adhesion of the penis to the scrotum, seem both referable to the head rather of disease than of original malformation. This latter indeed appears in all probability only an effect or result of adhesive inflammatory action in the affected parts during embryonic or fœtal life. Both of the two remaining forms of spurious hermaphroditism,—viz. those consisting of hypospadic fissure of the urethra, scrotum, and perinæum in the male, and of abnormal magnitude of the clitoris in the female,—seem readily explicable upon the doctrine of arrestment and anormality in the development of the malformed parts.

We have already described at sufficient length the process of development of the different copulative organs, and have shewn that those various degrees of hypospadic malformation which constitute the common form of spurious hermaphroditism in the male, may be traced to arrestment of this process at various periods or stages of its progress. And we may here remark that the earlier this arrestment occurs, the distinction of the true sexual type of the malformed organs will always be the less marked, because the younger the embryo, and, on a similar principle, the lower we descend in the scale of animal existence, we find the differences between the organs of the two sexes proportionally the less pronounced, until at last we arrive at that primitive type in which these organs present altogether a common, neutral, or indeterminate character.

We have also already shewn that at a certain early stage of the development of the female organs, the female clitoris holds the same, or nearly the same relatively larger size to the whole embryo as the penis of the male, and that so far we may consider the occasional occurrence of spurious hermaphroditism from magnitude of the clitoris, and its resemblance in this respect to the male organ, as a permanent condition of a type of embryonic structure that is normally of a temporary or transitory existence only. But besides this permanence of the embryonic type of the clitoris, we must farther, in all the more complete instances of spurious female hermaphroditism, admit an excess of development in the malformed external sexual parts, and more particularly in the line of the median reunion of the two primitive lateral halves or divisions of these parts. In this way the vagina (a remnant in the female of the primitive perinæal cleft or fissure) is often in such cases more or less contracted and closed, so much so indeed in some instances as to leave only, as in the male, a small canal common to the genital and urinary passages. If the median junction is extended still farther, this canal comes also to imitate the male urethra in this respect, that it is united or shut up *below* in such a way as to be carried onward to a greater or less length, and in a more or less perfect condition along the under surface of the enlarged clitoris; and occasionally the male type of structure is still more completely repeated in the female organization by the median reunion of the two labia, giving the appearance of the united scrotum and closed perinæum of the opposite sex.

If we divide the whole sexual apparatus of the male and female into three corresponding transverse spheres or segments,—the first or deep parts including the testicles and ovaries, the second or median comprehending the male seminal canals and prostate gland, and the female oviducts and uterus, and the third or external embracing the copulating organs of the two sexes,—we shall find that, relatively speaking, the deep and the external spheres are naturally most developed in the male economy, while the median, comprising the uterus, (the principal and most active organ in the female reproductive system,) is developed in the greatest degree in that sex. In malformed females presenting a spurious hermaphroditic character, this important portion of the female sexual organization is, in general, either itself in some respects malformed, or, from the structure of the other parts of the sexual apparatus being imperfect, its specific importance in the economy is cancelled, and therefore the energy of development takes the same direction as in the male, being expended upon the more complete evolution of the organs of the external and deep spheres. Hence the greater size of the clitoris, and the greater development which we have just now pointed out, in the median line of reunion of the external sexual parts; and hence also the occasional though rare occurrence, in the same cases, of the descent of the ovaries through the inguinal rings into the labia,—an anomaly that certainly consists in a true excess of development, and which we cannot but regard as interesting, both in this respect, and as affording a new point of analogy between these organs themselves and the male testicles.

There is another and equally interesting point of view in which we may look upon this subject. Not only are the forms of spurious hermaphroditism which we have been considering, capable of being traced backward to certain transitory types of sexual structure in the embryos of those animal species in which the malformations in question occur, but they may be shewn also to present in their abnormal states repetitions of some of the normal and permanent conditions of the sexual organs in various species of animal beings placed lower in the scale of life. Thus the occasionally imperforate penis of the male hermaphrodite has been supposed to have an analogue in the naturally solid penis of some of the species of the genera *Doridium* and *Hyalæa*.* Its more or less grooved or hypospadic condition is similar to the natural type of the same part in some hermaphrodite Mollusca, as in the *Planorbis* and *Murex*:† in its occasional diminutive size it approaches the general smallness of the partially fissured penis of most birds and reptiles; and we find it in the Rodentia and Marsupiata tied down by a short prepuce in a way analogous to what is seen in some cases of severe hypospadias. In the sloth (*Bradypus tridactylus*) the penis is small and grooved in its lower surface, and has the urethra opening at its base;‡ and in several of the male Rodentia the scrotum is also cleft, and has its two opposed surfaces smooth, humid, and free of hair, as in most cases of hypospadic hermaphroditism in man. In Ophidian and in most Saurian Reptiles, the male seminal ducts open at once externally, as in some male hermaphrodites, at the root of the fissured penis.

The fact of the testicle some time remaining, in cases of hermaphrodite formation in the human subject, within the cavity of the abdomen, presents to us in a permanent state their original but changeable position in the early fœtus, and at the same time affords a repetition of their normal situation, in almost all the lower tribes of animals, and in the Cetacea, Amphibia, Edentata, and some Pachydermata, as the Cape Marmot (*Hyrax*) and Elephant, among the Mammalia.

The malformed clitoris in instances of spurious hermaphroditism assumes also, in its abnormal state, types of structure that we find as the normal condition of the organ in various inferior animals. Thus in female Cetacea and Rodentia, and in the animals included in Cuvier's order of Carnassiers, but more particularly among the Quadrumana, the clitoris retains as its permanent normal type that relatively larger size which we observe in the early fœtus, and in female hermaphrodites in the human subject: and further, as is sometimes seen in such malformed individuals, the clitoris becomes partially traversed by the urethra, as in the Ostrich, Emu,§ and Anteater;‖ and in the Loris (as we have noticed in a preceding page) and Maki, it is completely enclosed, like that of the male, in the body of the organ, forming a continuous and perfect canal through it.

We may here further observe, (though the illustrations should more properly belong to the next section,) that in cases of true hermaphroditism also in man and quadrupeds, as well as in the above spurious varieties, there may be often traced in some portions of the abnormal structures a sexual type bearing a greater or less analogy to the corresponding parts of those inferior animals that are naturally androgynous. Thus, in instances of true hermaphroditism, the orifices of the sexual ducts or passages occasionally open into a common cavity, as is normally the case in some species of *Doridium*, *Helix*, and other Mollusca; or the female oviducts or Fallopian tubes, and the male vasa deferentia, run closely alongside of each other without any communication between their canals, as in the *Alypsia* and most Gasteropoda. Indeed the occasional co-existence even of both testicles and ovaries in individuals among the higher animals would be only a repetition of, or retrogression to, the normal sexual type of those genera of animals that we have just named, and of the Planaria, Cestoidea, and other natural hermaphrodites.

In this way we see, that, (as in many other monstrosities,) the several varieties of malformation in the sexual organs occurring in spurious human hermaphroditism do not consist of the substitution of an entirely new and anomalous type of structure, but are only repetitions of certain types of the same organs that are to be met with both in the human fœtus and in the inferior orders of animal beings. The investigation of the whole subject shews us in reference to the sexual organs, what is equally true in regard to all the other organs of the body,—that their different stages of development in the embryos of man and of the higher orders of animals correspond to different stages of their development in the series of animal beings taken as a whole; so that here, as elsewhere, the facts of Comparative Anatomy are reproduced in those of Embryology, and both are repeated to us by nature on a magnified scale in the anatomy of the malformations of the part,—a circumstance amply testifying to the intimate relations which subsist between Comparative Anatomy, the anatomy of Embryonic Development, and that of Monstrosities. Indeed proportionally as our knowledge of malformations has increased, it has shewn us only the more strongly that the laws of formation and malformation,—of normal and abnormal development, are the same, or at least that they differ much more in degree than in essence, and that the study of each is calculated reciprocally to illustrate and to be illustrated by the study of the other.

2. *Nature of true hermaphroditic malformations.*—Of the nature of local malformations by duplicity, we at present possess much less precise knowledge than of those of simple defect or simple excess of development; but there are certain facts ascertained with regard

* Burdach's Physiologie, Bd. i. § 132, p. 231.

† Tiedemann's Zeitschrift fuer Physiologie, Bd. i. s. 15, or Cuvier, Anat. Comp. tom. v. p. 182.

‡ Meckel, Beitræge zur vergleichenden Anatomie, Bd. ii. esp. i. p. 125.

§ Cuvier, Anat. Comp. t. v. p. 129.

‖ Meckel, Archiv. fuer die Physiologie, Bd. v. s. 66.

e formation of the sexual organs, which to th[e]nable us to make an approach at least to may e[x]e ideas of the character and origin of accurat[e] normalities that constitute the several those a[b] of true hermaphroditism. These facts varieties the interesting subject of the unity of relate to which is manifested in the correspond- structure and female reproductive organs of the ing male an[d] and of other species of bisexual human subject, animals. Greek, Roman, and Ara-

By several of the Gr... ...ctive organiza- bian physiologists,* the respe... ...ed as in tions of the two sexes were consider... ...be some degree typical of one another, the fema[le] being regarded as an inverted male, with the testicles and penis turned inwards to form the ovaries and uterus. This doctrine of analogy between the male and female sexual organs has, with various modifications, been very generally admitted by modern physiologists, and in some of its bearings it has been made, more particularly of late years, the subject of considerable discussion. The testicles are still regarded as organs which correspond with the ovaries in their original situation, in their vascular and nervous connections, and in their relative sexual functions. The recent progress of the anatomy of the development of the embryo has also shewn that the two organs correspond in their primitive origin. It is now well ascertained that the large masses occupying each side of the abdomen of the embryo at an early stage of development, and which Rathke has named the Wolffian bodies after their illustrious discoverer, form, in Birds and Mammalia at least, the primordial matrices upon which the urinary and genital organs are developed. On the inner side of each of these matrices a small body is early developed, which seems to become afterwards either a testicle or an ovary, according to the particular ulterior sexual type which the embryo assumes.

In further following up the analogy of structure between the organs of the two sexes, the vasa deferentia of the male are generally compared to the Fallopian tubes of the female, the scrotum to the external labia, the body of the penis to the clitoris, and its corpus spongiosum, or, according to others, its prepuce, is regarded as corresponding in type with the female nymphæ. A considerable difference of opinion, however, still prevails as to the prototype of the female uterus in the male system. Some anatomists, as Burdach, Steghlener, and Blainville, regard the uterus and male vesiculæ seminales as corresponding parts; while others, as Meckel, Carus, Schmidt, Ackermann, and Serres, compare the uterus to the male prostate. A sufficient number of facts seems still wanting to determine the accuracy and justness of either of these analogies. There are instances of malformation on record which appear to favour both opinions, and there are other cases which almost incline us to believe that the vesiculæ seminales correspond to the fundus or body of the uterus in the human subject, and to the cornua uteri in quadrupeds; while the prostate represents in the male structure the lower portion or cervix of the same organ. The phenomena of the development of the reproductive organs in the embryo will, when more fully investigated, probably serve to clear up this question.

M. Geoffroy St. Hilaire has propounded views of the analogy of the male and female organs in some respects different from the above. He divides the uterus of the human subject into the body and the upper part or fundus, the latter corresponding to what constitutes the cornua uteri in the human embryo, and in adult quadrupeds. Further, believing that in the determination of all analogies in type and structure between different organs, the origin and course of the bloodvessels supplying the part ought to be our principal criterion, he has been led, by the study of the distribution of the branches of the hypogastric arteries, to consider the body of the uterus and the vesiculæ seminales as repetitions of each other in the two sexes; and, contrary to the opinion of most anatomists, he conceives that the male vasa deferentia strictly correspond with the fundus or cornua uteri, and that the epididymis represents a coiled-up Fallopian tube, or in other words that the Fallopian tube is an unrolled epididymis. M St. Hilaire has offered the following table to shew what he conceives to be analogous organs in the two sexes:—*

In the male.		*In the female.*
Testicle	=	Ovary
Epididymis	=	Fallopian tube
Vas deferens.	=	Cornu of the uterus.
Vesicula seminalis	=	Body of the uterus
Sheath of the penis	=	Vagina
Penis	=	Clitoris

In tracing out the analogies between the male and female parts, the mode in which we ought to consider the female vagina has given rise to some diversity of opinion. From the above table it appears that M. St. Hilaire considers it to be represented in the male organization by the sheath of the penis, but we are certainly inclined to view it in a different light, and to regard it as a part in so far peculiar to the female, that it consists of a permanent condition of that urino-genital perinæal fissure that we have already described as existing at a certain period in the embryos of both sexes, and which is latterly shut up in the male, or, speaking more accurately, it is contracted into what forms the pelvic portion of the male urethra.

If this were a fit opportunity for following out the consideration of the unity of type between the male and female reproductive organs, it would be easy to shew the justness of those greater analogies that we have mentioned, by pointing out other numerous minor, but still strong points of correspondence manifested in

* Aristotle, Hist. An. lib. i. 17. Galen, De Semine, lib. ii. & De Usu Partium, c. i. Rhases, De Re Medica, lib. i. cap. 26. Avicenna, De Membris Generat. lib. iii. 21, &c.

* Phil. Anat. tom. i. (1822,) p. 471.

the abnormal conditions and localities of the ovaries and testicles in the higher animals, and in their conformity of structure in some of the lower. Thus among Insects, in the genus *Libellula* the long cylindrical testes of the males correspond with the long-shaped ovaries of the females; in the *Locusta* and *Gryllotalpa*, there are ramose bunched testicles with analogous fasciculated ovaries; in the *Lamellicornia* we find compound radiating and united testes, with similar radiating and united ovaries; and sometimes, as in the genera *Melolontha* and *Trichius*, the number of the single bodies in the testicles corresponds with the number of the oviducts.*

We have already, when considering spurious hermaphroditism in the female, mentioned several facts illustrative of the analogical peculiarities in structure between the male penis and female clitoris in some species of animals; and Burmeister,† who regards the ovipositors and stings of female insects as corresponding to the clitoris in the female Vertebrata, has pointed out a remarkable conformity of structural type between its valves and those of the penis of the male of the same species.

Some organs that are, as far as regards their functions, peculiar and essential to one sex only, are nevertheless found to be repeated in the opposite sex in the form of an analogous rudimentary type of structure. Thus, in the male we may observe the unity of sexual structure maintained in the presence of the rudiments of the mammary gland, which is *functionally* an organ of the female system only. In the human subject, and in animals whose females have pectoral mammæ, these organs occupy the same position in the male; while in those species of quadrupeds in which they are placed in the inguinal region, we find them in the corresponding males forming the scrotum or bags for containing the testicles. Hence, as we have already seen, the testicles, in cases of malformation in these animals, are often laid upon or imbedded in the udder. In the same way in the Marsupiata, the bone which the female has for supporting the marsupium is repeated in the organization of the male, although in the latter we cannot conceive it to serve any possible use.‡

In the female also we observe in some points a similar disposition to the rudimentary repetition of parts that are essential or peculiar only to the male organization, as in the repetition in the clitoris of some female Rodentia, of the penis-bone of the male, and in the formation of rudimentary forms of those processes of peritonæum which constitute the tunicæ vaginales. We are ourselves inclined also to regard the common crescentic form of the hymen of the human female in the same light,§ and to consider it merely as an abortive attempt at that closure of the perinæal fissure which we have already described as effected at an early period in the male embryo—an opinion in which we conceive we are borne out both by the history of the development and the study of the malformations of the external sexual parts in the female.

M. Isidore St. Hilaire read, in 1833, to the French Academy a memoir,* in which, following up the doctrine of his father with regard to the determination and distinction of the type of parts by the particular vessels distributed to them, he endeavoured to shew some new points of analogy between the male and female organs, and to develop new views with regard to the origin and particular varieties of hermaphroditic malformations. With Burdach, he divides the whole reproductive apparatus of either sex into three transverse spheres and into six portions or segments in all, or three on each side, viz., 1 and 2, the deep organs, including the male testicles and female ovaries; 2 and 3, the middle organs, or male prostate and vesiculæ seminales, and female uterus; 3 and 4, the external organs, comprehending the penis and scrotum of the male, and the clitoris and vulva of the female. Each of these portions or segments is, M. St. Hilaire points out, supplied by an arterial trunk peculiar to itself, and the corresponding organs of the male and female by corresponding arterial branches, as the deep organs of both sexes by the two spermatics, the middle by branches of the two hypogastrics, and the external by some other hypogastric branches, and by the external pudics. This circumstance, he conceives, renders all the segments in a certain degree independent of the others, both as regards their development and existence, and allows of the occasional evolution of any one or more of them on a type of sexual structure, different from that upon which the others are formed in the same individual.

Though assuredly we cannot subscribe to the speculations of the elder St. Hilaire, that the development in the embryo of male testicles or female ovaries, and consequently the whole determination of the sex, is originally regulated by the mere relative angle at which the first two branches of the spermatic arteries come off, and the kind of course which they follow,† (more particularly as it is admitted by most physiologists that the bloodvessels grow, not from their larger trunks or branches towards their smaller, but from their capillary extremities towards their larger branches,) yet we believe that the doctrine of the comparative independence of the different segments of the

* Burmeister's Entomology, § 154. p. 222.

† Loc. cit.

‡ Home's Lect. on Comp. Anat. vol. ii. pl. v.

§ Burdach (Phys. § 137,) considers the small cutaneous fold situated at the orifices of the vasa deferentia, and Stiebel the membrane placed at the extremity of the urethra (Meckel's Archiv. für Physiol. Bd. viii. s. 207,) as the analogue in the male for the female hymen.

* Arch. Gén. de Méd. (1833) tom. i. p. 306.

† Anat. Phil. tom. i. p. 359. . . "L'ordre de variations des sexes tient à la position d'un artère. . . Le plus ou le moins d'ecartement des deux branches spermatiques motive effectivement cette preference. Que les deux branches de l'artère spermatique descendent parallelement et de compagnie, cette circonstance, je le repete, cette circonstance donne le sexe male; qu'elles s'ecartent à leur point de partage, nous avons le sexe femelle."

reproductive organs pointed out by the son is in its general principles correct. At the same time we would here remark that we conceive the doctrine would have been founded more on truth if the influence of the nervous branches supplying the different reproductive organs had been taken into account along with that of their arterial vessels, because, as we shall point out when speaking of the causes of hermaphroditism, there appears to be some connection between the state of the nervous system and the degree or condition of sexual development.

The consideration of the preceding analogies in structure between the male and female organs is interesting in itself, and, as far as relates to our present subject, important in this respect, that it enables us in some degree to understand how it happens that, without any actual monstrous *duplicity*, we should sometimes find, in an organization essentially male, one or more of the genital organs absent and replaced by an imperfect or neutral organ, or by the corresponding organ of the opposite sex, and *vice versa ;* inasmuch as it shews us that the moulds in which the analogous organs of the two sexes are formed are originally the same. Hence there is no difficulty in conceiving that, in the body of the same individual, the primitive structural elements of these parts should occasionally, in one or more points or segments, take on, in the process of development, a different sexual type from that which they assume at other points. Indeed some physiologists, as we shall immediately see, deny that the most complete hermaphroditic malformations ever consist of anything except such a want of conformity between the sexual type of different portions of the reproductive apparatus.

If each of the six segments (and we believe that their number might be shewn to be really greater than this,) is thus an independent centre of development in the formation of the sexual apparatus, and is consequently liable also in abnormal cases to have its own particular malformations, and to assume, either alone or along with some of the other segments, a sexual type different from the remainder, it is evident that we may have as many varieties of true hermaphroditism, without any real duplicity, as it is possible to conceive differences of arrangements among these six segments. Again, however, one or more of these segments may preserve from a development its original indeterminate or neutral sexual type, while the others are variously formed either upon one or upon both sexual types; or one or more of the segments may, by a true malformation by duplicity, have evolved within them the corresponding organs of the two sexes; and if we consider the different arrangements of double and single sexual parts that might thus occur in the six separate segments, we may gain some idea of the great diversities of structure in the sexual parts that are liable to be met with in instances of true hermaphroditism.

The above forms, as it appears to us, the most sound and rational solution of the nature and origin of many forms of true hermaphroditism which physiological science is capable of affording, upon our present limited knowledge of the laws of development; and its application to the explanation of the different varieties of lateral, transverse, and vertical hermaphroditism is so obvious as only to be required to be alluded to. It offers to us, however, no insight into the probable origin of those varieties of double hermaphroditism in which there is an actual co-existence upon one or upon both sides of the body, or, in other words, in the same segment of the sexual apparatus, of both the corresponding male and female organs. We can only refer all such instances to the laws which regulate the occasional production of *local* duplicities in different other organs of single bodies, and at the same time confess our present ignorance of what these laws are. We know that various individual muscles, nerves, &c. are not unfrequently found double, and that in the internal organs of the body examples of duplicity in individual viscera are occasionally, though rarely, observed in the heart, tongue, trachea, œsophagus, intestinal canal, &c. In the several organs composing the reproductive apparatus, instances of similar duplicity would seem to be even more common than among any other of the viscera. Examples of *three* mammæ upon the same person are mentioned by Bartholin,* Borelli,† Lanzoni,‡ Drejer,§ Robert,|| Petrequin,¶ and others;** and cases in which the number of these organs was increased to *four* have been recorded by Faber,†† Gardeux,‡‡ Cabroli,§§ Lamy,|||| Tiedemann,¶¶ Champion,*** Sinclair,††† R. Lee,‡‡‡ and Moore.§§§ An instance in which *five* mammæ even existed upon the same woman is reported to have been seen by Gorré.|||||| Valentin¶¶¶ and Gunther**** have recorded supposed cases of duplicity in the male penis; and Arnaud†††† has related an example of an analogous malformation in the female clitoris. Weber‡‡‡‡ met with a double vesicula seminalis

* Acta Med. Hafn. tom. iii. obs. 93.

† Observ. Rar. cent. i. p. 55.

‡ Eph. Nat. Cur. Dec. ii. Ann. v. obs. 55.

§ Arch. Gén. de Méd. tom. xvii. p. 88.

|| Journ. Gén. de Méd. tom. c. p. 57.

¶ Gazette Medicale for April, 1837. Three distinct mammæ in a father, and in his three sons and two daughters.

** Dict. des Sc. Méd. tom. xxxiv. p. 529.

†† Eph. Nat. Cur. Dec. i. Ann. ii. p. 346.

‡‡ Journ. de Méd. de Corvisart, tom. ix. p. 378.

§§ Obs. Anat. vii.

|||| Fantoni Anat. p. 267.

¶¶ Zeitschrift für Physiologie, Bd.v. s. 110. One case with three, and three with four nipples. In one case the malformation was hereditary.

*** Dict. des Sc. Medic. t. xxx. p. 377. See also p. 378.

††† Statistical Account of Scotland, xix. p. 288.

‡‡‡ London Med.-Chirurg. Trans. vol. xxi. p. 266.

§§§ Lancet for February 24, 1838.

|||||| Dict. des Sc. Méd. tom. xxxiv. p. 529.

¶¶¶ Eph. Nat. Cur. Dec. iii. Ann. iii. obs. 77.

**** Cohen vom Stein, Halle, 1774, p. 107.

†††† Mém. de Chir. tom. i. p. 374.

‡‡‡‡ Salzburg Medicinische Zeitung, 1811, s. 188.

on each side; and Hunter* alludes to the occasional occurrence of an imperfect supernumerary vas deferens. In 1833 a case of a double human uterus, furnished with four Fallopian tubes and four ovaries, was shewn by Professor Moureau to the Academie de Médecine.† Blasius‡ dissected the body of a man on whom he detected the co-existence of three testicles; the additional testicle was of the natural form and size, and was furnished with a spermatic artery and vein that joined in the usual manner the aorta and vena cava; it lay in the right side of the scrotum. Arnaud found, on dissection, three testicles in a dog; the third was placed in the abdomen, and of the natural consistence, figure, and size; it was furnished with a vas deferens.§ Other instances of triple and quadruple testicles of a more doubtful character, inasmuch as the observations made during life were not confirmed by dissection after death, are related by Voigtel,‖ Sibbern,¶ Brown,** Rennes,†† and others.‡‡ Scharff§§ even gives an alleged case of a man with five testicles, three of which are stated to have been well formed, while the other two were much smaller than natural. And, lastly, Loder‖‖ is said to have exhibited to the Gœttingen Academy drawings taken from the body of a male infant, on whom *all* the sexual apparatus existed double, there being two penes, a double scrotum, and urinary bladder, and, as it was supposed, four testicles.

In all the preceding instances the local duplicity of the particular reproductive and other organs adverted to existed independently of any duplicity in the body in general, or in any other individual parts of it. And if we once admit, (what the preceding instances will scarcely allow us to deny,) that there may occur a duplicity of some of the male sexual organs in a male, or of some of the female sexual organs in a female, it is certainly easy to go one step farther, and admit that the double organ or organs may, however rarely, be formed in other instances upon an opposite sexual type. Indeed all our knowledge of the unity of structure and development between the various analogous male and female reproductive organs, as well as the fact of the occasional replacement of an organ of the one sex by that of the other in cases in which the sexual type is entirely single (as seen in instances of lateral hermaphroditism), would lead us *à priori* to suppose that, if a local duplicity in any of the sexual organs was liable to occur, this duplicity would sometimes shew itself in the double organs assuming opposite sexual characters, and thus constituting some of those varieties of double or vertical hermaphroditism that we have already had occasion to describe.

In the preceding observations we have proceeded upon the opinion commonly received by physiologists, of the fundamental unity of sex among all individuals belonging to the higher orders of animals; or, to express it otherwise, we have assumed that each individual is, when normally formed, originally furnished with elemental parts capable of forming one set of sexual organs only. We do not here stop to inquire whether this single sexual type is, in all embryos, originally female, as maintained by Rosenmüller, Meckel, Blainville, Grant, and others; or, of a neutral or intermediate character, as supposed by the St. Hilaires, Serres, Ackermann, Home, &c., and as we are certainly ourselves inclined to believe it.* On this subject, however, a physiological doctrine of a different kind has been brought forward by Dr. Knox, and this doctrine is so intimately connected with the question of the nature and origin of true hermaphrodites, that we must here briefly consider it.

Dr. Knox,† in conformity with some more general views which he entertains on transcendental anatomy, is inclined to regard the type of the genital organs in man and the higher animals, as in the embryo, originally hermaphroditic, or as comprising elementary yet distinct parts, out of which both sets of sexual organs could be formed; and he believes that, owing to particular but unknown circumstances, either the one or the other only of these sets of elements comes to be evolved in the normal course of development. In those abnormal cases, again, in which, as in instances of double hermaphroditism, more or fewer of both sets of genital organs are present upon the same individual, he maintains that this is not to be considered as a malformation by duplicity, but is only a permanent condition of the original double sexual type, and is attributable to the simultaneous development to a

* Bell's Anatomy, vol. iii. p. 428.
† Journ. Hebdom. tom. x. p. 168.
‡ Obs. Med. pars iv. obs. 20.
§ Mém. de Chirurg. s. i. p. 131.
‖ Handbuch der Path. Anat. Bd. iii. s. 393.
¶ Acta Hafn. tom. i. p. 320.
** New York Medical Repository, vol. iv. p. 801.
†† Arch. Gén. de Méd. t. xxiii. p. 17.
‡‡ See Haller's El. Phys. tom. v. p. 411, 12.—and Arnaud's Chem. de Chirurg. t. i. p. 128, &c.
§§ Eph. Nat. Cur. Dec. iii. Ann. v. vi. obs. 89.
‖‖ Göttingen Anz. 1802, p. 466.

* Meckel (De Duplicitate Monstrosa, p. 14), and Andral (Anat. Path. tom. i. p. 101) assume it, after Haller, as a fact, that a much larger proportion of monsters belong to the female than to the male sex; and while they attribute this circumstance to the genital organs in these beings retaining, from the general defect of development, their *original female* sexual character, they at the same time consider this circumstance to be strongly corroborative of this particular doctrine. Isid. St. Hilaire has shewn (Hist. des Anomal. t. iii. p. 387) that the supposed fact itself does not hold true in respect to some genera of monsters, and is even reversed in others; and he doubts if it be of such a degree of generality in respect to monsters in general as to merit to be raised into a teratological law. If the views of Meckel were correct, we should certainly expect at least that spurious hermaphroditism, where the development of the sexual parts is commonly abnormal from *defect*, should be much more frequent in the female than in the male. The list, however, of recorded cases of it in the latter is, we believe, more than double the number of it in the former.
† Brewster's Edinburgh Journal of Science, vol. ii. p. 322.

greater or less extent both of the male and female sets of sexual elements.

This doctrine of the original but temporary double sexed character of all embryos derives, perhaps, its principal support from a source to which Dr. Knox does not advert,—we mean the existence of this as the normal and permanent sexual type in most plants and in many of the lower orders of animals. But this argument by analogy certainly cannot by any means be considered as a sufficient basis for the establishment of so broad and important a generalization in philosophical anatomy. Dr. Knox himself seems to have been induced to adopt the idea principally because it afforded (when once assumed as a fact) a simple and elegant solution, upon the laws of development, of the occasional occurrence of cases of true hermaphroditism; and in doing so, he appears to have proceeded upon the mode in which most such physiological hypotheses have been made, viz. by drawing his premises from his deductions instead of his deductions from his premises. In the present state, however, of anatomical and physiological knowledge, Dr. Knox's hypothesis, however ingenious in itself, is one which we cannot subscribe to; for first, it is totally opposed to all the facts which have been ascertained, and all the direct observations which have been made by Rathke, Meckel, Müller, Valentin, and other modern anatomists upon the sexual structure of the embryos of the higher animals in their earliest state; and, secondly, if we were to admit it merely as a probable hypothesis, it is still even in this respect equally as incapable as the old doctrine of sexual unity, of explaining all the cases of malformation by duplicity of the genital organs; for, as we have already shewn, there are some apparently well-authenticated instances of the existence of three or four testicles upon the same man, or three or four ovaries upon the same woman; and in reference to all such cases we would, if we proceeded upon the same data and the same line of argument as those adopted by Dr. Knox, be obliged to suppose that the original sexual type is not, as he imagines, double only as respects the two sexes, but double even as respects each sex, and that all embryos had originally not simply the elements of two, but those of three or four testicles and ovaries. In explaining such cases as those to which we allude, Dr. Knox, on his own doctrine, must of necessity admit the existence of a malformation by duplicity of the sexual organs in question; and if we grant this in regard to these instances, it is surely unnecessary to invent a particular and gratuitous hypothesis for the explanation of the analogous anatomical anormalities observed in hermaphroditism. At present we must, we believe, merely consider the occurrence of anomalous duplicity of the sexual organs, and of various other individual parts of the body, as so many simple empirical facts, of which we cannot, in the existing state of our knowledge, give any satisfactory explanation, or, in other words, which we cannot reduce to any more simple or general fact; though from the success which has attended the labours of many modern investigators in this particular department of anatomy, it seems to us not irrational to hope that ere long we may be enabled to gain much new light upon the question of double hermaphroditism and the whole subject of malformation by duplicity.

ANATOMICAL DEGREE OF SEXUAL DUPLICITY IN HERMAPHRODITISM.

Though the cases which we have brought forward do not present any instances of such perfect hermaphrodites in the human subject or in quadrupeds as those which are represented upon the ancient Greek statues and medals,* or that have been described and delineated by Lycosthenes, Paré, Schenkius, and the older authors on monstrosities, they yet present to us a sufficient number of instances in which, in accordance with the definition we have previously given of true hermaphroditism, there actually co-existed upon the body of the same individual more or fewer of the genital organs both of the male and female.

From the relations and size of the bony pelvis, and the fact of the penis and clitoris being repetitions only in situation and structure and organic connections of each other in the two sexes, it is useless perhaps to expect that we should ever find in any one case all the parts of both sexes present at the same time. For since the male penis is only a magnified condition of the female clitoris, and since both of these organs are connected by the same anatomical relations to the same part of the pelvis, it would almost require some duplicity in the pelvic bones themselves to admit of the simultaneous presence of both; and in no authentic case has any approach to their co-existence upon the same individual been observed.

Various authors who have written upon the subject of hermaphroditism have gone so far as to endeavour to refer all instances of it to some one or other of those varieties that we have described under the name of *spurious*. Thus, dogmatizing in a spirit of unphilosophical scepticism, Parsons† and Hill‡ have endeavoured to shew that all reputed hermaphrodites are only malformed females having a preternatural development of the clitoris, and in some instances with the ovaries descended into the labia. Others, on the contrary, as

* See Winckelman, Hist. de l'Art, t. i. p. 364; and Caylus, Recueil d'Antiquités, t. iii; Heinrich, Commentatio quâ Hermaphroditorum artis antiquæ operibus illustrium, origines et causæ explicantur. Hamburg, 1805. Blumenbach, in his Specimen Hist. Nat. Antiq. artis (Goetting, 1808), mentions and figures (pl. i. f. 5, p. 15), a small ancient silver cast or impression of a case of hypospadias of the male genital parts, which he supposes to have formed a votive offering from some individual malformed in the manner represented.

† Enquiry into the nature of Hermaphrodites, p. 145. We would particularly point out the cases quoted by Dr. Parsons at p. 14, 26, 30, 88, 95, 130, &c. of his able essay as directly contradictory of his own doctrine, or as instances of hermaphroditic appearances in persons not of the female but of the male sex.

‡ Review of the Philosophical Transactions.

Professors Osiander* and Feiler,† maintain with equal inaccuracy that every supposed instance of hermaphroditism is referable to a hypospadic state of the penis and scrotum, in persons that are in other respects essentially male.

Various physiologists, again, while they admit the occurrence of all the different varieties of spurious hermaphroditism, are inclined to deny that any such combinations of male and female organs upon the same body as those which constitute our several varieties of true hermaphroditism, are ever observed to occur in the human subject, or among the higher classes of animals.‡ In despite of the recent accumulation of new and authentic cases, Professor Müller of Berlin is, in particular, in his excellent treatise on the development of the genital organs, published in 1830,§ still inclined to coincide in a great degree in this opinion. This distinguished physiologist does not indeed, as some have done, doubt in any degree the authenticity of the recorded cases, and even goes so far as to admit the occasional occurrence of a combination of male and female organs upon the same individual, when that combination does not (as in lateral and transverse hermaphroditism) imply a true sexual duplicity or repetition of any of the corresponding male and female parts; but he doubts altogether the probability of our third division of double or complex hermaphroditism, and conceives that in the examination of the cases referable to that section a sufficient degree of attention has not been directed to the accurate anatomical distinction of the particular parts supposed to exist, from others with which it is possible to confound them. We shall here, therefore, shortly inquire into some of the principal sources of fallacy which are apt to mislead the incautious observer in the examination of such instances as those to which we allude; and in doing so we shall consider the various sources of error in an order conformable with those divisions of double hermaphroditism that we have previously adopted,—speaking of the mistakes which may be committed in judging of the supposed co-existence, 1st, of a female uterus, and male vesiculæ seminales and vasa deferentia; 2d, of a female uterus and male testicles, &c.; 3d, of both testicles and ovaries.

1. *Fallacies in judging of the addition of male seminal ducts to a female type of sexual organs.*—That form of sexual duplicity which we have formerly described as consisting in the supposed superaddition of male vesiculæ seminales and vasa deferentia to an organization in other respects female, appears to have been hitherto observed principally, or indeed only among the Ruminantia, and has in particular been repeatedly found in free-martin cows. In judging of the reality of this variety of hermaphroditic malformation in any given case, there is one source of fallacy that requires to be particularly guarded against, and the consideration of which may probably go far to explain away most of the recorded examples of the malformation. In the female sexual parts of some Ruminantia and Pachydermata,* but particularly in the domestic cow and sow, Dr. Gaertner of Copenhagen pointed out in 1822† the existence of two canals or ducts which have since that time been generally described under his name. On each side of the body, one of these ducts arises in the vicinity of the ovary, or near the fimbriated extremity of the Fallopian tube, runs down first in the duplicature of the broad ligament, and afterwards in the substance of the parietes of the uterus and vagina, to near the meatus urinarius, and there opens into the vaginal cavity. Each duct communicates with several small glands, follicles, or cysts that are scattered along its course, and which perhaps may not be improperly described as diverticula from the ducts themselves. Now when we consider the relations of those imperfect ducts and cysts that are occasionally observed in the free-martin cow, situated along each side of the defectively developed uterus, and which Mr. Hunter has described as male vasa deferentia and vesiculæ seminales, it seems to us not at all improbable that these supposed male organs are only in reality the ducts of Gaertner, with their accompanying follicles or cysts generally perhaps existing in a morbidly developed and dilated condition. They seem at least to correspond much in their origin, course, and position with the canals and cysts discovered by Gaertner; and certainly in the present state of our knowledge it would appear more reasonable to refer them to this *normal* portion of the female structure, than to regard them, until we have more decided evidence on the subject, as *abnormal* male organs, and as affording, in consequence, an example of sexual duplicity.

In the course of the preceding pages we have had occasion to allude to cases in the human subject, and in the dog and sheep, in which vasa deferentia were stated to have existed in the same individual along with Fallopian tubes. Whether, in any of these instances, the supposed male seminal ducts were merely canals analogous to those described by Gaertner in the cow and sow, we shall not take it upon us to determine, but in connection with this inquiry it is interesting to remark that Malpighi, who seems to have been well acquainted with the existence of the ducts in the

* Neue Denkwuerdigk. für Geburtshülfe. Bd. i. n. 8.

† Ueber Angeb. mensliche Misbildung. Landshut 1820.

‡ Thus Portal, Anat. Méd. t. v. p. 474; Haller, El. Phys. t. viii. p. 7, "merito dubitatur;" Voigtel, Handbuch der Path. Anat. Bd. iii. s. 364; Lawrence, Art. Generation, in Rees's Cyclopædia.

§ Bildunsgeschichte der Genitalien.

* M. Delmas seems to have observed a somewhat similar structure in the Kangaroo. (Ephem. Medic. de Montpellier, t. v. p 115.)

† Anatomisk Beskrivelse over et ved Nogle Dyr-Arters uterus undersögt Glandulëst organ, &c. Copenhagen, 1822; Edin. Med. and Surg. Journ. vol. xxi. p. 460.

cow, has suggested that they may also exist in a more obscurely developed state in the human female, and may perhaps be identified with the ramous lacunæ described by De Graaf, Bartholin, Riolan, &c.

A. C. Baudelocque has, in a case published in the Rêvue Médicale for March 1826, described a human uterus which contained in its parietes a canal coming from the right Fallopian tube, and opening upon the internal surface of the cervix uteri; and Moureau and Gardien seem to have met with a second (?) similar instance.*

Before leaving this subject of the probable source of fallacy which we have to guard against in confounding the ducts of Gaertner with the male seminal canals, it is necessary also to observe, that some anatomists† are now inclined to consider these canals as the permanent remains of the ducts of those Wolffian bodies which we shall presently have occasion to allude to more at length, as forming a temporary type of structure in the sexual development of the early embryo; and certainly the two appear to accord in most points with respect to their situation and course. If, however, it happens that further and more accurate observations prove the two to be different, then the possible permanent state of the ducts of the Wolffian bodies must be looked upon as affording another source of error, by which we may deceive ourselves in judging of sexual duplicity from the supposed superaddition of male seminal canals to a female sexual apparatus.

2. *Fallacies in the supposed co-existence of a female uterus with testicles and other organs of a male sexual type.*—We have, in a previous part of this communication, adduced about twenty different instances in the human subject, and in the quadruped, in which a female uterus, or both an uterus and Fallopian tubes were described as having been found upon the bodies of individuals that were in other respects essentially males.

In reference to some of these instances it has been doubted whether the sexual organization of the malformed animal was not *entirely* male, the supposed and generally imperfect uterus being conceived to be formed either by a morbid dilatation and unfolding of the substance of the male prostate gland, or by an abnormal union and development of the vesiculæ seminales. Thus, in the case detailed by Ackermann, the only male sexual organ that was entirely deficient was the prostate, and the only reputed female organ which was present was an imperfect cystiform uterus differing greatly in structure from the form of this organ in the infant, and having, as in the normal state of the prostate, the vasa deferentia penetrating through its substance without opening into its cavity, and ultimately terminating along with it in the posterior part of the urethra. In the analogous instance quoted in a preceding page from Steghlener, a similar arrangement of parts was observed; and in that case there was, in the enlarged ureters and renal infundibula, sufficient evidence (as we shall afterwards point out when speaking of the probable causes of hermaphroditism) of a distending power having acted upon the whole internal surface of the urinary and genital organs, and with so great a force (we may in the meantime allow) as to be capable of producing such a morbid dilatation and unfolding of the substance of the prostate as the doctrine alluded to requires. Such an effect would be the more liable to be produced if we can suppose this latter organ to have been disposed, by original tenuity of its coats, or by morbid softening or other diseased states of its tissues, to yield more easily to the dilating power, than any of the other surfaces to which it happened to be applied. At the same time, however, we confess that we conceive it unphilosophical to endeavour to account for *all* the cases which we have previously quoted of the addition of a female uterus to a male type of sexual organization upon this mechanical principle, or to attempt to explain away, in the mode we have just referred to, the evidence which these cases afford of the occasional occurrence of this combination as a true form of sexual duplicity. For even granting that the instances given by Ackermann and Steghlener, and perhaps one or two other cases, are not at all satisfactory in regard to the reputed existence of such a variety of sexual duplicity, and allowing, what seems indeed not at all improbable, that the supposed very imperfect uterus in these examples was merely an organ formed by a dilatation of the prostate and seminal ducts, there is still a sufficient abundance of cases left to which this explanation cannot possibly apply.

Thus, in the person dissected by Petit, the imperfect uterus was furnished with two perforate Fallopian tubes of three and a half inches in length, and at the same time it is distinctly stated that not only the prostate gland, but the vesiculæ seminales and vasa deferentia were also present. The vasa deferentia, between their origin from the testicles and their urethral termination, were each above seven inches long, and they entered the urethra by two apertures that were quite distinct and separate from the orifice of the uterus, which opened into the urethral canal at a point placed between the neck of the bladder and the prostate. In this case we cannot suppose that the uterus and Fallopian tubes were formed at the expense of the prostate gland or male seminal ducts, as they and all the other male organs were present; and consequently we can only consider the female organs as a *superaddition* to, and not a *transformation* of the male structures; or, in other words, we must look upon the above as an instance of duplicity in a part of the sexual apparatus.

The same reasoning and remarks might be shewn, if it were necessary, to apply in a greater

* Medical Repository for 1826, p. 571.

† As Jacobson of Copenhagen in Journal de l'Institut, t. ii. p. 160; and Die Okenschen Koerper, &c. Copenhagen, 1830.

or less degree to the other analogous examples in the human subject given by Harvey and Professor Mayer,* as well as to the hermaphroditic sheep described by Thomas, and the different cases in the goat mentioned and delineated by Gurlt and Mayer. In all these latter cases in the quadruped, the male organization appears to have been perfectly developed, the testicles, epididymes, vasa deferentia, and vesiculæ seminales being present in all of them; and in Thomas's sheep the superadded female uterus shewed internally the usual characteristic rugose structure, while its cornua terminated in two long Fallopian tubes. In Gurlt's goat case all the internal male sexual organs were found, with the exception of Cowper's glands; and yet we cannot suppose that these glands could have been transformed and moulded out into that distinct and hollow uterus with its two very long curved cornua, which the reporter has represented as being present; not to mention the total want of any collateral evidence in this and in the other cases to which we have just now referred, of any dilating power having acted upon the genital or urinary organs in the embryo.

3. *Fallacies in the supposed co-existence of testicles and ovaries.*—In several of those instances in which there has been supposed to be a co-existence of both testicles and ovaries upon the same side or sides of the body, it seems highly probable that there has been a fallacy in the observation, owing to a want of knowledge of some anatomical circumstances that are liable to lead us into error in making an examination of such a case.

We have previously had occasion to allude to the existence in the fœtal state of the Wolffian bodies, which are placed one along each side of the spine, and occupy at an early period in the embryo a great part of the cavity of the trunk. These bodies, as is now well known from the investigations of Rathke, Meckel, Müller, Burdach, and others, form in Mammalia and Birds at least, and equally so in both sexes, the primordial matrices of the genital and urinary organs (see article OVUM), and in the natural course of development altogether disappear in man and in the quadruped during the earlier periods of development, leaving no vestige of their presence in the extra-uterine animal.

This particular fœtal type of structure, like every other temporary type of the embryo, may, from an impediment or arrest in the natural course of the changes occurring in the development of the body in general, or of the genital organs in particular, become, we have every reason to believe, occasionally permanent in one or more of its parts, and thus by its presence in the animal lead us to suppose that a rudimentary testicle exists in an otherwise well-marked female, or, on the other hand, that an ovary exists in an otherwise well-marked male. Both of these mistakes will be the more apt to be committed if the original excretory duct of the Wolffian body remains, for it may give the appearance of the addition of a vas deferens to the supposed testicle, or of a Fallopian tube to the supposed ovary.

The error, also, of confounding a permanent Wolffian body with the testicle will be the more liable to occur, in consequence of the former body being naturally composed of an accumulation of convoluted diverticula which might be readily mistaken by an incautious observer for the seminiferous ducts of the latter.

There is certainly strong cause for doubting whether, in some of the cases that we have cited of the supposed co-existence of testicles and ovaries upon the same sides, the unremoved Wolffian bodies and their ducts had not either been mistaken for testicles and vasa deferentia, while the sexual organization was otherwise truly female, or for ovaries and Fallopian tubes, while the type of structure was in other respects strictly that of the male. This remark may perhaps with confidence be applied, for example, to the case of the free-martin described by Mr. Hunter; and in this and in most other similar instances the supposed testicles and ovaries have not been at all examined with any thing like sufficient anatomical accuracy. At the same time, however, it appears to us impossible to explain away all the recorded cases of the supposed co-existence of testicles and ovaries upon this principle. In reference to this point we would particularly observe that the consideration of the *relative position* occupied by the reputed testicles and ovaries may perhaps afford us an useful guide in cases of doubt. In some of the instances that have been previously cited, the relative situation of the supposed testicles and ovaries was exactly such as the Wolffian bodies are known to bear to these parts. In other instances, however, as in the ape described by Dr. Harlan, the relative situation in which the testicles and ovaries were found, was that which they occupy in the perfectly formed male and female; and in such a case as this it would surely be over-sceptical, and at the same time in opposition to all that we yet know of the history of the Wolffian bodies, to suppose that these bodies had imitated the testicles so far as to move out of their original locality and travel downwards through the inguinal rings. At the same time we must recollect that in this case the distinctive anatomical structure both of the testicles and ovaries seems to have been satisfactorily made out, in so far that the former are described as "perfectly formed," and the latter as having "minute ova visible in them." "The male and female organs of generation," Dr. Harlan adds, "were as completely perfected as could have been anticipated in so young an individual, and resembled those of other individuals of a similar age." Now if we once admit in this, or in any one other particular instance, that the evidence of the co-existence of testicles and ovaries is satisfactory, then certainly we may in any equivocal case be entitled to doubt until we have some more sufficient criterion for distinction pointed out, whether the dubious double bodies that we may meet with be a

* See his second case in the fœtus and those of the two adults in a preceding page.

rudimentary testicle or ovary conjoined with an imperfect Wolffian body, or really a true instance of the presence of both testicles and ovaries upon the body of the same individual.

PHYSIOLOGICAL DEGREE OF SEXUAL PERFECTION IN HERMAPHRODITES.

Among those lower tribes of animals, such as the Abranchial Annelida, Pteropoda, &c. that are naturally hermaphrodite, every individual is in itself a perfect representation of the species to which it belongs. In the higher orders, however, in which the distinction and separation of the sexes comes to be marked, each individual being either solely male or solely female, can, as has often been remarked, be regarded only as representing one-half of its entire species. In most instances of hermaphroditism among these more perfect animals, the malformed being does not even attain to this degree of perfection, but is in general so defectively constituted as not to have the proper physiological characters and attributes of either sex. In cases of spurious hermaphroditism it would appear that sometimes, though the copulative or external sexual parts are greatly and variously malformed, the internal or proper reproductive organs are developed with sufficient perfection to enable them to perform the functions belonging to them. We have very little proof, however, that in any instances of what we have described as true hermaphroditism, the apparatus of either sex is even formed with such anatomical perfection as to empower the malformed being to bear a successful part in the reproductive function. Indeed in all, or in almost all cases belonging to this last order of hermaphroditism, the individual who is the subject of the malformation may, with much more than poetical truth, be described both anatomically and physiologically, as, in the words of Ovid,

> Concretus sexu, sed non perfectus utroque,
> Ambiguo venere, neutro potiundus amore.

There is on record one remarkable instance of apparent exception to this general observation, a notice of which we have reserved for this place on account of the want of any such precise knowledge of the true anatomical peculiarities of the case as might enable us to refer it to the section which it ought to occupy in our classification. The case to which we allude was described by Dr. Hendy of New York, in a letter dated from Lisbon in 1807, and the subject of it was a Portuguese, twenty-eight years old, of a tall and slender but masculine figure.* "The penis and testicles," to adopt the words of Dr. Hendy's own narrative, "with their common covering the scrotum, are in the usual situation, of the form and appearance, and very nearly of the size of those of an adult. The præputium covers the glans completely, and admits of being partially retracted. On the introduction of a probe, the male urethra appeared to be pervious about a third of its length, beyond which the resistance to its passage was insuperable by any ordinary justifiable force. There is a tendency to the growth of a beard, which is kept short by clipping with scissors. The female parts do not differ from those of the more perfect sex, except in the size of the labia, which are not so prominent, and also that the whole of the external organs appear to be situated nearer the rectum, and are not surrounded with the usual quantity of hair. The thighs do not possess the tapering fulness common to the exquisitely formed female; the ossa ilii are less expanded, and the breasts are very small. In voice and manners the female predominates. She menstruates regularly, was twice pregnant, and miscarried in the third and fifth months of gestation. During copulation the penis becomes erect. There has never existed an inclination for commerce with the female under any circumstances of excitement of the venereal passion." In the preceding case, (if we may confidently trust to the account given of it,) we have ample proof of the existence of the internal female sexual organs in the circumstances of menstruation and impregnation taking place; and at the same time there appears considerable evidence for believing that some of the male organs were present. For even if we were to argue that the bodies present in the scrotum or united labia might be ovaries and not testicles, and that the supposed semi-perforate penis was only an enlarged clitoris, still the masculine figure of the individual, the imperfect beard, the narrowness of the pelvis, and the form of the lower extremities would tend to indicate the probable existence of the rudiments of some male organs; and if we go so far as to admit this, we must further allow the present to be an instance of hermaphroditism, in which *one* of the sets of sexual organs was capable of assuming their appropriate physiological part in the process of reproduction, though perhaps unable, if we may judge from abortion having twice occurred, of ultimately perfecting that process.

The preceding remarks upon the functional reproductive powers of reputed true hermaphrodites have been meant to apply only to the supposed perfection of *one* order of their sexual organs. It becomes a still more interesting question whether it ever occurs that in any abnormal hermaphrodite among the more perfect tribes of animals, both kinds of sexual parts may be found in so perfectly developed a state as to enable the individual to complete the sexual act within its own body; or, in other words, to impregnate and be impregnated by itself. Though we have assuredly no positive proof to furnish* that a hermaphrodite so physiologically perfect has ever yet been observed, and should very strongly doubt its occurrence

* New York Medical Repository, vol. xii. p. 86.

* We do not certainly feel entitled to place among the category of correct observations either the alleged case given by Linneus (Mangetus' Bibliotheca Chirurg. lib. iv.) of a sow with perfect male organs on one side, and a womb containing several fœtuses on the opposite; or that mentioned by Faber (Hernandez' Nov. Plant. Anim. Mexic. Histor. p. 547) and quoted by Haller and Rudolphi, of the co-existence, in a rat, of ovaries and a uterus with nine fœtuses, along with complete male organs.

from the almost universal imperfection, in an anatomical point of view, of the malformed organs, yet we have, on the other hand, no very rational ground, except that of the experience of all observers up to the present date, for denying entirely and unconditionally the utter possibility of it. And perhaps we should look upon this possibility with a less degree of scepticism when we consider that a double hermaphroditism exists as the normal sexual condition of some of the lower tribes of animated beings, and at the same time take into account the fact of the more or less direct communication which has been generally found to exist between the female uterus and the male passages, in cases of lateral and of complex hermaphroditism in the human subject and in quadrupeds.

In one of the cases of hermaphroditism in the goat, previously quoted from Mayer, and where there were present two male testicles, epididymes, vasa deferentia, and vesiculæ seminales, and a female vagina, uterus and Fallopian tubes, with a body at the abdominal extremity of one of these tubes that was supposed by Mayer to resemble a collection of Graafian vesicles, the male vasa deferentia opened into the female vagina; and its cavity with that of the uterus, and of all the male sexual canals, was distended with a whitish fluid of the odour and colour of male semen, and containing, according to Bergmann, the chemical principle proper to that secretion. It is not, therefore, altogether without some appearance of foundation in fact, that Mayer has added to the history of this case the following problematical remark: "Fuit ergo revera hermaphroditus semetipsum fœcundare studens."*

In a similar strain Dr. Harlan has added to the account that he has given of the very complete case of hermaphroditism already mentioned as met with in the Borneo ourang-outang, the following observations and queries. "Admitting," he remarks, "what in reality appeared to be the fact, that all the essential organs of both sexes were present in this individual, had the subject lived to adult age, most interesting results might have been elicited. Could not the animal have been impregnated by a male individual, by rupturing the membrane closing the vulva? or by masturbation, might not the animal have impregnated itself? by this means exciting the testicles to discharge their seminal liquor into its own vagina. The imperfection of the urethra most probably would have prevented the animal from ejecting the semen into the vagina of another individual."†

It has been sometimes urged as an argument conclusively illustrative of the fact of a double hermaphrodite impregnating itself, that in the hermaphrodite *Gastrophaga pini* described by Scopoli,‡ the insect is stated to have been seen to advance its penis and copulate with its own female organs; and afterwards, we are informed, the female side laid eggs from which young caterpillars were produced. Before, however, admitting this case to present an incontrovertible instance of absolute hermaphroditism, with the functions of the two sets of sexual organs existing in a perfect condition upon the same individual, it is necessary to recollect a possible source of fallacy in this circumstance, that female Gastrophagi have been observed to lay fertile eggs, although they had not had previously any connection with the male, as remarked by Professor Baster* in one instance in a female *Gastrophaga quercifolia*, and in another in the *Gastrophaga pini* by Suckow.† The same fact is further alleged to have been observed in some few instances by Pallas, Treviranus, Bernouilli, and others,‡ in regard to individuals belonging to some other of the higher orders of insects and animals, as in the *Limnæus auricularis*§ and *Helix vivipara*‖ among Mollusca, thus bringing them in this respect into analogy with the Aphides and Cyprides.

* Icones, &c. p. 20.
† Medical and Physical Researches, pp. 23, 24.
‡ Introd. ad Hist. Nat. p. 416.

CAUSES OF HERMAPHRODITIC MALFORMATION.

As yet we possess very little accurate knowledge either in respect to the mode in which the determining causes of hermaphroditic malformation act, or the nature of these causes themselves.

Most of the varieties of spurious hermaphroditism may, as we have just explained, be traced to an arrest in the development of the sexual organs at one or other period of their evolution, in consequence of which some of those types of structure in these parts which were intended to be temporary and transitory only, are rendered fixed or permanent in their character. Our knowledge of the more immediate causes of such arrested development in these and in other individual parts and organs of the body, is as yet extremely limited, and for the discussion of it we must refer to another part of the present work, (see article MONSTROSITIES). We may, however, in reference to the particular forms of arrested development observed in hermaphroditism, remark that in consequence of the great influence which, as we have already pointed out, is exercised by morbid states of the ovaries and testicles, in retarding or preventing the evolution of the sexual apparatus and characters after birth, it has been suggested with considerable probability by Meckel¶ and Isidore St. Hilaire,** that in their ultimate analysis certain cases of hermaphroditic malformation may be traced in the course of their causation to morbid influences exercised in the early embryo, at a period more or less near to conception, upon the ovaries or testicles, or upon those organs of a neuter or yet undetermined sex which afterwards assume the structure of one or other of

* Mém. de l'Acad. Roy. de Berlin, 1772.
† Heusinger's Zeitschrift für Organ. Phys. Bd. ii. s. 263.
‡ Burmeister's Entomology, s. 204. Burdach's Physiologie, t. i. § 44, 4-8.
§ Isis for 1817, p. 320.
‖ Spallanzani, Mém. sur la Resp. p. 268.
¶ Anat. Gén. t. i. p. 609.
** Hist. des Anomal. de l'Organiz. t. ii. 58.

these bodies. Further, the effects which this supposed morbid influence exercises directly upon the embryonic ovaries and testicles, and indirectly through them, upon the rest of the genital apparatus, and consequently the modifications of sexual structure which it produces, may possibly be much varied according to its extent, duration, and nature, and according to the particular period of development at which it comes into action. It is evident that this explanation of hermaphroditism can only refer to the varieties of the malformation which consist of an imperfection or deficiency in the development, and cannot apply to those instances in which there is a superaddition of sexual organs. If, however, we can once satisfy ourselves that any set of cases whatever are traceable to a morbid action affecting the testicles or ovaries of the early embryo, our investigations into the causes of these cases will necessarily be much simplified, for our inquiries would be reduced from a vague and indefinite search after the production of a number of anomalies of structure affecting several different organs at the same time, to an attempt to trace out the nature of those morbid conditions to which the embryonic testicles and ovaries were subject, and which were capable of so far changing the structure and action of these organs as to give rise to the effects in question. Of the diseased states, however, to which the reproductive and other organs of the system are liable during the progress of their early development, we at present know little or nothing, although in the investigation of this subject a key, we believe, may possibly be yet found to the explanation of many of those malformations to which different parts of the body are subject.

Osiander* and Duges† have suggested that the variety of spurious hermaphroditism which consists of a division of the perinæum in the male, may be produced *mechanically* in the embryo by the præternatural accumulation of fluid in the urinary canal, on account of an imperforate state of the urethra, and the consequent distension and ultimate rupture of the urethra, &c. From cases published by Sandifort, Howship, Billard, and many others, we are now fully aware of the fact that all the urinary canals of the fœtus in utero are occasionally found morbidly distended with a fluid, which, according to the interesting observations of Dr. Robert Lee,‡ would appear to possess the more characteristic qualities of urine. We have dissected one case in which the dilated fœtal bladder was as large as an orange, and have seen in the Anatomical Museum of Dr. William Hunter at Glasgow the preparation of another instance in which the bladder of a full-grown fœtus was dilated to the size of that of the adult subject. In one case mentioned by Dr. Merriman, the distended organ contained half a pint of urine,* and in another detailed by Mr. Fearn it was capable of containing as much as two quarts of fluid.†

It is not impossible that the causes in question,—namely, the obliteration of the urethra and the consequent distention of all the urinary passages, and probably also of the sexual canals communicating with these passages,—may occasionally produce in the male embryo a re-opening of the perinæal fissure, giving thus to the external parts the appearance of a female vulva, and perhaps at the same time may lead to the retention and imperfect development of the testicles by the distention of their ducts, and the unusual compression to which these organs may be subjected. Indeed we have satisfactory evidence, in a few instances, that such a cause may have been in operation, by our detecting the other acknowledged effects of the urinary accumulation in question,—such as preternaturally dilated ureters, and a cystic form of the infundibula of the kidneys, as in a case of hermaphroditism given by Mayer, in a human fœtus,‡ in the kid described by Haller,§ and in the child whose case we have already quoted from Steghlener. (See *transverse hermaphroditism.)*

At the same time the total absence of these collateral proofs in most other cases of hypospadias, our knowledge of the fact that the perinæal aperture is in some cases never shut, and the difficulty of conceiving the possibility of its being re-opened when once it is firmly closed, are perhaps sufficient to shew that the cause or causes alluded to produce in but few if any instances the effect here attributed to them.

We deem it not uninteresting to point out in this place, under the question of the origin of hermaphroditic malformations, a circumstance which has struck us in considering one or two of the cases in which the sexual apparatus of one side of the body was more imperfectly developed than that of other, viz. that the opposite side of the encephalon was at the same time defectively formed. Thus in the case of Charles Durge, on the right side of whose body there was a well-formed testicle, and on the left an imperfect ovary, the right hemispheres of the cerebrum and cerebellum, but particularly of the latter, were found by Professor Mayer to be smaller and less developed than the left, and the left side of the occiput was externally more prominent than the right. The same author, in the account of his case of hermaphroditism in a person of eighteen years of age, which we have previously quoted,|| and where there was an imperfect testicle, &c. on the right side, but no trace of testicle or ovary in the left, incidentally mentions that the right side of the cranium was somewhat prominent,—"dextra pars cranii paullulo prominet," in correspon-

* Neue Denkw. für Aertzte und Geburtsh, Bd. i. t. 264, 267.

† Ephem. Méd. de Montpellier, t. v. p. 17, 45, and 52.

‡ London Med.-Chirurg. Trans. vol. xix.

* London Med. and Phys. Journ. vol. xxv. p. 279.

† Lancet for 1834-35, p. 178.

‡ See p. 8, of Icones, &c.

§ Comment. Soc. Reg. Sc. Gotting. tom. i. p. 2.

|| Icones, p. 12.

dence, there is every reason to believe, with a slight predominance in size in the hemispheres of the encephalon of the same side. In adducing these two cases we do not wish to draw any inference with regard to the relation of causation between the size and development of the encephalic mass and the determination of the sex, but would merely point out the facts themselves in the meantime, for the purpose of drawing attention to the subject in the observation of any future similar instances that may happen to occur.

In connection with the question of the causes of hermaphroditism, it is interesting to remark that in some instances malformations of the genital organs giving rise to appearances of hermaphroditism have been observed both to be *hereditary* in particular families, and in other cases to occur among several of the children of the same parents. Thus Heuremann* mentions an example of a family the females of which had for several generations given birth to males who were all affected with hypospadias; and Lecat† alleges that a degree of hypospadias is not uncommon among families in Normandy. In Rust's Magazine an instance is related of a degree of hypospadias existing in a father and son.‡ Baum,§ in his essay on congenital fissures of the urethra, has referred to two instances of the existence of hypospadias in brothers of the same family, the first mentioned by Walrecht,|| and the second by Gockel.¶ Sir Everard Home** found two cases of hypospadias in two children belonging to the same parents. Kauw Boerhaave†† mentions an example of four hypospadiac brothers, and Lepechin another instance of three.‡‡ Naegele has reported a case in which two male twins were both hypospadic,§§ and Katsky |||| and Saviard ¶¶ have mentioned similar instances.

We have already, when treating of transverse hermaphroditism, alluded to another fact long and extensively known among our agriculturists, but first prominently brought before the notice of physiologists by Mr. Hunter, that the free-martin cow, or the cow that is born a co-twin with a male, is generally barren and has its sexual organs more or less defectively developed or hermaphroditically formed.*** In three different instances Mr. Hunter confirmed the fact of the anomalous sexual development of such animals by dissection; and Scarpa* and Gurlt† have published some additional observations and cases. We have lately had an opportunity of dissecting the sexual parts of two adult free-martins, and found them, as already detailed, formed after an abnormal and imperfect sexual type; and our friend Dr. Allen Thomson made some years ago a similar observation upon a free-martin twin fœtal calf. Cases, however, exceptional to the general fact of the sterility and imperfect sexual conformation of the free-martin twin cow are not unfrequently met with. Mr. Hunter found the sexual organs of a free-martin calf that died when about a month old apparently naturally constituted. He speaks also of having heard of some free-martins that were so perfectly formed in their sexual parts as to be capable of breeding; and different instances of their fecundity have been published by Dr. Moulson and others‡ since the time that Mr. Hunter directed attention to this subject. In some pretty extensive inquiries which we have made in regard to this point among the agriculturists of the Lothians, we have learned only of two instances in which free-martins proved capable of propagating, and such cases seem to be always looked upon as forming exceptions to the general rule.

We are not aware that among other uniparous domestic animals, as the goat, mare, &c, when a female is born a co-twin with a male, this female is sterile, and has its sexual organs hermaphroditically formed, as in the free-martin cow; and we are sufficiently assured that no such law holds with regard to twins of opposite sexes among sheep. Sir Everard Home, in his essay on monstrous formations, § mentions that in warm countries nurses and midwives have a prejudice that such women as have been born twins with males seldom breed; and we have found the same prejudice existing to a considerable degree among the lower orders in Scotland. Mr. Cribb,|| of Cambridge, published in 1823 a short paper in order to refute this notion as far as regarded the human subject. He refers to the histories of seven women who had been born co-twins with males. Six of these had children, and the remaining seventh subject alone had been married for several years without any issue. We have ourselves made a series of extensive inquiries of the same nature

* Medicin. Beobacht. Bd. ii. s. 234, and Laroche sur les Monstrosités de la Face, p. 30.

† Armand, l. c. p. 312.

‡ Magazin fuer die Gesammte Heilkunde, Bd. xviii. s. 113.

§ De fissuris urethræ virilis fissuris congenitis, p. 54.

|| Burdach's Metamorphose des Geschlechter, p. 52.

¶ Eph. Nat. Cur. Dec. ii. Ann. 5. (1686), p. 85.

** Comp. Anat. iii. p. 320.

†† Nov. Com. Acad. Sc. Petropolit. t. i. p. 61. tab. xi.

‡‡ Ibid. t. xvi. p. 525.

§§ Meckel's Archiv. Bd. v. s. 136.

|||| Acta M. Berol. Dec. 1. tom. ix. p. 61.

¶¶ Observ. Chirurg. p. 284.

*** From the Romans employing the female noun *taura* to signify a barren cow, it has been ingeniously conjectured that they were not unacquainted with the free-martin. Thus Columella de Re Rustica, lib. vi. chap. 22, speaks of "*tauræ* which occupy the place of fertile cows;" and Varro in like manner (lib. ii cap. 5.) states that "the cow which is barren is called *taura*" (quæ sterilis est, *taura* vocatur). There is no evidence, however, that they were acquainted with the particular circumstances relative to birth under which free-martins are produced.

* Mem. della Societa Italiana, t. ii. p. 846.

† Lerbuch der pathol. Anat. Bd. ii. s. 188.

‡ Loudon's Magazine of Natural History, vol. v. p. 765. See also Youatt on Cattle, p. 539, Farmers' Magazine for Nov. 1806 and Nov. 1807.

§ Comp. Anat. vol. iii. p. 333-4.

|| London Med. Repos. vol. xx. p. 213.

as those published by Mr. Cribb, and have obtained authentic information regarding forty-two adult married females who had been born as twins with males. Of these, thirty-six were mothers of families, and six had no children, though all of them had been married for a number of years. Two of the females who have families were each born as a triplet with two males.* In the Medical Repository for 1827 (p. 350) an anonymous author has mentioned an instance of quadruplets consisting of three boys and a girl, who were all reared: the female afterwards became herself the mother of triplets. Limited as the data to which we here allude confessedly are, they are still amply sufficient to show that in by far the majority of cases the females of twins of opposite sexes are in the human subject actually fertile, and, as some of the cases we have collected show, they are occasionally unusually prolific.

On the other hand, however, it may be considered by some that the same data rather tend in a slight degree, as far as they go, to support the popular prejudice of the infecundity in a number of cases of the female twin, and her analogy in this respect with the free-martin cow; for out of the forty-two instances which we have mentioned, we find six in which the woman has had no children, though living in wedlock for a number of years, or one out of seven of the marriages of such women has proved an unproductive one,—a proportion, we believe, considerably above the average of unproductive marriages in society in general, or among women of any other class. But perhaps, before drawing any very decided conclusion with regard to this point, a more extended foundation of data would be requisite than any we have hitherto been able to adduce, as it is perfectly possible that *our* having met with six exceptional cases may be a mere matter of coincidence.

As to the cause of the malformation and consequent infecundity of the organs of generation in the free-martin cow, we will not venture to offer any conjecture in explanation of it. It appears to us to be one of the strangest facts in the whole range of teratological science, that the twin existence in utero of a male along with a female should entail upon the latter so great a degree of malformation in its sexual organs, *and in its sexual organs only*. The circumstance becomes only the more inexplicable when we consider this physiological law to be confined principally or entirely to the cow, and certainly not to hold with regard to sheep, or perhaps any other uniparous animal.

The curiosity of the fact also becomes heightened and increased when we recollect that when the cow or any other uniparous animal has twins both of the same sex, as two males or two females, these animals are always both perfectly formed in their sexual organization, and both capable of propagating. In the course of making the preceding inquiries after females born co-twins with males in the human subject, we have had a very great number of cases of purely female and purely male twins mentioned to us, who had grown up and become married, and in only two or three instances at most have we heard of an unproductive marriage among such persons.

Further, we may, in conclusion, remark that among the long list of individual cases of hermaphroditism in the human subject that we have had occasion to cite, we find only one instance, (Eschricht's case of transverse hermaphroditism,) in which the malformed being is stated to have been a twin. Katsky, however, Naegele, and Saviard have each, as before stated, mentioned a case in which both twins were hermaphroditically formed in their sexual organs.

* Notes of the histories of these cases individually were read to a meeting of the Royal Physical Society of Edinburgh in the beginning of 1837.

HERMAPHRODITISM IN DOUBLE MONSTERS.

One of the most curious facts in the history of double monsters is the great rarity of an opposite or hermaphroditic sexual type in their two component bodies, the genital organs of both bodies being almost always either both female or both male.

Physiological science affords us at present no satisfactory clue to the explanation of this singular circumstance. From two cases of double monstrous embryos observed in the egg of the domestic fowl by Wolff* and Baer,† and from a similar case met with in the egg of the goose by Dr. Allen Thomson, it appears certain that double monsters sometimes originate upon a single yolk, probably in consequence of the existence of two cicatriculæ upon this yolk,‡ or of two germinal points (or two of the vesicles of Purkinje and Wagner) upon a single cicatricula. In such a case the two bodies of the double monster are so early and intimately united together as to form, almost from the commencement of development, a single system; and therefore the fact of the uniformity of their sexual character is the less remarkable. But in other instances when the double monster originates (as from the phenomena of incubation in double-yolked eggs we know to be frequently the case,) on two separate yolks or in two separate embryos becoming fused or united together, at a more advanced stage of development, it appears more extraordinary that the sexes of the two conjoined fœtuses should be so constantly uniform as they seem to be in monsters perfectly double. This uniformity only becomes the more singular when we reflect that twin children are not at all unfrequently of opposite sexes.§

* Nov. Comment. Acad. Petropolit. tom. xiv. p. 456.

† Meckel's Archiv. für Physiologie, &c. for 1827, p. 576.

‡ We have in our possession a preparation, taken from a duck's egg, in which two full-grown fœtuses are developed on opposite sides of a *single* yolk of the common size.

§ In the Edinburgh Lying-in Hospital forty-six cases of twins occurred from 1823 to 1836, both years inclusive. In seventeen of these cases the two children were both females; in sixteen both males; and in the remaining thirteen instances one child was male and the other female. We know of

The fact itself, however we may explain it, of the comparatively extreme rarity of both male and female sexual organs upon double monsters seems sufficiently established by various careful investigations made into the subject. Thus out of forty-two perfectly double monsters which Haller* was able to collect at the time at which he wrote, there were only two that were supposed to be of double sex, or, in other words, that had one body male, and the other female. Among double-headed monsters with single lower extremities, he found an hermaphroditic type more common, and adduces three examples of it.

In re-investigating this matter, the late Professor Meckel† could discover among the numerous class of monsters with perfectly double bodies united anteriorly or laterally by the thorax and abdomen, only one very doubtful case of exception to the above general fact. In the class of double monsters united in the region of the pelvis he mentions two exceptional cases from Valentin‡ and Hasenest;§ of double-headed monsters with single bodies, he quotes three similar cases from Lemery,|| Bacher,¶ and Bilsius;** and of monsters with a single head and double body he adduces two cases from Brissæus†† and Condamine,‡‡ in which in a like manner one body of the monster was supposed to have female, and the other male sexual organs. Several of these cases, however, certainly rest upon too doubtful authority and insufficient observation.

Isidore St. Hilaire has still further extended the data on which the above general fact is founded, by shewing that the same uniformity of sex holds good with respect to double parasitical monsters,§§ and even in monstrosities double by inclusion. Thus out of this last interesting class of double monsters, he alludes|||| to ten distinct cases in which the sex of the included being was ascertained. In six out of these ten cases the including and included body were both male; and in the other four they were both female.

On the whole, therefore, we must consider as founded on a proper induction from the existing data, the axiom of Meckel,—"Sexuum diversorum indicia in eodem organismo, quantumvis duplicitate peccet, non dari, sed unum tantum observari."¶¶ But while all the data hitherto collected with regard to this subject would seem to point it thus out as one of the most constant and best ascertained laws in teratology, still we are not altogether disposed to consider it with Zeviani* and Lesauvage† as subject to no exceptions whatever. In the study of monstrosities, as in the study of other departments of medical science, we find many general, but no universal laws.

Bibliography.—*Affaitat (J.)*, De hermaphroditis, Venet. 1549. *Columbus*, De re anatomica, lib. xv. Venet. 1559. *Bauhin (Gaspar)*, De hermaphroditorum monstrorumque partium naturâ. Francof. 1609. *Schenkius (J. G.)*, Monstrorum historia memorabilis, Frankf. 1609. *Riolan*, Discours sur les hermaphrodites, Paris, 1614. *Zacchias*, Questiones medico-legales, lib. vii. Frankf. 1657. *Polfyn*, Licetus' Traité des monstres. Leid. 1708. *Parsons*, A mechanical and critical inquiry into the nature of hermaphrodites, Phil. Trans. No. xli. and 8vo. London, 1741. *Burghard*, Gruendliche Nachrict von einem Hermaphroditen, Bresl. 1743. *Mertrud*, Dissertation sur la fameuse hermaphrodite, &c. Paris, 1749. *Morand*, De hermaphroditis, Paris, 1749. *Arnaud*, Treatise on hermaphrodites, London, 1750; also in Mémoires de Chirurgie, tom. i. London and Paris, 1768. *Haller*, Commentatio de hermaphroditis, et an dentur? in Comment. Societ. Reg. Sc. Gottingensis, tom. i. p. 1-26. Gotting. 1752; and Ib. in his Opera Minora, tom. ii. Lusan. 1764. *Gautier*, Observations sur l'histoire naturelle, &c. p. 16, &c. Paris, 1752. *Ferrein*, Sur le véritable sexe de ceux qu'on appelle hermaphrodites; in Mém. de l'Acad des Sciences, 1757. *Hunter (J.)*, Account of a Free-martin, Philos. Trans. 1779; and Animal Economy, p. 55. London, 1792; or in the recent edition by Owen, 1838. *Seiler*, Observ. nonnul. de Testiculorum Descensu et Part. Genit. Anomalis, Leipzig, 1787. *Osiander*, Ueber die Geschlechtsverwechselungen Neugeborner Kinder, in his Denkwurdigkeiten für Geburtshülfe, Bd. II. s. 462. Gotting. 1795, and in the Neue Denkwurdigk, Bd. I. s. 245. *Wrisberg*, De Singulari Deformitate Genitalium in puero Hermaphroditum Mentiente, Gotting. 1796; and in his Comment. Medici, Physiolog. &c. Argumenti. Gotting. 1800, p. 504-551. *Pinel (Ph.)*, Vices de conformation des parties genitales, &c. in Mém. de la Soc. Méd. d'Emulat. tom. iv. p. 234. Paris, 1796. *Moureau de la Sarthe*, Quelques considerations sur l'hermaphrodisme, ibid. tom. i. p. 243; also in his Histoire Naturelle de la Femme, tom. i. p. 211. Paris, 1803. *Pietsch*, Gedanken von den Zwittern, in the old Hamburgh Magazin. Bd. IV. s. 538. *Home (Ev.)*, Dissection of an hermaphrodite dog, and Obs. on hermaphrodites in Philos. Trans. 1795; On animals preternaturally formed, Lect. on Comp. Anat. vol. iii. London, 1823. *Voigtel*, Handb. der Pathol. Anat. Bd. III. Halle, 1805. *Ackermann*, Infantis androgyni hist. et iconog. Jena, 1805. *Schuberth*, Von Unterschiede der beiden Geschlechter, in his Allgem. Gesichte des Lebens. Th. I. Leipz. 1806. *Schneider*, Der Hermaphroditismus, in Kopp's Jahrb. der Staatsarzneikunde, p. 193, 1809. *Meckel*, Ueber die Zwitterbildung, in Reil's Archiv fuer die Physiol. Bd. XI. Halle, 1812; Handb. der Pathol. Anat. Bd. II. Leipz. 1816; System der Vergleich. Anatomie, Halle, 1821. *Burdach*, Metamorphose der Geschlechter, in Anatom. Untersuchungen, Leipzig, 1814; Physiologie, Bd. I. Leipzig, 1826. *Metzger*, Syst. der Gerichtl. Arzneywiss. Konigsb. 1814. *Marc*, Bulletin des Sc. Médicales, tom. viii. p. 179 & 245; Articles on hermaphrodites in the Diction. des Sciences Médicales, tom. xxi. p. 36-121, Paris, 1817; and Dict. de Médecine, tom. xi. p. 91, Ib. 1824. *Steghlener*,

one family in the different branches of which twelve pairs of twins have been born within three generations. In eleven out of these twelve pairs the co-twins have been of opposite sexes.

* Opusc. Anat. (1751,) p. 176.

† De Duplicitate Monstrosâ, p. 21.

‡ Eph. Nat. Cur. Dec. ii. Ann. iii. p. 190.

§ Comment. Lit. Norimb. (1743,) p. 58.

|| Mém. de l'Acad. des Sc. de Paris, for 1724.

¶ Roux' Jour. de Méd. (1788,) p. 483.

** Blankaart's Coll. Med. &c. (1680.)

†† Six Observat. de M. Brisseau, (Paris, 1734,) p. 33.

‡‡ Mém. de l'Acad. des Sc. (1733,) p. 401.

§§ Hist. des Anomal. de l'Organiz. tom. iii. pp. 235 and 386.

|||| Ib. p. 311.

¶¶ De Duplic. Monst. p. 21.

* Mem. della Soc. Italian. tom. ix. p. 521.

† Mém. sur les Monstr. par Inclusion (Caen, 1829); or Archiv. Gén. de Méd. tom. xxv. p. 140.

De hermaphroditorum Natura, Leipz. et Bamb. 1817.; *Virey*, Article hermaphrodite ou Androgyne, in Nouveau Diction. d'Histoire Naturelle, Paris, 1817. *Jacoby*, De Mammalibus Hermaphroditis alterno latere in sexum contrarium vergentibus, Berlin, 1818. *Lawrence*, Article Generation, in Rees' Cyclopædia, vol. xvi. London, 1819. *Feiler*, Ueber Angeborne Menschliche Missbildungen, &c. Landshut, 1820. *Pierquin*, Cas d'hermaphrodisme, Montpell. 1823. *Henke*, Untersuchungen ueber Hermaphroditen, Gerichtliche Medicin, Berlin, 1824. *Penchienati*, Observat. sur quelques prétendus hermaphrodites, Mém. de l'Acad. de Turin, tom. x. *Rudolphi*, Beschreib. einer aelt. Menschlichen Zwitterbildung, &c.; Abhand. der Königl. Akad. der Wissens. zu Berlin für 1825. Berl. 1828. *Lippi*, Dissert. Anatomico-Zootomico-Fisiologiche, &c. Firenze, 1826. *Dugès*, Mém. sur l'hermaphrodisme, in Ephemerides Médicales de Montpellier, tom. i. Montp. 1827. *Knox*, Outline of a theory of hermaphrodism, in Brewster's Edinburgh Journal of Science, vol. ii. p. 322. Edinb. 1830. *Müller*, Bildungsgeschichte der Genitalien, Düsseldorf, 1830. *Gurlt*, Lehrb. der Pathology. Anat. der Haus-Saugthiere. Bd. II. Berlin, 1831. *Mayer*, Icones Selectæ præparat. Musei Anatom. Bonnensis; Decas Hermaphroditorum, p. 8. Bonn. 1831; and Walther's and Graefe's Journal, &c. Bd. XVII. *Beatty*, Article Doubtful Sex, in Cyclopædia of Practical Med. London, 1833. *Beck*, Medical Jurisprudence, chap. iv. p. 69-81, Doubtful Sex, London, 1836. *Isidore St. Hilaire*, Histoire des Anomalies de l'organization, &c. Paris, 1836. *Barry*, On the Unity of Structure in the Animal Kingdom, and in Jamieson's Edinb. New Philos. Journ. for April, 1837. See also the references in the foot-notes.

(James Y. Simpson.)

HERNIA (in morbid anatomy). The protrusion of any viscus from the cavity in which it ought naturally to be contained is termed a hernia, and thus the apparent escape of any part from any of the great cavities of the body may seem to constitute the disease: still, however, as the real existence of cerebral or thoracic ruptures rests upon very doubtful authority and is extremely questionable, and as abdominal protrusions are unfortunately equally palpable and frequent, the application of the term is usually limited to them. To this frequency many causes seem to contribute. In the walls of the abdomen there are three remarkable natural openings, or perhaps it would be more correct to say, there are three situations so weak and unprotected that they easily yield and permit the escape of any viscus that may be directed against them with even a moderate degree of force: these are, the umbilicus, through which during fœtal life the umbilical cord passes; the inguinal canal, which allows the passage of the spermatic cord in the male, and the round ligament of the uterus in the female; and the crural ring, which transmits the great bloodvessels to the thigh and lower extremity. The nature of the walls too, which are principally composed of muscle, and the condition of the viscera within, loose, liable to change of size and situation, and subject to irregular pressure by the contractions of these muscular walls, dispose to the occurrence of the disease in any of these situations, where the resistance to such pressure is but feeble. Hence herniæ are most frequently met with at one of the places already mentioned,—the umbilicus and the inguinal and femoral canals. But there are other situations* at which protrusions may possibly take place, although fortunately they are infrequent, such as, at the side of the ensiform cartilage, at the obturator foramen, at the sacro-ischiatic notch, and between the vagina and rectum in the female. It is also evident that if the muscles or tendons of the diaphragm are wounded, some portions of the contents of the abdomen may escape, thus constituting the varieties of ventral and phrenic herniæ. Accordingly the forms of this disease have been arranged and named from the different places at which they occur,—an arrangement of the greatest practical importance; for as the structure, the size, and shape of each aperture must exert a peculiar influence on the condition of the protruded viscus, on its liability to become incarcerated, on the possibility of its being returned, on the steps to be adopted for this purpose, and above all on the safety and success of an operation should such be necessary, a knowledge of each of these in connexion with hernia is absolutely indispensable.

Besides this division of hernia as to situation, there is another of very considerable importance derived from the nature of the viscus displaced: thus in abdominal ruptures the contents of the tumour may be intestine alone, in which case it is called *enterocele;* or omentum alone, the *epiplocele*; or both these may be engaged, constituting the *entero-epiplocele.* There is not a viscus in the abdomen or pelvis, excepting perhaps only the pancreas and kidneys, that has not at one time or another formed the contents of a rupture. The stomach has been partially displaced through the diaphragm, or pushed through the walls of the abdomen: the duodenum has formed part of a ventral or umbilical hernia: the jejunum or ileum are very likely to be protruded in any situation: the omentum is often displaced, particularly in inguinal herniæ at the left side: the large intestines from being more fixed are not so frequently thrust out, yet the cœcum and colon are but too often found among the contents of a rupture. I have seen a large portion of the liver in an umbilical hernia of the infant: Verdier† relates numerous cases of herniæ of the urinary bladder; and Pott‡ mentions one which renders it nearly certain that the ovaria in females may suffer in a similar manner. However, the natural situation of any viscus within the abdomen is but an uncertain criterion by which to judge of the contents of a hernia in its vicinity. The strangest displacements have been observed occasionally in the examination of this disease: thus the sigmoid flexure of the colon has been protruded at the right side, and the cœcum and valve of the ileum at the left. In all large and old herniæ the parts are dragged out of their proper situations,

* Sur plusieurs hernies singulières. Garengeot, Mémoires de l'Academie Royale de Chir. tom. iii. p. 336. Paris edit. in 15 vols. 1771.

† Mém. de l'Acad. Royale de Chir. tom. iv. p. 1.

‡ Pott's Works, by Earle, vol. ii. p. 210.

and their appearances on dissection and relative positions are often such as no one from anatomical knowledge alone could ever have suspected to be possible.

In all forms of abdominal hernia excepting those only which immediately supervene on penetrating wounds, the contents of the rupture are lodged within a pouch or bag termed the *hernial sac*, which is formed of the peritoneum. This membrane lines the entire cavity so perfectly and completely that nothing can pass out from it without the membrane also participating in the derangement and being pushed out before the displaced viscus. Once formed, this sac is rarely capable of being replaced or returned into the cavity of the abdomen; never unless the hernia is small and recent, and "the cellular substance accompanying it and the spermatic cord through the ring has not lost its natural elasticity and contractility."* Many surgeons have doubted the possibility of such an occurrence at any period,† but the fact has been demonstrated by dissection, and still more forcibly by the circumstance of the hernia having been thus strangulated within the abdomen when the sac has been returned along with it. However, as I have said, the sac when once formed is rarely capable of being replaced, nor does it long remain in this abnormal situation without undergoing some change in its pathological condition—a change which it is not always easy satisfactorily to explain. In small herniæ that have recently come down, the structure of the sac differs in nothing from that of the abdominal peritoneum; and if the rupture is not reduced or kept up by a truss, it will probably increase in size without any remarkable alteration of tissue, for the membrane is extremely distensible, and will accommodate itself to any quantity of contents. But, if the hernia is carefully kept up, there can be no doubt that the sac will gradually contract and seem to rise up and approach the opening through which it originally passed, so that, although its cavity is never completely obliterated, it is palpably diminished in size, and incapable of receiving and retaining the same quantity of contents it originally held. Sometimes in old and neglected herniæ the sac *seems* to become so thin that the peristaltic motion of the intestines within it has been clearly perceived: this most frequently occurs in umbilical hernia, and is one of the reasons why this form of rupture was supposed not to have been enveloped in a sac at all. Again, on the contrary, in old herniæ also, and particularly where bandages have been worn to support or compress the tumour, it *seems* to become very thick, strong, and tense, and is said to have been met with as tough and as thick as cartilage. But in the great majority of instances these changes are rather apparent than real, and though doubtless the structure of the sac is no longer exactly that which it possessed before protrusion, the alteration is not so great as some writers have supposed. It was the opinion of Scarpa that an old hernial sac is in reality but slightly if at all thickened, and that the apparent thickening is caused by the condensation of the cellular tissue external to and around it. And here I may remark that differences of opinion as to the altered structure of the sac may have arisen from a difference of accuracy and minuteness in examination, either during the progress of an operation or after death. We shall find hereafter that the normal anatomy of the parts connected with hernia is largely indebted to the knife of the anatomist for the shapes of the different openings, the division and enumeration of the different layers of fascia, and many other points; but in the morbid anatomy of the disease the same patient investigation and the same accuracy of description has not been so uniformly observed, and hence our knowledge of the latter part of the subject as compared with the former is by no means so defined and exact.

Where a rupture has been a long time down, it is not probable that the intestine shall thus remain in an abnormal situation without occasionally suffering from inflammation, and hence adhesions between it and the sac are by no means unfrequently formed: the same effect may be produced by accidental violence, or from the latter cause the sac may be ruptured and its contents left lying under the usual coverings independent of the peritoneum. This is another of the cases in which a hernia has been supposed to exist without the investment of a sac.

The peritoneal aperture leading from the cavity of the abdomen into that of the rupture is narrow, and is called the neck of the sac: its dimensions as to length, however, vary with circumstances. As long as the communication is open and free between the two cavities, all that portion of peritoneum which is placed between them and corresponds to the canal through which the rupture has passed, may be termed the neck, and thus in inguinal hernia may be an inch, and in crural half an inch in length. But when the protruded parts are strangulated, the little circle only around which the compression directly operates is more properly entitled to the appellation, and its extent is seldom greater than two lines. When the neck of the sac of a *very recent* hernia is viewed from the cavity of the abdomen, the peritoneum in its vicinity is seen thrown into slight folds or plaits, which appear to be prolonged downwards into the tumour; but on slitting open the neck, I have never seen this appearance within it, the membrane there being smooth, rather whiter and more opaque, and evidently thicker and more unyielding than elsewhere. If such a hernia in the living subject has been reduced and kept up by a truss, the neck gradually contracts under the pressure, and its diameter with respect to that of the ring through which it has passed is altered to a degree that is of the greatest importance in the event of another protrusion, for it will be shewn hereafter that such a diminution of size greatly predisposes to the occurrence of strangulation. It is also possible

* Scarpa on Hernia, translated by Wishart, p. 68.
† See Louis, Mém. de l'Acad. Roy. de Chir. tom. ii. p. 486.

that the neck shall be so contracted that in the new occurrence of hernia an additional portion of peritoneum may be detruded, and then the sac must present the shape of an hour-glass, narrow in the centre and broad at either end: sometimes two, three, or more of these successive protrusions take place, and then the sac is divided into so many sacculi with incomplete intercepts or partitions between them. Or one portion of peritoneum may be forced within another, so that the intestine is actually included within a double sac. This last is a curious and very uncommon occurrence. On the other hand the neck of a hernial sac may suffer distension. In very old ruptures that have become irreducible or from any other cause been long down, the neck of the sac sometimes becomes wonderfully dilated, and the portion of intestine immediately passing through it scarcely subjected to the slightest pressure.

There is one form of hernia, the chief peculiarity of which lies in the nature of its peritoneal investment, for, correctly speaking, it possesses no proper sac. It is the hernia congenita,* a species of rupture which occurs in very young infants, and sometimes, under peculiar circumstances, in persons of a more advanced age also.

During the early periods of fœtal existence the testes do not occupy that situation which they possess in after life. They are placed within the abdomen, above the pelvis, which at this time is so small and imperfectly developed that many of the viscera lodged within it afterwards, seem now to lie within the belly. They are just below the kidneys, in front of the psoas muscle at each side, and possess, like other viscera, an investiture of peritoneum, which is afterwards to be the tunica vaginalis testis. About the sixth month, or perhaps the seventh or even later, (for it observes no exact rule in this respect,) the testis begins to descend, not gliding behind the peritoneum, but preserving its own investing coat until it comes to the internal abdominal ring, where it pushes a process of peritoneum out before it, just as an intestine would do in the production of a hernial sac. This is afterwards to become the tunica vaginalis scroti. The testicle then passes on through the inguinal canal, through the external ring,† and finally drops into the scrotum. After some time the canal of communication with the cavity of the abdomen begins to contract and close, and if the usual process goes on healthily and without interruption, very shortly a complete obliteration takes place, and the testis is separated from the abdomen perfectly and for ever. The time at which this is accomplished is extremely uncertain: sometimes it is perfect at birth; in other cases the canal is more or less open, and then, if the infant cries or struggles, a portion of the contents of the abdomen is protruded into the cavity of the tunica vaginalis, and the hernia congenita is formed. If any part of the above-mentioned process is interrupted or postponed, it will occasion some variety. Thus the tunica vaginalis may not exhibit its usual disposition to close and become obliterated at its neck, and then for a length of time the patient is exposed to all the inconvenience and hazard of the descent of a hernia: sometimes the testicle does not come down until a much later period, a circumstance that is often occasioned by the gland contracting adhesions with some adjacent viscus in its passage, and may be attended with the additional inconvenience of drawing down such viscus along with it. The surgeon should also be aware of the possibility of the protrusion of another portion of peritoneum into the open tunica vaginalis, and thus a mixed case may arise of a congenital containing within it a proper sacculated hernia.

The congenital rupture, then, has no proper sac, but is lodged within the tunica vaginalis in close apposition with the testis · hence many of its peculiarities can be explained. It is obviously the only kind of hernia in which an adhesion can exist between the testicle and the protruded viscus, and it is also evident that the testis does not bear the same relation to the protruded viscus in this that it does in cases of ordinary rupture. Here it is higher up, and seems to be more mixed and identified with the other contents; the entire tumour is more even and firm, the protruded parts are less easily felt and distinguished; and Hesselbach states that when strangulation is present, the sac is every where equally tense, and the testis cannot be felt at all. In very young infants a small quantity of fluid is often present along with the intestine in the tunica vaginalis: it disappears when the child is placed in the recumbent position, and does not add to the difficulty or importance of the case. It has been stated that the tunica vaginalis has a natural tendency to become closed at its neck, and therefore is it more likely to thicken and diminish in capacity in this situation so as to form a band round the protruded viscus. Pott* was of opinion that congenital hernia was more subject to be constricted at the neck of the sac than any other: Wilmer stated that out of five cases of congenital hernia on which he operated, three were strangulated at the neck of the sac; and Sandifort and others maintained the same doctrine. Scarpa† thought that every displaced portion of peritoneum possessed the same tendency to contraction, and advanced it as a reason why stricture in the neck of a hernial sac should be more frequent in all kinds of hernia than is generally supposed. It is not easy to place implicit reliance on this latter opinion, because the neck of the common hernial sac when once formed is never again completely closed; but with respect to congenital hernia the observation appears to be equally correct and important.

Scarpa‡ describes a form of hernia which may

* Hunter's Animal Œconomy.

† See some observations on the descent of the testicle by the late Professor Todd, of Dublin, in the 1st vol. Dublin Hospital Reports. See also Hey's Observations in Surgery, p. 226.

* Pott, op. citat. p. 184.

† Page 131.

‡ Op. citat. p. 205 et seq.

under certain circumstances of imperfect or careless examination appear to be devoid of a proper sac, formed by a descent of the peritoneum. This occurs at the right groin, is always large, and is formed by a protrusion of the cœcum with the appendix vermiformis and the beginning of the colon. The cœcum is placed in the right ileo-lumbar region, and a portion of it does not possess a peritoneal covering, but lies absolutely *without* the great abdominal membranous sac: when therefore these parts are protruded, a portion of the cœcum and the beginning of the colon will be found included and contained in the hernial sac, while another portion of the same intestines will be necessarily without the sac, and lying denuded in the cellular substance which accompanies the descent of the peritoneum in the hernia. If this tumour is opened into by an incision carried too much towards its external side, the cœcum and colon will be exposed lying outside of the peritoneum, and apparently devoid of a hernial sac; but if cut into precisely in the middle or a little towards the inner side, under the cremaster muscle and the subjacent cellular tissue, the true hernial sac will be found, formed of the peritoneum. Within this will be seen "the greater portion of the cœcum with the appendix vermiformis, and likewise the membranous folds and bridles which seem to be detached from the hernial sac to be inserted into these intestines, the smaller portion of which will be without the sac, in the same manner as when these viscera occupied the ileo-lumbar region." This form of rupture I have never seen, and must therefore refer the reader to Scarpa's work, wherein he will find the peculiarity most satisfactorily explained.

But in the arrangement of herniæ, that division is most practically interesting which has reference to the condition or state of the intestine or other protruded viscus, and the disease is then described as being reducible, or irreducible, or strangulated.

1. A hernia is said to be reducible when it either retires spontaneously on the patient assuming the recumbent posture, or can be replaced without difficulty to the operator or future inconvenience to the patient beyond that resulting from the employment of measures adapted to retain it within the cavity. This condition supposes that the relation (particularly as to size) between the hernia and the aperture through which it had escaped has not undergone any alteration.

2. It is irreducible when there is such a change in the structure, situation, or other condition of the protruded viscus as to render it impossible to be returned, although the aperture through which it passed may offer no impediment. There is another case in which a hernia has been considered irreducible, namely, when it would be impolitic or unwise to attempt the reduction, supposing it to be perfectly practicable.

3. A hernia is strangulated when the relation as to size between the protruded viscus and the aperture through which it has passed is so altered as not only to prevent reduction, but to cause such a degree of compression at the aperture as will interrupt the circulation through the escaped viscus, and endanger its vitality. This condition has been supposed to exist in two different forms, strangulation by inflammation and by "engouement,"* or as Scarpa terms them, "the acute and chronic;"† but this division only has reference to the severity of the symptoms and to the rapidity or slowness of their progress, for although an intestine may be in a state of obstruction which will, if unrelieved, proceed to strangulation, yet the latter state cannot be said to have arrived until the return of the venous blood from it is actually impeded. The protruded viscus is then in a situation precisely similar to that of a limb round which a cord had been tied with sufficient tightness to interrupt the circulation and threaten to induce mortification.

These different conditions will be best understood by tracing a rupture through each of them in succession.

A person may be suspected to have a reducible hernia when, after the application of some force calculated violently to compress all the viscera of the abdomen, an indolent tumour appears proceeding from some of those places where the walls of the abdomen are known to be weakest and least resisting. And the suspicion is increased if the tumour is elastic, if it sounds clearly on gentle percussion, and becomes suddenly puffed up and swelled, as if by air blown into it, when the patient coughs, sneezes, or performs any of those actions which forcibly agitate the abdominal parietes. The reducible hernia becomes smaller or perhaps disappears altogether when the patient lies down: it appears of its full size when he stands erect; if neglected, it has a constant tendency to increase, which it does sometimes by degrees, slowly and almost imperceptibly, but more frequently by sudden additions to its bulk, which are formed by new protrusions. In this form of the disease the qualities of the viscus engaged within the sac, as to form, size, and structure, may be considered as unchanged: within the abdomen, however, the fold of mesentery which supports the protruded intestine is constantly more elongated than it naturally should be, and likewise thicker and more loaded with fat. It is also marked with dilated and tortuous veins.

Although thus displaced, the viscus is still capable of performing its part in the function of digestion, and as long as the contents of the bowel pass fairly and uninterruptedly through it, there can be little or no danger; but it is not difficult to conceive how a gut so circumstanced may occasion great inconvenience. The peristaltic motion must be more or less impaired; the passage of the contents may be delayed, and hence will arise nausea, colicky pains, eructations, and those other dyspeptic symptoms from which even the most favoured patients do not escape. These irregularities

* Goursaud, Mém. de l'Acad. Roy. de Chir. tom. ii. p. 382.

† Op. cit. p. 290.

again can scarcely exist for any length of time without producing some inflammation, and thence it follows that it is rare to meet with an old hernia in which adhesions have not formed either between the intestine and the sac, or between the convolutions of the protruded viscera, circumstances that must render it impossible to replace the hernia, or supposing it replaced by force, will be likely to occasion incarcerations within the cavity of the abdomen itself. These adhesions, as discovered either during operation, or by dissection after death, are of different degrees of closeness, firmness, and tenacity, and have been arranged under three classes, the gelatinous, the membranous, and the fleshy.

"The gelatinous adhesion, a very general consequence of the adhesive inflammation which attacks membranous parts placed in mutual contact, is only formed by a certain quantity of coagulable lymph, effused from the surface of the inflamed parts, which coagulating assumes sometimes the appearance of a vesicular reddish substance stained with blood, sometimes of threads or whitish membranes easily separable from the parts between which they are interposed and which they unite together, without any abrasion or laceration being produced by the separation, on the surface of the parts agglutinated together."* This kind of adhesion being the result of *recent* inflammation can rarely be met with in operations performed for the relief of strangulated hernia, for the condition of a viscus so engaged is that in which such an effusion would be unlikely, if not impossible. Its vessels are loaded and congested with venous blood: there is effusion of serum to a greater or less quantity, as is seen in every instance of obstructed venous circulation; and if there is recent lymph, it must be owing to the fortuitous circumstance of the viscus having been inflamed immediately before it became strangulated. In a vast number of cases operated on, I have seen but one instance of the existence of this soft adhesion, and in that the hernia was not strangulated: it was a case (such as is related by Pott) of inflammation affecting the intestines generally, in which those within the hernial sac, of course, participated.

The membranous and fleshy adhesions are the results of former attacks of inflammation, and are exactly similar to those attachments so frequently met with between serous surfaces in other situations. When the opposed surfaces lie motionless and undisturbed, their connexion is firm and fleshy, and hence this kind of adhesion is seen at the neck of the sac, between the omentum and the sac, and occasionally between the intestine and the testicle in congenital hernia; whilst between the convolutions of the intestine itself, or between it and the sac, any union that exists is more generally loose and membranous.

Besides adhesion, there are many other causes that may render a hernia irreducible, one of the most prominent of which is the patient's neglect in leaving the hernia down, and the alterations in shape and structure that thence ensue. In such case, the parts within the tumour, as the mesentery and omentum, have room to increase, whilst at the mouth of the sac they remain constricted and of their natural size, though condensed and solidified in structure. This happens particularly with the omentum, which becomes hard, very dense, and compact, and not unfrequently resembles a fibrous structure covered by a fine smooth membrane, and then there is within the sac a tumour actually much larger than the aperture it would have to pass, and through which no force could be capable of pushing it.

It may happen that the part of the omentum which is below the stricture shall remain loose and expanded, and enjoy its natural structure, whilst that which is lodged within the neck of the sac is compressed and hardened, in which case the hernia will probably prove irreducible.

It sometimes happens that scirrhus of the intestine renders a hernia irreducible. Such a malignant alteration of structure is by no means frequent in the intestinal tube—certainly far less so than in the omentum, but the possibility of the occurrence is proved by a case under my own immediate superintendence. The patient had a large hernia which he had been able occasionally to reduce, but which was usually left down. On a sudden he was attacked with symptoms of strangulation, small quick pulse, tenderness of the abdomen, acute pain in the tumour, constipation, general low fever and fœcal vomiting. The operation was performed, and the cause of the symptoms found not to have been in the situation of the neck of the sac, which was more than commonly open and free, but in a scirrhus of one of the lesser intestines.*

The form of hernia already noticed as being apparently devoid of a sac has been mentioned by Pott† as one peculiarly difficult of reduction. "They have consisted of the cœcum with its appendicula and a portion of the colon. Nor," continues this distinguished surgeon, "will the size, disposition, and irregular figure of this part of the intestinal canal appear upon due consideration a very improbable cause of the difficulty or impossibility of reduction by the hand only."

The last circumstance to be considered as rendering a rupture irreducible is the absolute size of the tumour and the quantity of viscera it contains. It is amazing to what extent the contents of the abdomen may be protruded from it, and the patient nevertheless enjoy a state of health that might be called good, so far as the annoyance of such a tumour could warrant the expression. Every surgeon must have heard of herniæ in which all the loose intestines were protruded, and in fact every thing that could with any degree of probability be supposed to have been capable of being pushed from the cavity of the abdomen. I

* Scarpa, p. 180.

* The preparation of this interesting case is in the Museum of the Medico-Chirurgical School, Park Street, Dublin.

† Pott, op. cit. p. 24.

have seen and dissected a case of this description in which the tumour during life reached to within two inches of the knee, and obliged the unfortunate subject of it (who was a lamplighter) to wear a petticoat instead of breeches. Similar instances are not very unfrequent, and it is obvious that an attempt at reduction here would be injudicious even if it was practicable. It is the nature of all hollow structures in the body, whether cavities or vessels, to accommodate their size and capacity to the quantity of their contents, and the cavity of the abdomen will, under such circumstances, become so contracted as to be either incapable of immediately receiving the protruded viscera again, or else the sudden distension will excite peritoneal inflammation—an evil greater than the existence of the hernia. These latter, however, cannot be regarded as permanently irreducible, for Arnaud, Le Dran, and Iley have succeeded in gradually restoring them by means of a bandage shaped like a bag, which being laced in front admitted of being tightened still as the tumour diminished.

The last and most fearful condition of a rupture is its state of strangulation, in which the protruded viscus, no longer capable of being returned to its former situation within the abdomen, no longer fit for the performance of its functions, is banded and bound down at its neck in such wise as to interrupt and impair the circulation through it. In order properly to understand this part of the subject, it will be necessary to consider it under three heads:—1. the causes that seem to produce the strangulation; 2. its effect on the structures within the hernial sac; 3. its effect on the viscera within the cavity of the abdomen.

1. Of the three natural apertures at which abdominal herniæ commonly occur, one, the umbilicus, is unquestionably seated within tendon, and so circumstanced that any contraction of any muscle connected with it, whether spasmodic or permanent, must rather expand the opening than contract it. Another, the crural ring or canal, is composed of tendon and of bone, and so constructed that although certain positions of the trunk or inferior extremity might possibly diminish its size, no muscular action can exert any influence over it. The third, the inguinal canal, is of greater length and more complicated in its construction, and it is a question whether the same pathological condition can be predicated of it, or whether strangulation does not here occasionally occur in consequence of muscular action alone.* Sir A. Cooper seems to acknowledge the possibility of a spasmodic stricture at the internal ring, the strangulation then being effected by a compression exercised by the inferior edge of the internal oblique and transversalis muscles.† Guthrie speaks of herniæ being frequently strangulated by passing between the fibres of the internal oblique, which are separated at the inferior and external border of the muscle above the origin of the cremaster.* Scarpa says that "towards the side, at about eight lines distance from the apex of the ring, the lower muscular fibres of the internal oblique muscle separate from each other to allow the spermatic cord to pass between them:"† and again, "the small sac or rudiment of the hernia, not unlike a thimble, when it makes its first appearance under the fleshy margin of the transverse, rests immediately on the anterior surface of the spermatic cord; it then extends and passes in the middle of the separation formed by the divarication of the inferior fleshy fibres of the internal oblique and of the principal origin of the cremaster muscle."‡ It must, however, be conceded that Scarpa did not attribute the strangulation of any form of inguinal hernia to a contraction of these muscular fibres. Now, although it is almost presumptuous to differ from authorities of so high a class, yet I cannot agree either with the opinion that herniæ are liable to a spasmodic constriction, or with the descriptive anatomy on which such an opinion might be founded.

In about one subject out of every three or four there certainly is a slight divarication or separation of fibres of the external oblique muscle, or rather there is a cellular connexion between the origin of the cremaster muscle and the inferior fibres of the oblique, which is easily separable by the knife; but the question is, does the spermatic cord in the natural condition, or the hernia in its course to the external ring, pass through or between these fibres? I believe they do not. I have dissected numerous cases of hernia without observing such a disposition of parts, and I think that if either the spermatic cord or the hernia took such a course, the protrusion must then come to lie in front of the cremaster muscle—a position that has not been hitherto observed. When a hernia is found at the groin, the tendon of the external oblique is somewhat stretched and arched forwards above Poupart's ligament in front of the inguinal canal: the fascia transversalis may be stretched also, and the epigastric artery pulled out of its place and made to approach the linea alba; but the muscles arising from Poupart's ligament, the internal oblique and transversalis, remain unchanged, and if ever strangulation is effected through their operation it is in the manner suggested by Sir A. Cooper. But it is more simple and perhaps more scientific to place muscular contraction out of the question altogether. The phenomena of strangulation exhibit nothing like the irregularities of spasm: there is no sudden exacerbation, no succeeding relaxation—no alternation of suffering and relief, no assuagement of symptom from medicines decidedly antispasmodic; the disease once established goes on with an uninterrupted and certain progression that will not admit of explanation by a cause so irregular as spasm.

But it is unnecessary to resort to an explanation which might prove so practically dan-

* See the anatomy of inguinal and femoral hernia in a future part of this article.
† Cooper on Hernia, p. 21.

* Guthrie.
† Scarpa, op. cit. p. 27.
‡ Ibid. p. 50.

gerous, because the existence of strangulation with all its fearful sequelæ may be proved, in situations and under circumstances where the influence of spasm or of muscular action is obviously impossible. Thus intestines have been found strangulated within the cavity of the abdomen itself, as when a fold of intestine has passed through an accidental opening in the mesentery or the omentum, or when artificial bands or nooses have been formed by lymph, the products of former inflammation. Scarpa relates a very interesting case in which he found that the appendix vermiformis surrounded in the manner of a ring and strangulated a long loop of the ileum just before its insertion into the colon.

If it be conceded that the natural openings at which abdominal herniæ occur are composed either of tendon or of tendon and of bone, and therefore are not subject to accidental variations of size from irregular muscular action, it would seem on a *prima facie* view that wherever any substance had passed out it ought to be able to return, provided an equal degree of force is employed with that which originally caused the displacement. And this actually does take place, for the hernia returns spontaneously or is easily reduced as long as the original proportion between the size of the protruded part and that of the aperture remains unaltered. Again, as long as this relation is maintained, the circulation through and from the protruded viscus will continue equable and healthy, but an intestine from its structure and its functions is extremely liable to a change of size, and when that happens, the proportion no longer exists, and the hernia begins to become incarcerated. If not relieved, the protruded viscus continues to swell, and is thus made to form an acute angle at the spot where it escaped, which tightens the ring of intestine immediately at the neck of the sac: the return of the venous blood is thus prevented; the swelling then increases until not even gas can pass through, and then strangulation is complete. In this way a number of circumstances connected with hernia can be explained. If the ring is small, a very trifling change of size in the protruded part will be sufficient to cause strangulation: hence crural hernia is more liable than inguinal, and very recent ruptures in which the ring is of its natural size than those of long standing, in which that aperture is probably enlarged. Persons who are formed with large rings, and thus possess an hereditary disposition to hernia, are less liable to strangulation: this may explain Pott's remark that "if the hernia be of the intestinal kind merely, and the portion of the gut be small, the risk is the greater, strangulation being more likely to happen in this case;" for assuredly if the ring is so small as to permit only the escape of a knuckle of intestine, a very trifling change in the latter will be sufficient to establish a disproportion between them. Again, if a hernia has come down, and been reduced, and kept up until the neck of the sac has been diminished in size, and if afterwards a protrusion takes place, a very trifling alteration in this latter will render it incapable of return, and explain why such herniæ are so frequently strangulated at the neck of the sac. Hence it appears that a straitness or tightness at one of the rings may be a predisposing cause of strangulation, that is, may be a reason why one hernia should become sooner strangulated than another, but the immediate or efficient cause is a change in the condition of the viscus itself. Thus when a loop of intestine is gangrened, and its contents have escaped totally or partially into the sac, the hernia often returns spontaneously, the parts in the immediate neighbourhood of the ring remaining unaltered. Also if such a hernia is the subject of operation, there is no necessity for dilating the seat of the stricture: indeed Louis forbids the practice lest some essential point of adhesion should be destroyed. "Dilatation," says he, "is only recommended in order to facilitate the reduction of the strictured parts. In the gangrened intestine there is no reduction to make, and there is no longer strangulation, the opening in the intestines having removed the disproportion that had existed between the diameter of the ring and the volume which the parts had acquired; and the free passage of the excrement which the sphacelus has permitted removes every symptom that depends on the strangulation."* In like manner may be understood why omental herniæ are less liable to become strangulated, because this structure is not subject to any sudden change of shape or increase of volume: when it does occur, the progress of the disease is more slow, and the symptoms are said to be less severe.

The division of herniæ into the incarcerated and strangulated, or into the acute and chronic forms of strangulation, however practically valuable if it inculcates a different mode of treatment for these affections, is yet pathologically incorrect if it supposes any analogy between them and the acute and chronic species of inflammation. An incarcerated hernia is not strangulated; it is really in a condition resembling irreducibility. I have before stated that in large and old herniæ the neck of the sac generally becomes enlarged, and of course such a change of dimensions in the protruded viscera as is necessary to cause their strangulation will be proportionally less likely to occur. But hard and unwholesome and indigestible substances may gain admission into some of them and lodge there, for it must be recollected that the process of digestion cannot be very favorably carried on in intestines thus protruded, placed in positions that will render it necessary that their contents must ascend against the influence of their own gravity, and deprived of the salutary pressure exercised by the walls of the abdomen on the viscera within it. If such a lodgment is formed, it will be the cause of future accumulation, and may occasion a determination of blood to the part or even inflammation within it, thus gradually increasing its volume and leading it to a state that must end in strangulation. Undoubtedly, if the dura-

* Mém. de l'Acad. Roy. de Chir. tom. viii. p. 45.

tion of such a case is reckoned from the first occurrence of symptoms, which at that period are only those of indigestion, it will be an example of a very chronic case of strangulated hernia; but these two stages of the disease ought to be distinguished, for the treatment that would be judicious in the one might be injurious or destructive in the other. The incarceration of a hernia does not, moreover, necessarily involve its eventual strangulation, and this constitutes a vast difficulty in the case, for on the one hand few surgeons will advise an operation until there is an obvious and decided necessity for it, and on the other it is quite possible in a case of this description that the symptoms shall never be urgent, and yet the intestine be found in a state of actual sphacelus. I have seen a patient operated on in whom the hernia had been down and the bowels constipated for eighteen days. The intestine was completely mortified.

That strangulation which is most rapidly formed is the most severe in its symptoms and the most dangerous in its consequences, but between these extremes there is every possible degree of intensity. A hernia has been gangrened in eight hours after protrusion. Mr. Pott frequently mentions a single day as causing a most important difference in the case, and I have found an intestine sphacelated on the day following the first occurrence of the disease; however, in general the case is not so quickly decided, although every moment of its duration is pregnant with danger. The change that is effected in the strangulated viscus next demands attention. Its altered condition has been always spoken of under the name of inflammation,* not from want of a perfect and accurate knowledge of its pathology, but probably from the term appearing convenient and being hastily adopted by one writer from another. Yet as it is not inflammation, the name is incorrect, and perhaps it has been injurious in leading practitioners to attempt a mitigation of the inflammation in the tumour, instead of the more obvious indication, a diminution of its size. The volume of a strangulated intestine is always increased. In small herniæ (which in this respect can be more accurately examined) the intestine, on the sac being divided, starts up and swells out as if relieved from a compressive force. It always contains air, and if cut into, a small portion of dark-coloured serum will generally escape. Its colour, which is manifestly occasioned by an accumulation of venous blood, is at first of a reddish tint of purple, soon however changing to a coffee brown, and there is always more or less of serum within the sac, as in every other case of venous congestion. If unrelieved, dark and fibrous spots appear which are truly specks of mortification; they very soon separate and allow a discharge into the sac of a quantity of putrid fæces and horribly fetid gas. This done, the intestine either remains collapsed within the sac, or retires spontaneously into the abdomen.

In the meantime the parts covering the hernia become inflamed; in the first instance probably from sympathy with the deeper structures, afterwards obviously as an effort of nature to get rid of the putrid and sphacelated matter underneath. In the early stages the local symptoms are seldom very severe: the tumour is scarcely painful, and will permit reiterated attempts at the reduction of the hernia, and endure considerable pressure, whilst the abdomen may not be touched without intense suffering. In a little time, however, it becomes tense and tender to the touch, red, œdematous, and pitting under the finger, which leaves a white impression for a moment after it has been withdrawn. In fact, it is erysipelatous inflammation attacking the coverings of the hernia, and its approach is often accelerated by handling the tumour or by repeated injudicious attempts to reduce it. This (if the patient lives sufficiently long) always terminates by the formation of one or more sloughs, on the separation of which the putrid coverings are thrown off, and the contents of the bowels being evacuated, the patient's life may be saved, but with the inconvenience and danger of an artificial anus at the groin. It is seldom that the efforts of nature are thus capable of procuring relief, the contents of the rupture being generally sphacelated, and incurable mischief effected within the abdomen long before its external coverings shew any disposition to burst spontaneously. I think the condition of the sac has some influence on this external inflammation. In all cases it undergoes a less injurious alteration of structure than the intestine contained within it, and is often found comparatively sound while the latter is in a state approaching to sphacelus. The superiority of its vascular organization, its containing a greater quantity of blood, and moreover the volume of air always contained within the bowel, will explain this pathological difference; but the sac itself sometimes suffers from congestion to a greater or less extent, and this, of course, in proportion to the degree of constriction fixed upon its neck. An old hernial sac, the neck of which is thickened and accustomed to its new position, and which is itself probably one of the chief causes of the stricture, will be less likely to suffer from an interrupted circulation than a recent protrusion just forced out through a narrow undilated ring. It is in this latter case that the external structures ought to be the soonest engaged, and it has been in recent and acute cases of hernia that I have seen the earliest examples of superficial inflammation.

3. Such, during the progress of a hernia, is the condition of the parts more locally engaged;

* "The inflammation that takes place in strangulated hernia is different from almost every other species: in most cases it is produced by an unusual quantity of blood sent by the arteries of the part, which become enlarged; but still the blood returns freely to the heart, and the colour of the inflamed part is that of arterial blood; whilst in hernia the inflammation is caused by a stop being put to the return of the blood through the veins, which produces a great accumulation of this fluid, and a change of its colour from the arterial to the venous hue." Cooper on Hernia, p. 20.

but a far more serious because a more fatal process is going forward within the abdomen. It must be recollected that a gangrene of the intestine when out of the abdominal cavity is not necessarily fatal; that the gut may die and putrefy, and be thrown off by the results of external inflammation and sloughing, and yet the patient live for many years with an artificial anus, or even have the natural passage *per anum* restored again. Numberless cases of artificial anus have thus occurred, not one of which could have been saved if the sloughing of the intestine was inevitably mortal. But soon after the strangulation is effected, either from the pressure on the viscus, which may be supposed to have a material influence, or from the mechanical obstruction to the passage of the fæces, inflammation is established within the cavity, commencing probably at the strictured spot, and spreading thence with great rapidity. The part of the peritoneum most engaged is that which covers the line of intestine interposed between the stricture and the stomach; the least, that which invests the walls of the cavity. This inflammation may be in part salutary, for it occasionally causes an adhesion of the intestine at the neighbourhood of the ring so firm that it cannot be removed therefrom, and thus provides for the occurrence of an artificial anus subsequently without the danger of any internal effusion; but unless the stricture is relieved at this time, and a check thus given to the progress of the disease, the intestines become matted with lymph, effusions are poured out of a similar nature to those that occur in other forms of peritonitis, and the patient dies—not of the gangrene of the protruded intestine, but of the peritoneal inflammation within.

On opening the body of a person who has thus died, the intestines above the stricture are found inflamed, of a red or pink colour, greatly distended with flatus and perhaps with fæcal matters; below the stricture they are inflamed also, but remarkably diminished in size. There is always an effusion of lymph to a greater or less extent glueing the convolutions of the bowels together, and there is often on the surface of the peritoneum not covered with lymph, a dark appearance as if blood was ecchymosed beneath it. Effusions are also constantly met with, sometimes apparently of pure pus, diffused, particularly throughout the spaces formed by the apposition of the convoluted intestines, sometimes more abundant, and consisting of serum mixed with lymph in loose and floating flakes; and occasionally a more gelatinous substance is observed very much resembling the jelly-like material that surrounds frog-spawn in stagnant ponds. I have never met the existence of gangrene within the abdomen in any case of death from strangulated hernia.

The line of intestine, then, within the abdomen, and the loop within the sac, are differently circumstanced. Above the stricture there is active inflammation exactly such as might occur idiopathically, presenting the same morbid appearances, and accompanied by a similar train of symptoms: below, there is a state of venous congestion in which the vessels endeavour to relieve themselves by pouring out a serous effusion, and in which gangrene supervenes with a rapidity proportioned to the tightness of the constriction. Between these, and immediately under the stricture, it is white, pale, and bloodless all round for the space of two or three lines, and appears to be diminished in size more than it really is on account of the great enlargement immediately above and below. The condition of this strictured ring of intestine is of the utmost importance in the progress of the case, for it is not uncommon for it to ulcerate or to slough under the influence of the continued pressure. I have seen an operation admirably performed, and the intestine returned under apparently favourable circumstances, yet the patient sink and die in the course of a few hours: a small hole existed in the constricted spot, through which fæcal matter had escaped and become diffused within the cavity. In another instance, from the anxiety of an operator to inspect the condition of this spot previous to the return of a hernia, the intestine in the act of being drawn out tore almost as easily as a wetted rag.

It will not be difficult to connect the symptoms of this disease with the morbid alterations just described. When a hernia is about to become strangulated, the earliest symptom is in general pain, at first referred to the seat of the stricture, but soon becoming diffused over the abdomen, when the chief suffering is often seated in the region of the navel. The belly then becomes hard and tense, at first rather contracted, but subsequently swollen and tympanitic: it is exquisitely tender to the touch, cannot endure the slightest pressure, and in some cases even the contact of the bed-clothes is intolerable. The patient lies in bed with his legs drawn up, and if possible his shoulders bent forward on the trunk; he cannot without excessive torture endeavour to move himself in any direction, and a moment in the sitting posture is not to be endured. Of course when the whole canal of the intestine is constricted, there must be constipation of the bowels; yet cases have been mentioned in which, though all the other symptoms of strangulated hernia were present, the discharges from the bowels have not ceased,—a circumstance that has been explained by the supposition that only a portion of the circumference of the intestine was engaged. I believe, however, that most of these cases were delusive, and that when the alvine discharges have continued to a very late period, the case was one of incarceration in which peritoneal inflammation may not be established for a long time or perhaps at all; or else the practitioner was deceived by some of those discharges from the line of intestine below the stricture which are so frequently brought away by the administration of enemata. The explanation of the symptom is too mechanical, particularly when it is recollected that idiopathic inflammation of the peritoneum will generally (although not always) produce the same effect, and that it is as regular, as constant, and as complete in omental as in intestinal ruptures. At a very early period of the case the stomach becomes engaged, and there is vomiting, at first in large quantity until the contents of the stomach are evacuated; it is then less, dark-coloured, and excessively bitter; and finally a substance is discharged having the appearance and fetor of the feculent contents of the great intestines. Considering the structure and functions of the valve of the ileum, it appears curious how an anti-peristaltic motion could be so completely established as to permit of actual fœcal vomiting, and the fact (if it is a fact) cannot be explained except by supposing the action of all the constituent structures of the intestine so deranged that the influence of the valve is altogether lost. But it is more than doubtful whether this material is really feculent, although it is difficult from its sensible qualities to consider it in any other point of view; for I have frequently seen this vomiting in cases where the herniæ were formed of loops of the lesser intestines, and therefore when the contents of those beyond the iliac valve could not have been thrown off; and in every case it is difficult from the examination of the discharge to determine its nature with accuracy. After the stomach has been emptied of its natural contents, the act of vomiting assumes a very peculiar character: strictly speaking, it is not vomiting or retching, nor is it hiccup, but a slight convulsive effort like a gulp, which brings up without much effort the quantity of a single mouthful at a time. The forehead is now bedewed with a cold and clammy sweat; the countenance presents a remarkable expression of agony and anxiety; and the pulse is small, quick, hard, and vibrating, as is the case in all internal inflammations of vital parts.

After some further time (and the period is very variable) the characters of the disease undergo a fearful alteration. Mortification attacks the incarcerated viscus, and in most instances *seems* to bring the result of the case to a very speedy issue. The tumour now loses its tense feel, and becomes soft, flabby, and perhaps emphysematous: in some instances it retires altogether. The belly also may become soft, and in general there is a discharge per anum of dark-coloured and abominably offensive fæces. This evacuation leads the patient into the encouragement of false hopes, for he may have seen his surgeon endeavouring to procure stools during the progress of the case, and combining this circumstance with the removal of the pain and the comparative ease he so suddenly experiences, he fancies so favourable a change to be the harbinger of recovery. But the delusion lasts not long. The pulse becomes low, weak, and faltering: often it intermits irregularly. The countenance is sunken, and assumes an appearance that cannot be described, but is known by medical practitioners as the "facies Hippocratica." The eye has a suffused and glassy look, and there is a certain wildness of expression very characteristic. The forehead is bedewed with a cold and clammy sweat; the extremities become cold; the sensorium is affected with the low muttering delirium, and death soon finishes the picture.

These symptoms have been laid down as indicative of mortification having taken place, probably because the protruded viscus has generally been found in that state; and from habit many practitioners have on their appearance in cases of purely idiopathic peritonitis decided on the presence of gangrene, and the hopelessness of recovery. Such cases are hopeless, and patients have died, but not of mortification, for although these symptoms are present in most cases of fatal peritonitis, yet dissection after death very rarely exhibits gangrene in that disease, and perhaps for this reason, that the functions of the abdominal viscera are too important to life for a patient to struggle sufficiently long with their inflammation to permit of mortification being established. Whilst the inflammation is very active, and the serous membrane dry, or lymph only secreted on its surface, then is the pain intense, and the first order of symptoms developed: but when effusion has taken place, and the vessels are relieved by the pouring forth of serum or sero-purulent fluid, the pain abates, and the symptoms are those of extreme debility. In confirmation of this remark it may be observed that, when a patient dies from any sudden effusion into the peritoneal cavity, whether from a ruptured intestine, or gall-bladder, or bloodvessel, or from any other source, the symptoms from the very commencement are those of debility and collapse—the same sunken and anxious look, the same feeble and fluttering pulse, and the same kind of universal sinking of the entire system.

However, although the symptoms may be very formidable, the state of the patient is not altogether hopeless. Art may still accomplish a great deal, and even the operations of nature alone and unassisted may succeed in prolonging life, although under circumstances that render life scarcely desirable. When the hernia has proceeded to gangrene and the patient still lives, the skin of the tumour assumes a very dark red and livid colour, and then becomes black in spots. The cuticle separates and peels off in patches, and some one or other of the sphacelated parts giving way, a profuse discharge bursts forth, of a horribly offensive nature. In the same way may the surgeon's interference prove serviceable. It is related by Petit, that travelling once, he met in the outhouse of an inn an unfortunate being thrown on a heap of straw in a corner to die. He immediately recognized the smell of a gangrened hernia, and proceeded to give the poor fellow all the relief within his power. He made an incision, allowed the feculent matter to escape, cleared away the gangrenous and putrid parts, and having ordered a poultice left him to his fate. On his return he found him able to move about and perform active service within the stable, and even free from the disagreeable accompaniment of an artificial anus at the groin. This is a most gratifying piece of successful surgery, but it is not one that is very frequently realised. In order to the possibility of an artificial anus being formed, the patient and the hernia must be placed under circumstances so very peculiar that it will be easily perceived how unlikely it is that they should be united and combined in one individual.

1. Although the protruded viscus has become sphacelated, the inflammation within the abdomen must not have reached such a height as to preclude the possibility of recovery.

2. Adhesions must be established between the bowel and the peritoneum either at or immediately above the neck of the sac, so that when the stricture is free and the enormous alvine accumulation allowed to escape, it will be impossible for the gut to withdraw itself within the cavity or be removed from the external aperture.

And in order that the annoyance of the artificial anus should be subsequently removed, it is necessary that the intestine and the peritoneum to which it is adherent should retire into the abdomen, and that the angle between the two intestinal tubes should be diminished or removed.

1. If the first of these conditions is indispensable, it follows that the chance of recovery with artificial anus is inversely as the acuteness of the symptoms and the rapidity of their progress. As it is the inflammation of the intestines that destroys the patient, it is pretty evident that after it has reached a given point, no operation performed on the hernia and no evacuation of the contents of the bowels can arrest its progress, or cause the absorption of the lymph, or of the sero-purulent fluid that has been effused into the peritoneal cavity. In operating on the living subject within twenty-three hours after the first appearance of the hernia, I have found the intestine sphacelated: in this case, when the stricture was divided, the discharge from the intestines within the abdomen was trifling in quantity, and in order to relieve the patient, I was obliged to introduce a gum-elastic tube for a considerable way into the superior fragment of the bowel. He died on the subsequent day, and on examining the body the front of the intestines seemed to be one mass of plastic lymph, which obliterated every appearance of convolution, and must have glued together the bowels in such a manner as to prevent the possibility of a peristaltic motion. In a case so aggravated no hope could be entertained from the establishment of an artificial outlet. It can now be easily imagined how persons of a very advanced age,* and in whom the symptoms of strangulation are mild and chronic, recover with artificial anus, in short that such a consummation is most to be expected in the cases to which the name "incarcerated" has been applied, whereas in most instances of "strangulated" hernia its occurrence is unlikely, and in many altogether impossible.

2. The second great requisite for the establishment of an artificial anus is, that adhesion shall take place between the bowel and the peritoneum, either at or immediately above the neck of the sac, so that when the stricture is free and the alvine discharges allowed to escape, it will be impossible for the gut to withdraw itself within the cavity, or be removed from the external aperture. This adhesion has, I think, been generally supposed to occur "during the inflammation which precedes the gangrene,"* but is nevertheless probably always not only subsequent to it, but to the separation of the unsound and sphacelated parts; and the attachment is, not between the contiguous and opposing smooth surfaces of the serous membrane, but between the divided edges of the sound portions of the tube remaining after the slough has been thrown off, and the part of the neck of the sac adjacent to them. I have operated on a great number of gangrened herniæ, and never found such an adhesion to have previously existed, neither have I ever met with it on dissection, and I cannot conceive the possibility of a spontaneous return after sphacelus (an event that but too frequently occurs) if the parts were thus attached together. Assuredly if such adhesions were formed at so early a period, they ought to be much more frequently found, and they would be amongst the most calamitous complications that could attend a hernia; for they would offer an almost invincible obstacle to its reduction, or supposing the bowel to have been pushed up by force, such a sharp angular fold would be formed as must prevent the passage of its contents and create an internal strangulation. Nor is the consideration of this fact practically unimportant, if it leads us to adopt every possible precaution that may conduce to the undisturbed progress of this adhesive process, and at the same time warns us not to be too sanguine in our expectations. I have (as I have said) operated on a vast number of cases of gangrened hernia, not one of which recovered with artificial anus: some, the great majority, perished, as has been remarked, in consequence of the inflammation within the abdomen having reached an incurable height; some others sank exhausted and died, the system being apparently worn out and incapable of a recuperative effort: others still, from a retraction of the divided end of the bowel and the escape of its contents into the cavity; and one, from a cause which, as it has not been mentioned by any pathological writer, may be noticed here. On the spontaneous separation of the sphacelated bowel, a frightful and incontrollable hemorrhage took place, some of which flowed into the peritoneal cavity, and was found after death diffused through the convolutions of the intestines.

When a case has been so fortunate as to permit of the formation of an artificial anus, after the mortified parts and putrid sloughs have been removed a cavity is seen, generally irregular and puckered at its edge, leading down to and communicating with the injured

* See Louis' Memoir on hernia followed by gangrene. Mém. de l'Acad. Roy. v. 3.

* Scarpa on hernia, p. 323. See also Travers on wounded intestines. "Dans les hernies, ces adhérences *précèdent* la destruction des parties, et elles previennent le plus souvent l'epanchement des matières dans le ventre."—Dupuytren, Leçons Orales, tom. ii. p. 197.

intestine, from which the fæcal discharge is constantly trickling, and as there is often a sufficient space for a portion of this to lodge and remain, it may prove a source of troublesome and dangerous ulcerations. In a short time the mucous membrane becomes everted and protrudes, often, if neglected, to the extent of several inches: it is a true prolapsus of the membrane, not very unlike the prolapsus ani in appearance. At the bottom of the cavity already mentioned, are the orifices of the intestines, the superior of which is the larger, as it is from it the discharge proceeds, whilst the inferior is small and so contracted as frequently to be discovered with difficulty. The partition between the orifices is formed by the juxtaposition and adhesion of the sides of the intestine: it is termed the "eperon" by Dupuytren, and is larger and more obvious when a portion of the bowel has been completely removed so as to divide the tube into two parts, smaller when only a knuckle has been pinched up and gangrened without engaging the entire circumference. To this "eperon" and double partition the mesentery is attached, and the functions of this membranous ligament are said to exert a very important influence on the progress and after-consequences of artificial anus.

Not only is the superior portion of the intestine (that which is in relation with the stomach) larger, but its extremity being fixed by the new adhesions, the progress of its contents is greatly facilitated, and according to Dupuytren actually accelerated as to time. The inferior or rectal portion, not performing its functions, becomes diminished in calibre, and contains a white, pulpy, albuminous material, which is sometimes discharged by stool, but may remain undecomposed within it for months or even years. The contracted condition of this portion of the gut is of the highest importance to be attended to in all instances where a recovery is possible or likely to be attempted. This disposition of all hollow structures in the body to accommodate themselves to the bulk or quantity of their contents has been already noticed, and to obviate the inconveniences likely to arise from such diminution, the older surgeons* strongly recommended the use of enemata, in order, amongst other advantages, to preserve the intestine in a sufficient state of distension.

The progress and termination of a case such as has been under consideration may be extremely variable. The aperture may be situated in the lesser intestine so high up or so near the stomach that the space to be traversed by the aliments and their period of detention are shortened: their digestion is then incomplete and nutrition so far impaired that the patient sinks gradually, and dies from the effects of inanition; or a permanent artificial anus may be established without a hope or a chance of the natural passage ever being restored; and this seemed at one time to have been the great object of surgical practice in these cases, for we find M. Littre, a celebrated French surgeon, actually tying up the lower portion of the gut when he could find it, as if to preclude for ever a possibility of the continuity of the tube being restored. This is a most deplorable condition, yet have patients endured the annoyance of a permanent discharge at the groin for a great length of time; and in the Museum of the School in Park Street, there is a preparation taken from a man who had thus existed for upwards of ten years. There is a curious instance mentioned by Louis in which something resembling the regular action of a sphincter was clearly observable, and although the discharge of the fæces was involuntary, yet it was periodical, and the gut once evacuated remained closed until a new accumulation took place. This person, of course, was comparatively free from that constant trickling of fæces which is the patient's chief annoyance, and which, if not palliated by some ingenious contrivance, absolutely renders his life loathsome.

The natural passage of the fæces has been restored. This is so desirable, so fortunate a consummation, and its practicability so clearly established by the circumstance of its being occasionally accomplished solely by the operations of nature, that it can be no matter of surprise if surgeons have laboured to attain it and diligently observed the entire process. An intestine of which a portion has sloughed away is placed in a very different condition from one that has been simply wounded. When an entire loop of bowel has been removed, the two portions within the abdomen passing down to the neck of the sac lie more or less parallel to each other, or approach by a very acute angle: they are in the same degree perpendicular to the ring, and between them is that double partition termed "eperon" or buttress by Dupuytren, and the "promontory" by Scarpa. Now as the intestines are fixed and fastened in this position, the canal can never again become continuous *in directum*, and therefore any material that passes from the upper into the lower portion must do so by going round this intervening promontory. Even when only a small fold or knuckle has been lost, although the complete continuity of the tube is not destroyed, and the partition is less evident and prominent, still an angle must inevitably be formed of sufficient acuteness materially to impede the progress of the fæces. In neither case, then, can the wounded edge of one portion of the intestine come to be applied to that of the other, nor can adhesion or union by the first intention ever be accomplished between them. In lieu of this, however, the edges of the intestine become united with the peritoneum opposed to them, which must of necessity be the neck of the sac, and then if the external wound can be healed, a membranous pouch or bag is interposed between them, of a funnel-shape, and which serves as a medium of communication and of conveyance for the fæcal matters from one portion of the tube into the other.

Reflecting on this pathological condition of parts, it will not be very difficult to explain some of the varieties observed in cases of artificial anus. The chief obstruction to the re-establishment of the canal is the intervention of the promontory.

* See Louis' Memoir, loc. citat.

If it is so large or otherwise so circumstanced as entirely to impede communication, and if in this condition it is neglected, the discharge must take place at the groin, and the disease is permanent. Such, I believe, is the history of most of those unhappy beings who have borne about them for years this loathsome and disgusting affliction, until relieved by a death that could not have proved unwelcome. In a vast number of cases the projection is not so great, and although it may impede and delay, it does not altogether prevent the passage of fæces from one portion of the tube to the other: then as the external wound contracts, the neck of the sac forms into a membranous funnel or canal of communication, and the fæces begin to pass. The wound then heals, in some instances leaving a small fistulous opening through which a limpid, straw-coloured, but fetid fluid constantly distils, whilst in others a perfect and complete cicatrix is formed. But we must recollect what happens in this seemingly perfect cure before we can fully appreciate the entire nature of the case, and the degree of danger that always overhangs it. It is evident that the viscus must (at least at first) be firmly fixed at the situation of the cicatrix; that it no longer enjoys any freedom of motion, and that it forms an angle more or less acute at the place of adhesion. It is also probable that the diameters of the two portions of intestine do not correspond. Hence the process of digestion is impaired, the patient must study every article of food he consumes, and the slightest indiscretion is followed by colicky pains, flatulence, and tormina of the bowels; often there is nausea, vomiting, loss of appetite, and a dragging sensation at the stomach, this latter symptom being explained by the omentum having formed a part of the protrusion, and become adherent at the new-formed cicatrix. It often happens that the scar gives way, and a fæcal discharge takes place again, the groin thus alternately healing up and bursting out anew. This is more likely to occur in cases where the very small fistulous canal has remained, and therefore many surgeons have regarded this event as more fortunate than where the cicatrization has been complete; for the course of the fistula serves as a guide to direct the bursting of the accumulation externally, whereas if, as sometimes happens, the intestine should give way internally, its contents are then poured out into the peritoneal cavity, and the result must be inevitably fatal.

The most curious circumstance connected with the healing of an artificial anus is, that the position of the united intestines and the intervening infundibulum or funnel behind the cicatrix is not permanent. "It is," says Scarpa,* "a certain fact confirmed by a very great number of observations, that after the separation of the gangrene the two sound segments of intestine retire gradually beyond the ring towards the cavity of the abdomen, notwithstanding the adhesion which they have contracted with the neck of the sac, whether this is caused by the tonic and retractile action of the intestine itself and of the mesentery, or rather by the puckering of the cellular substance, which unites the hernial sac to the abdominal parietes within the ring. And this phenomenon is likewise constant and evident even in herniæ not gangrenous, but merely complicated with fleshy adhesions to the neck of the sac, and therefore irreducible. In these herniæ, the immediate cause of strangulation being removed, the intestine, together with the hernial sac, gradually rises up towards the ring, and at last is concealed behind it." The same fact has been observed by Dupuytren,* who attributed it to the continued action of the mesentery on the intestine. Many individuals who had been cured of artificial anus without operation returned to the Hôtel Dieu at very remote periods, and died of diseases having no relation to the original complaint. The parts were curiously and carefully examined, and the intestine, instead of being fixed to the walls of the belly, was found free and floating within the cavity. There could be no doubt of the identity of the individuals, and moreover a fibrous cord was seen extended from the point of the wall of the abdomen which corresponded with the former artificial anus, to the intestine. This cord, some lines in diameter and some inches in length, thicker at its extremities than in the middle, covered by peritoneum, and formed entirely by a cellular and fibrous tissue without any cavity, was evidently produced by the progressive elongation of the cellular membrane that had united the intestine to the wall of the abdomen; and the cause which had occasioned this elongation was nothing else than the traction exercised by the mesentery on the intestine in the different motions of the body during life.

Having now endeavoured to describe generally the circumstances or conditions under which protrusions of the abdominal viscera may exist, I proceed to consider the peculiarities that arise from situation, premising that it is not my intention to enter very minutely into the descriptive anatomy of those several situations in their normal or healthy states, but only in reference to and in connexion with the existence of the disease under consideration.

Inguinal hernia.—When a viscus is protruded through one or both of the apertures termed rings, situated at the anterior and inferior part of the abdomen, near the fold of the groin, but above Poupart's ligament, the hernia is termed inguinal. It may exist, therefore, in three different conditions. 1. Where the intestine has been pushed through the internal ring only, and is lodged in the inguinal canal: it then appears as a small, round, firm, and moderately elastic tumour. 2. Where it has passed through the internal ring, through the inguinal canal, through the external ring, and dropping down into the scrotum of the male or the labium pudendi of the female, appears as a larger and more yielding tumour, of a pyramidal shape, the apex of the pyramid being directed towards the anterior superior spinous

* Scarpa, op. citat. p. 313.

* Leçons Orales, tom. ii. p. 207.

process of the ilium. As these are but different stages of the same disease, both come under the appellation of hernia by the oblique descent. But, 3, when the viscus has been forced through the parietes immediately behind the external ring, and passes out through that natural aperture only, it is then for obvious reasons termed the hernia by direct descent; and although the external characters of the tumour are not always such as to point out the peculiar nature of this protrusion, yet the relative position of the intestine with respect to adjacent parts must be somewhat different in these several cases, a difference that will be found to be of some practical importance.

The peritoneal sac, as viewed internally in the direction of the iliac and inguinal regions, is described by Scarpa as being divided into two great depressions at each side, the medium of partition being the ligament into which the umbilical artery of the fœtus had degenerated, together with the fold of peritoneum raised by that ligament. Of these fossæ the superior or external is the larger and deeper; it is that within which the intestines are collected when strongly compressed by the abdominal muscles and by the diaphragm in any violent exertion; and from it inguinal hernia is most frequently protruded, as the ligament and duplicature of the peritoneum prevent the compressed viscera lodged in this fossa from removing out of it to descend into the pelvis. The situation of the umbilical artery varies considerably: sometimes it is close upon the internal border of the internal ring, in other subjects at the distance of half an inch from it, or even more; but it is always at the pubic side of the epigastric vessels. Thus, in its direction upwards and inwards towards the umbilicus it crosses obliquely behind the inguinal canal: all herniæ, therefore, by the oblique descent pass out from the external or superior abdominal fossa, while those by the direct are in relation to and are protruded from the inferior or internal. Independent of this configuration there is nothing in the peritoneal cavity as viewed from within, to determine the occurrence of hernia at one place rather than at another. The membrane is in all parts equally smooth and polished, equally strong,* tense, and resisting. This, however, is not the case with respect to the muscular and tendinous walls of the abdomen, which vary very considerably in density and strength in different situations, and in these qualities dissection shews that the hypogastric or inguinal regions are the most deficient and therefore most disposed to permit of the occurrence of hernia.

In prosecuting the dissection from within (which is by far the most satisfactory manner), the peritoneum may be detached by the fingers or by the handle of the knife in consequence of the laxity of the cellular tissue connecting it to the adjacent external structures. The fascia transversalis then comes into view, and in it the aperture termed the internal ring, through which the spermatic cord in the male, and the round ligament in the female are transmitted. This aponeurosis varies in density and thickness in different individuals: it is continuous with the fascia iliaca, and is connected with the posterior edge of Poupart's ligament: it is denser and stronger externally, and becomes weaker and more cellular as it approaches the mesial line. Where the internal oblique is muscular, the connexion between it and the fascia transversalis is extremely lax, cellular, and easily separable; but after it becomes tendinous, the union is much more intimate, and the fibres of the one can scarcely be distinguished from those of the other unless by the difference of their direction. In most subjects the internal ring is very indistinct, its size, shape, and direction being in general determined rather by the knife of the anatomist than by nature. So far as the fascia is concerned, the external inferior border of the ring is its strongest part, but its internal edge *seems to be the stronger* as it is supported by the epigastric vessels, and sometimes by the remnant of the umbilical artery. Its size is about an inch in length, half an inch in breadth; its shape oval; and the direction of its longest diameter perpendicular or slightly inclining from above downwards and outwards.

The position of the epigastric artery with respect to the neck of the sac at once points out whether a hernia is by the direct descent or not, for it marks the internal or pubic boundary of the internal ring. This vessel is occasionally irregular in its origin, but in its normal or usual state it comes off from the external iliac before it has reached Poupart's ligament, and consequently in that position it lies behind the bag of the peritoneum, which it passes by forming an arch, the concavity of which is directed upwards. It then appears in front, between the fascia transversalis and the peritoneum, but more closely attached to the former, with which it remains when the membrane is torn away. The vas deferens is seen coming from the pelvis obliquely upwards and outwards until it reaches the spermatic artery, which, having descended from above, nearly in a perpendicular direction, meets the vas deferens at rather an acute angle, the former being to the outside and nearly in front of the latter. These vessels having passed the fascia transversalis disappear by arching round the epigastric artery and entering the inguinal canal, and they define the inferior margin of the internal ring. The remainder of its border is not so very distinctly marked, partly in consequence of a very delicate fascia which is given off from it and passes down a short way on the spermatic cord, where it becomes indistinct and is lost; and partly because the transversalis muscle lying before it renders the view obscure. The internal border of the internal ring is always (as stated by Sir A. Cooper) midway between the anterior superior spinous process of the ilium and the symphysis pubis.

When a protruded viscus, then, is passing

* The strength of the peritoneum is proved by a curious experiment of Scarpa's. He stretched a large circle of this membrane recently taken from the dead body, on a hoop like a drum, and found it capable of supporting a weight of fifteen pounds without being ruptured.

through this ring, it has the epigastric artery to its internal or pubic side, and generally the vessels of the cord behind it; but a variety sometimes occurs, for the hernia may protrude exactly at the spot where the spermatic artery and vas deferens meet each other at an angle, and separate these vessels from each other, leaving the artery rather to the outside and in front, the vas deferens still occupying its usual situation behind. After the hernia has passed the fascia transversalis, it is still behind the fibres of the internal oblique and transversalis muscles, and has to pass a few lines (the distance varying in different subjects) before it reaches the posterior surface of the tendon of the external oblique. On prosecuting this dissection further by detaching the fascia transversalis from the transversalis muscle in a direction downwards and outwards, the intestine will be found to have entered a canal of an inch and a quarter to an inch and a half in length, its direction being obliquely downwards and inwards to the external ring. This is termed the inguinal canal, and is thus formed. Poupart's ligament, whether it be considered as a portion of the tendon of the external oblique or not, is powerfully strong and thick: to it the fascia transversalis is firmly adherent behind, and the thinner and more expanded fibres of the tendon of the external oblique before. Between these, then, a sheath is formed in which the hernia is lodged, having in front the tendon of the external oblique, and also covered by the cremaster muscle, particularly that part of it which has its origin from Poupart's ligament. Behind it is the fascia transversalis, and more internally or nearer the pubis the conjoined tendon of the internal oblique and transversalis, and below is Poupart's ligament. Above, it is crossed obliquely by the inferior margin of the internal oblique and transversalis. These muscles have a fleshy origin from the external third of Poupart's ligament, from which they pass in an arched form to be inserted by a common tendon into the crest of the pubis. Under this arch the viscus slips and thus places itself anterior to the conjoined tendon before passing through the external ring and becoming a scrotal hernia.

Anatomists have not agreed in their descriptions of the internal oblique muscle, although a correct and accurate knowledge of the situation of it and of the transversalis in the neighbourhood of the rings is indispensable to the right understanding of hernia. According to Sir A. Cooper* and Lawrence,† the upper part only of the internal ring is shut up by these muscles, leaving the lower unprotected, and consequently, according to this view of the subject, *a hernia on entering the inguinal canal* should have them above it. Cloquet‡ states that the inferior border of the transversalis passes on a level with the superior, opening internally, but the edge of the internal oblique is lower down, covers the spermatic cord in the inguinal canal, and passes over it to be inserted into the pubis at the point where *it escapes from the inferior opening of the canal*, that is, the external ring. Scarpa* gives a different description still, where he says, "towards the side at about eight lines distance from the apex of the ring, the lower muscular fibres of the internal oblique muscle separate from each other to allow the spermatic cord to pass between them;" and Guthrie† considers the occasional passage of a hernia through the fibres of this muscle, and its compression by them, to be no unfrequent cause of strangulation. It is not easy to reconcile these conflicting authorities, which in themselves demonstrate the fact that the inferior border of this muscle exhibits some varieties in its relation to the inguinal canal and internal ring according to the extent of its origin from Poupart's ligament. When a hernia is present, I have always seen it arched over the neck of the sac, and although I would by no means assert that a rupture never takes its course between these muscular fibres, yet I have not met with an instance, and as I have observed elsewhere, I imagine such an occurrence would create a deviation from the usual relative anatomy of the cremaster muscle with respect to the hernial sac.—See Abdomen.

The inguinal canal terminates in front at the external ring, which is formed by a separation of the fibres of the external oblique muscle as it passes inwards and downwards to be inserted into the pubis. Almost immediately after the muscle has become tendinous, a disposition to this separation is observable, and a kind of split is formed in the tendon, the edges of which are, however, pretty firmly held in their relative positions by fibres passing closely and irregularly across from one to the other. These fibres have been called the intercolumnar fascia. Besides these there is a very remarkable arrangement of tendinous fibres seeming to arise from Poupart's ligament, and thence radiating in an arched form (the convexity of the arch looking towards the pubis) to form a strong interlacement with the fibres of the external oblique.‡ Independent of these adventitious bands the tendon itself, as it approaches the crural arch and the pubis, seems to become thicker and stronger; and (as has been remarked by Scarpa) in the dead body after the integuments are removed and the parts left for some time exposed, the lower portion of the aponeurosis appears opaque and dense, while the part above the umbilicus preserves its transparency, and allows the fleshy fibres of the subjacent muscle to be seen through it. The separation above alluded to being effected, the tendon is divided into two portions, termed the pillars of the ring: the anterior or internal is broader and flatter, and runs to be inserted into the pubis of the opposite side, and the ligamentous substance that covers the front of this bone. The

* Page 6.
† Lawrence on Ruptures, p. 162.
‡ Anatomy of Hernia, by Jules Cloquet, translated by M'Whinnie, p. 6.

* Page 25.
† Anatomy of Hernia.
‡ Sometimes termed Camper's fascia, from its being so admirably delineated in the "Icones."

inferior or external is rounder and more firm, and attached to the external part of the crest or tuberosity of the pubis. A triangular aperture is thus formed of about an inch or an inch and a quarter in length, the base of which, nearly half an inch across, is situated at the pubis, from which it tapers gradually off in a direction upwards and outwards. For a neat demonstration of this aperture we must also be largely indebted to the knife of the anatomist, its edges being obscured by a fascia* which comes off from them, and passing down on the cord is generally of sufficient density to admit of being traced as far as the tunica vaginalis testis. This ring is never well developed in the female, it then being smaller, rather of an oval figure, and from its deficiency of size appearing to be nearer the pubis than in the male: even in subjects of the latter sex the size of this opening exhibits considerable variety. When a hernia has descended through it, the shape and direction of the external ring are altered: the inferior pillar is still more flattened and runs in a more horizontal direction; the superior is banded in an arched form rather tightly above it; the shape of the entire ring is rendered more oval and its direction more horizontal; but still its relative position with respect to the bone is so far preserved that no hernia can pass, without its internal edge resting on this bone.

In dissecting a hernia of this description from without, after removing the skin and cellular tissue more or less loaded with fat, the fascia superficialis is exposed. This is a tegument investing most parts of the body, though far more dense in some situations than in others, and is situated beneath the subcutaneous fat, with which it is sometimes so much identified as to render its demonstration difficult. At the groin it is usually well developed, and is described as consisting of two distinct laminæ, but may (by such as are curious in these dissections) by care be separated into many more.† The superficial layer is very lax, passes over and has no connexion with Poupart's ligament, and is very generally removed along with the skin and fat by the inexperienced dissector. Its removal exposes some of the glands of the groin. The deep layer is more membranous, and possesses more of the determined character of a fascia. It adheres intimately to the muscular fibres of the external oblique, passes thence inwards over the tendon, to which it cannot be said to be attached, as the connecting cellular tissue is extremely loose, and meets its fellow of the opposite side at the linea alba, to which both are attached. It has an insertion into the pubis, and its adhesion to Poupart's ligament is in many respects extremely intimate. Passing down in front of the thigh, it covers* several of the lymphatic glands, or in many instances leaves small apertures or deficiencies in which glands are lodged: it then reaches the opening in the fascia lata for the transmission of the saphena vein, to the edge of which it adheres more or less closely, and afterwards descends upon the thigh, having this vein interposed between it and the fascia lata. At the external abdominal ring the fascia superficialis sends down a sheath-like process, investing the cord and descending down over the tunica vaginalis and the testicle: it must, therefore, under any circumstances give a covering to the hernial sac. On the removal of this, the fascia that comes from the edges of the pillars of the ring is observed, and this is generally much thicker and firmer than in the normal condition of the parts. When so thickened, it also admits of subdivision into several laminæ. Immediately underneath is the cremaster muscle, its fibres spread out and separated so as to resemble a fascia, though in some instances the contrary may be observed, and they are seen gathered into bundles and greatly thickened. Still deeper are three other layers of fascia, perhaps derived from that which comes from the edges of the internal ring, and finally the hernial sac is exposed.

In herniæ of moderate size, the spermatic artery, veins, and the vas deferens are usually found in one cord and enclosed in one common sheath lying behind the sac: some exceptions, however, to this rule are observed, one of which, wherein the bloodvessels are situated on its anterior and external surface, and the vas deferens posteriorly and internally, has been already noticed and explained. But there is another deviation that seems to be occasioned by the growth of the hernia, and the compression exercised by it on the cellular substance connecting the constituent parts of the cord together. It can therefore only be met with in large and old ruptures. Thus, as the tumour increases, it causes this cellular tissue to be stretched just as if the vas deferens and the artery were pulled asunder in different directions, whilst the sac insinuates itself between them, until finally the vessels come to lie on one side of the hernia, or it may be to occupy its anterior surface. The greatest divarication of these vessels exists, as might *à priori* be expected, towards the lower part of the tumour; it is less towards the middle, and scarcely if at all above, and in the vicinity of the neck of the sac. A knowledge of this fact may teach us to beware how we prolong an incision very far down in operating on large and old herniæ.

Perhaps the next point of practical importance to consider is, whether, with all this anatomical and pathological information, it might nevertheless be possible to mistake this disease and confound it with any other affection. The

* This also has been called an intercolumnar fascia, and a spout-like fascia, &c. It is to be regretted that such a confusion of nomenclature obtains in the description of these parts,—a confusion always embarrassing to the student, and rendering the subject uselessly perplexing and difficult.

† Velpeau describes three distinct layers. Anatomie des Regions, tom. ii. p. 70.

* The inguinal glands are generally described as lying between the layers of the superficial fascia. On dissection, this has not appeared to me to be the case.

hernia just described may exist in two different conditions; one, in which it is still lodged within the inguinal canal, and appears in the form of a tumour in the upper part of the groin, termed bubonocele; the other, in which it has escaped through the external ring, and having dropped down constitutes scrotal hernia.

When the rupture has descended no farther than the groin, there are but two affections that can bear any resemblance to it: these are, the testis itself whilst in the act of descending, if this process has been delayed beyond the usual period of life, and an enlarged inguinal gland. However possible in cases of crural hernia (as shall be noticed hereafter), a mistake of the latter description is not likely to occur in the disease under consideration, but there is an observation of Mr. Colles on this subject deserving of attention. "I do not suppose," says this distinguished professor, "that any surgeon of competent anatomical knowledge could mistake it for inflammation of those lymphatic glands which lie in the fold of the groin, but an enlargement, whether from a venereal or any other cause, of two lymphatic glands which lie on the side of the abdomen, as high up but rather more internally than the internal abdominal ring; an enlargement of these glands will produce appearances resembling those of inguinal hernia."*

It seems almost surprising how the descent of the testicle could possibly be mistaken for a hernia when the mere examination of the scrotum would throw such an explanatory light upon the subject, but a consideration of the following circumstances will be useful in solving the difficulty. 1st, The detention of the testicle within the abdomen until an unusually late period is by no means so infrequent an occurrence as is generally supposed even by surgeons in considerable practice: I have heard a military medical officer observe on the great number of young men that had passed before him for inspection after enlistment, in whom one and sometimes both the testes had not descended. 2d, The symptoms of both affections bear a general though not necessarily a close resemblance; for the situation of the tumour is exactly the same, and if the testicle is compressed and inflamed, the pain and tenderness and the inflammatory fever are to a certain extent like the symptoms of strangulation. But I have not met the same costiveness, at least the same obstinate resistance of the bowels to the operation of aperient medicines, nor the same vomiting, nor the same exquisite tenderness spreading over the abdomen, and the pulse is not that small, thready, hard, and rapid vibration that is produced by peritoneal inflammation. In one case I perceived that pressure on the tumour occasioned that sickening pain and sensation of faintness which a slight injury of the testicle so often produces; and I imagine that in this case a light and very gentle percussion might prove a useful auxiliary diagnostic. But, 3rd, it does not always happen that the surgeon takes sufficient pains to investigate the disease before him. "He is apt," says Mr. Colles,* "at once to set down the case as incarcerated hernia, a complaint with which he is familiar, and does not suspect the existence of a disease which is to him perhaps extremely rare. Boys sometimes indulge in the trick of forcing up the testicles into the abdomen, which may be followed by unhappy consequences, for the gland may not descend again, or if it does, perhaps a portion of intestine slips down along with and behind it, which may then become strangulated, while its presence is unsuspected and the symptoms attributed to compression of the testis." A boy, about seven years of age, had forced the left testicle into the abdomen: ten years afterwards, the inguinal ring having probably become unusually contracted, the testicle passed under the femoral arch with all the symptoms of strangulated hernia, on account of which he was obliged to undergo the operation.†

When the hernia has become scrotal, it then comes more to resemble diseases of the testis and of the cord, but in general these are very easily distinguished, and there are only three that could lead a practitioner into error, and then only through unpardonable carelessness; the hydrocele of the tunica vaginalis testis, the hydrocele of the spermatic cord, and the varicocele or a varicose condition of the veins of the cord.

There is not much likelihood that hydrocele of the tunica vaginalis could, in its earlier stages, be mistaken for hernia: it commences below and increases in an upward direction, while a hernia proceeds from above downwards; and at first in cases of hydrocele, the ring, the cord, and all these parts can be accurately felt. As the disease proceeds and the water reaches the ring, a diagnosis is not so easy; still in almost every case of rupture the testis and the cord, particularly the former, can be easily felt lying behind and at the bottom of the tumour, which is not the case in hydrocele. Besides, hydrocele is lighter as to weight; it gives a sensation of fluctuation to the touch; it never exhibits that soft doughy character that belongs to omental hernia: moreover it is diaphanous, and the light of a candle can be seen through it, if the tumour is examined in a darkened room.

A collection of water within the sheath of the cord must, I should think, be rather an infrequent occurrence; at least it has not fallen to my lot to meet with many examples of it. Still the practitioner must be aware of the possibility of the disease, and that both from the nature of the accident that occasions it, and many of the accompanying symptoms, it may very readily be mistaken for hernia. A young man fell with his groin against the edge of a tub, and in an incredibly short space of time afterwards a colourless elastic tumour appeared in the usual situation of hernia.

* Colles's Surgical Anatomy, p. 46.

* Colles, op. citat.

† Scarpa, op. citat. p. 235.

He was admitted into the Meath Hospital under the care of the late Mr. Hewson, and though some years have now elapsed I can well recollect the variety of opinions pronounced upon it. It could be partially pushed up, but re-appeared instantly on the pressure being removed: it was slightly influenced by coughing, and it was extremely tender to the touch. As the patient was not confined in the bowels, and in fact there was no urgency of symptom, no active treatment was adopted, and the tumour gradually disappeared. It had probably been an effusion of fluid into the sheath of the cord. The manner in which these diseases are said to be capable of discrimination is as follows. Let the tumour be pushed up if possible, and the finger of the operator still be pressed against the ring: if it is a hernia, such pressure will be sufficient to prevent a re-descent; but if it is only a fluid, it will insinuate itself by the side of the finger and the tumour shortly re-appear. Scarpa* denies the sufficiency of this test in cases of omental hernia of small size, when situated so high up as to occupy and dilate the inguinal ring, and asserts that he had repeatedly observed omental inguinal hernia of a cylindrical form, which, when scarcely returned, re-appeared again as before without the patient having changed his posture or made the slightest exertion; and in like manner hydroceles of the spermatic cord, which, when pushed beyond the ring, remained there as long as the patient kept himself in the supine posture without making an exertion. He seems to rely more on the difference of consistence and regularity of surface in the two tumours, and on the circumstance of the hydrocele being always broader inferiorly, contrary to what is observed in omental hernia.

A varicose enlargement of the spermatic vein is not easily confounded with hernia, unless it has increased to such a size as nearly to occupy that side of the scrotum: it is longer in proportion to the diameter of the tumour than hernia usually is, and its surface is hard, knotty, and uneven.† These circumstances, however, are not sufficient to remove all obscurity, and a farther investigation must be made by placing the patient in the horizontal position and endeavouring to empty the vessel; then let him stand up whilst firm and accurate pressure is maintained upon the ring. If it is a hernia, the tumour will not re-appear; but if varicocele, it will return as speedily or perhaps more so than if no pressure had been made. Mr. Colles‡ mentions that a varicose state of the cord may be combined with hernia, throwing great obscurity on the nature of the disease, and for obvious reasons increasing the difficulty of its management.

Inguinal hernia by direct descent.—I now proceed to offer a few remarks on the other form of inguinal hernia,—that by direct descent,* which occurs when, instead of passing through the canal, the protruded viscus is pushed out immediately behind the situation of the external ring, through which it passes directly. The inferior part of the inguinal canal is the weakest of all the parietes of the abdomen. Externally, independent of the external oblique muscle, it is protected as far as the external third or half of Poupart's ligament by the fleshy fibres of the internal oblique and transversalis muscles, and by the fascia transversalis, which is dense and strong in this situation, but becomes gradually weaker internally, and is nearly lost before it reaches the mesial line. More internally it is supported by the conjoined tendon of these muscles, but as it arches over the spermatic cord that portion of the peritoneal cavity which corresponds with the inferior and posterior part of the inguinal canal must depend on the fascia transversalis alone, now becoming weaker and less capable of resistance. More internally still, and immediately behind the external ring, this region is best supported, and there are many natural obstacles to the production of hernia in this situation. Besides the fasciæ already mentioned as tending to prevent the separation of one pillar of the ring from the other, and thereby offer an obstacle to the passage of any viscus through it, there is another† of a triangular shape arising by a pretty broad base from the crest of the pubis, and inserted into the linea alba for about an inch or an inch and a quarter. It lies behind the tendon of the external oblique, and before that of the internal oblique and transversalis, which latter it strengthens materially, and its external edge contributes to close up a part of the external ring. The edge of the rectus muscle extends itself laterally sufficiently far to occupy one-half or one-third of the space behind the external ring, and moreover here the conjoined tendon is particularly strong. Notwithstanding these supports, this part is weak; and yet when a hernia occurs here, it is not in consequence of yielding or stretching, but because the conjoined tendon actually undergoes laceration.

The causes of this hernia are said to be threefold:‡ an unnatural weakness of the conjoined tendon; its absence altogether in consequence of malformation; and its being ruptured by direct violence. Of these, the second is not likely to occur, and an example of it had not been met with by Sir A. Cooper at the time of the publication of his work: the other two in effect amount nearly to the same thing, or at least stand towards each other in the relation of a predisposing to an immediately exciting cause.

* Op. citat. p. 98.

† These symptoms are not certainly characteristic of varicocele. There is a preparation in the Museum of Park Street taken from a man who exhibited them all during life. His disease was an enlarged, knotted, and contorted condition of the vessels of the cord.

‡ Op. citat.

* The internal inguinal hernia of Hasselbach, Jules Cloquet, and Velpeau: hernia on the inner side of the epigastric artery of Sir A. Cooper, and a combination of ventral and inguinal hernia according to Scarpa.

† This is frequently termed Colles's fascia, having been first accurately described by that writer.

‡ Cooper, p. 51.

The hernia by direct descent is distinguished from the oblique, 1st, by the appearance of the groin, the apex of the tumour being at the situation of the external ring, and there being no enlargement whatever in the direction of the inguinal canal: this diagnostic, however, has been found fallacious, for in old oblique hernia the internal ring is dragged down and made to approach the external so as to appear to form one continuous opening. Nor is it easy to point out the difference even in dissection except by the position of the epigastric artery, which in case of oblique descent always lies to the pubic side of the neck of the sac. The neck in some of these cases appears to be arched over and strongly constricted by the superior portion of the ruptured conjoined tendon, which in these cases is more than usually developed, and (as it were) in a state of hypertrophy. It was probably this appearance that led to a belief that strangulation was occasionally produced by the action of these muscles. 2nd, By the relative position of the tumour with respect to the different structures composing the cord. The cremaster muscle in any hernia cannot be felt, but it occupies nearly its usual position in this, being spread out like a fascia in front of it, but rather towards its outside. The spermatic cord properly so called passes on its external rather than on its posterior side; and although all its constituent vessels may be separated in this as in any other species of large and old herniæ, yet generally there is less divarication in this, and the parts lie together more compactly. 3rd, "This tumour differs from the common bubonocele in being situated nearer the penis."* This is certainly true when it is only bubonocele; but when it has descended into the scrotum, the same difficulty that has been noticed as appertaining to old ruptures must also obtain here. In applying this diagnostic the student must recollect that the internal edges of both herniæ are equally near to the pubis: it is by looking to the external border of the neck of the tumour that he can render the test available. Scarpa† states that this hernia is returned without being attended by the gurgling sound: this, however, is an observation perfectly new to me, and which I can by no means verify. Lastly, these herniæ appear more suddenly and attain a larger size more rapidly: frequently they appear as scrotal ruptures almost from the earliest period. This, however, is still an uncertain criterion, and indeed with the assistance of all these circumstances it is always so difficult and frequently so utterly impossible to establish a diagnosis, that no operation should be undertaken under the conviction of the disease being certainly of one form or of the other.

This rupture should present to the anatomist the same number of layers of fascia as that by the oblique descent, the fascia transversalis supplying the place of that given off from the edges of the internal ring; ‡ but the young surgeon should be cautioned not to expect the same facilities of demonstration in the living subject that he possesses in the dead. In the former, the operator often meets with layer after layer of fascia, numerous beyond his expectation, and to which he can give no name; and it is no uncommon circumstance for him to operate on and return a rupture without being able to say of what nature it was—nay, even as to its being inguinal or crural.

Crural or femoral hernia takes place at the superior and internal part of the thigh, below the fold of the groin; the intestine passing out of the abdomen behind Poupart's ligament, between it and the transverse ramus of the pubis, through an aperture that has been termed the crural or femoral ring. A knowledge of the constitution, size, and boundaries of this ring must be of the last importance to the practical surgeon, and accordingly no part of the body has been examined with more minute attention; yet if by these labours anatomy has gained in accuracy of information and very diffuse description, still the student is not much the better for it, inasmuch as almost every anatomist has adopted views peculiar to himself, and thus in the details a degree of confusion has been produced that is extremely embarrassing to the beginner. I shall, therefore, avail myself as little as possible of authorities, and endeavour to describe these parts as they appear upon dissection, commencing from within, which is perhaps the best mode of studying the anatomy of every species of hernia.

The distance between the anterior superior spinous process of the ileum and the angle of the crest of the pubis is in the well-formed female about five and a half inches in length, along which space Poupart's ligament is stretched like a bow-string from point to point. The distance from the ligament thus extended, backwards to the edges of the ileum and pubis forming the border of the pelvis, varies according to the elevations and depressions of these bones; but the entire forms a very considerable space, which is, however, in general so well filled up that unless under peculiar circumstances this region affords sufficient support and protection to the viscera of the abdomen. On examining the corresponding peritoneal surface within, the membrane is found capable of being detruded only at one spot, internal to the view, and about an inch and a half distant from the symphysis pubis. Here, there is a natural aperture varying in size in different subjects, into which the finger may be pushed by a little violence, and a small artificial hernial sac like a thimble be thus produced. On tearing off the peritoneum it is easy to observe the different arrangements that serve to support and strengthen this region of the abdomen.

From Poupart's ligament three distinct layers of fascia pass off in different directions. The fascia transversalis has been already described as passing upwards on the front of the abdomen, where it is gradually lost. From the inferior and posterior part of the arch another fascia passes, at first downwards, then upwards and

* Cooper.
† Scarpa, op. citat. p. 84.
‡ The internal spout-like fascia.

backwards, to expand itself over the iliacus internus and psoas muscles; and it is therefore called the fascia iliaca. These fasciæ are perfectly continuous as far inwards as the external border of the artery, and form a smooth and strong membranous wall for the abdomen in this situation, rather attached to Poupart's ligament than coming off or derived from it.* These fasciæ separate at this spot and unite again between the artery and vein, thus forming a sheath for the former vessel: in like manner a separate sheath is formed for the vein, when they again separate and leave a small opening, which is the crural ring, but unite before they reach Gimbernat's ligament, to the abdominal surface of which they give an investment, but here the fibrous structure is very weak and differs little in appearance from cellular membrane. These fasciæ then form a flat, broad funnel, which has three apertures at top, and the membranous septa are of the greatest use in binding the anterior and posterior faces of this funnel together: hence a hernia cannot escape through in company with the artery nor with the vein, and hence also the vein is not compressed nor its circulation interfered with, even although a hernia close to it is in a state of strangulation. This funnel descends on the vessels, to which it becomes firmly attached, at about an inch and a half below Poupart's ligament, and, according to some anatomists, is there reflected up again on the vessels forming a cul-de-sac or bag. I thus consider the crural ring properly so called to be an aperture formed by a deficiency in the fascia iliaca and transversalis, just as the internal inguinal ring is formed in the latter membrane alone. It is occupied by a loose cellular tissue, and in general by a small absorbent gland.

This ring is of a different size in different individuals; and where it is large, the person may be said to have an hereditary or congenital disposition to the disease; but a liability to it may arise from accidental circumstances also. It is obvious that in proportion as the space beneath the crural arch is well filled, and the muscles tense and plump, the aperture at the ring must be small; also that it will be larger according to the greater breadth between the spinous process and the pubis, or as the space under the crural arch is deep. Hence it may be explained why this kind of rupture is frequent amongst women who have borne many children, with whom the parietes of the abdomen are relaxed; less frequent amongst young and healthy unmarried females, and scarcely known amongst men, the pelvis of the male being narrower, and his muscle better developed by use and exercise.

The crural arch or Poupart's ligament is nothing more than the inferior pillar of the external inguinal ring, and is (as has been before stated) inserted into the crest of the pubis; but it has another attachment to this bone, which, being in intimate relation with femoral hernia, I have delayed the description of until now. As the ligament approaches the pubis, its inferior edge becomes twisted upwards and backwards towards the linea ileo-pectinea, into which it is inserted for a length of from a half to three quarters of an inch. Its shape is triangular, its posterior attachment being somewhat shorter than its anterior; and its base, which has its aspect towards the vein, is somewhat lunated. In the male its situation corresponds nearly with the external inguinal ring; and the spermatic cord rests on it just as it is about to pass from the inguinal canal.

The fibrous funnel-like sheath already described is itself lodged within a cavity which may be called the *crural canal*, and is thus formed. The fascia lata of the thigh in front has two origins, one from the whole length of Poupart's ligament, the other from so much of the linea ileo-pectinea as gives origin to the pectinalis muscle, and from the ligament of the pubis. This latter portion having passed down the thigh unites with the former below the entrance of the saphena into the femoral vein, below which point they form one continuous sheath for the muscles of the limb. The portion, however, which comes from Poupart's ligament requires more attention. At first it lies completely in front of the upper part of the thigh, and of course leaves a triangular space between it and the other portion, in which are lodged the funnel-shaped fascial sheath, with its contents, the artery and vein, lymphatic vessels, and some glands. About half an inch, or in some subjects a little more, below Poupart's ligament the internal portion of this fascia appears to be wanting, leaving the vessels uncovered by it as far down as the point of union of the two fasciæ: I say *appears to be wanting*, because the fascia lata is really continued over this space, joins the pubic portion internally, and sends a process upwards to be inserted into the linea ileo-pectinea, external to the lunated edge of Gimbernat's ligament, and between it and the edge of the femoral ring; but it is here so thin and cellulated that it is generally removed in the dissection. When thus disposed of, the firm portion of the external fascia lata, as it passes to join the internal, assumes a lunated form above and below, and thus the entire apparent deficiency is made to appear of an oval figure, the edges of which are crescentic, and which have been called by the different names of Hey's ligament, Burns' ligament, and the crescentic edge of the fascia lata. A finger pushed from above through the crural ring will easily feel the superior margin of this aperture, and its influence on hernia in this situation will soon be made apparent. The femoral or crural canal then is from one-half to three-fourths of an inch in length, and is formed by the fascia lata: it is bounded above, anteriorly by Poupart's ligament and posteriorly by the linea ileo-pectinea; below, anteriorly by the crescentic

* Their importance in strengthening this part of the abdomen is proved by an experiment of Mr. Colles. "Make in the aponeurosis which covers the iliac muscle an opening capable of admitting the finger. Pass it between the aponeurosis and surface of the muscle, and you will be enabled, without much difficulty, to push the finger under Poupart's ligament down to the fore part of the thigh." Colles, op. citat. p. 68.

edge of the fascia lata or Hey's ligament, and posteriorly by its pubic portion: both externally and internally it is bounded by the junction of these two portions of fascia. Gimbernat's ligament, which is usually described as forming the internal boundary of the crural ring, rarely fills up more than half the space between the crest of the pubis and the femoral vein. This canal, as being composed of fascia, is firm, and unyielding: it cannot be influenced by the actions of any muscle in the neighbourhood, nor even so much as is generally supposed by the position of the limb. It should follow from this constitution of parts that any hernia thus restrained should forcibly compress the vein and artery before it suffered strangulation itself, and so it would if the protrusion had relation to this canal alone, and was not contained within its own proper portion of the funnel-shaped sheath already described.

The neck of the sac of a femoral hernia, then, has behind it the fascia iliaca and the ligamento-cartilaginous material that covers the sharp edge of the linea ileo-pectinea: internally it has the junction of the fascia iliaca and transversalis, the attachment of the fascia lata to the linea ileo-pectinea, and Gimbernat's ligament; internally it must also have the spermatic cord in the male and the round ligament in the female; anteriorly it has the fascia transversalis and Poupart's ligament, and *immediately above the neck* and in close contact with it is the spermatic cord, of course including the spermatic artery: externally is the membranous slip interposed between it and the femoral vein. The epigastric artery is also external to it, but although this vessel is somewhat irregular both in origin and position, yet the full breadth of the vein must be always interposed between it and the neck of the sac. But there is an irregular vascular distribution that must be borne in mind. In a great number of subjects (perhaps one out of every four or five) the obturator artery, instead of coming off from the internal iliac, arises by a common trunk along with the epigastric, which it soon leaves, and passing downwards and inwards crosses the superior aperture of the femoral canal before it dips into the pelvis to reach the obturator foramen. In this course it sometimes passes the border of the canal posteriorly, but much more frequently in front; and in this latter case, if a hernia existed, the vessel would embrace two-thirds of the circle of the displaced peritoneum close to and immediately above the neck. It appears, then, from these anatomical relations that in all subjects a considerable degree of danger may arise from too free and unguarded a use of the knife in operation—a danger that is necessarily enhanced in the male subject: indeed in consequence of the risk of hæmorrhage Scarpa seemed disposed to trust to dilatation and laceration of Poupart's ligament for relieving the stricture, and where these means were insufficient he recommended a new and particular direction to be given to the incision. But from careful dissection and examination of these parts I am disposed to believe there is always sufficient space to free a stricture without endangering either the spermatic or the irregular obturator artery. It must be recollected that if the intestine is sufficiently liberated to permit the passage of gas through the immediate seat of the stricture, its return is perfectly practicable, and a very small incision will be sufficient to accomplish this. Now these vessels lie, not on the neck of the sac, but above it; and there is quite space enough to set the stricture free without interfering with them: when they are wounded, it is in consequence of the introduction of the cutting edge of the bistoury too far within the stricture.

When a portion of intestine has escaped through the femoral ring, (and by reason of the small size of the aperture herniæ here are seldom large,) it lies at first within the crural canal, where it is restricted by the fascia lata, and its existence recognized with difficulty. It has happened that patients have perished from the incarceration of a small fold or knuckle of intestine without the circumstance ever having been discovered during life. But after it has passed the crescentic edge of Hey's ligament, and is relieved from the pressure of the fascia, it comes forward, and if it increases farther, its direction is rather inwards and upwards, so that it may assume the position of an inguinal hernia to the extent of being mistaken for it. Having proceeded so far, the hernial sac has assumed somewhat of the form of an arch: it has passed, first downwards through the femoral canal, then forwards under the sharp edge of the fascia lata, either passing through the weak cellular portion of it or pushing it before, and then upwards and inwards in front. The hollow of this arch looks upwards, and is occupied by the crescentic edge of Hey's ligament. Perhaps this particular position of the hernia, as well as the extreme straitness and unyielding nature of the crural canal, has contributed to the frequency of strangulation to which this form of hernia is liable.

When a person stands erect and without exertion, Poupart's ligament forms nearly a direct line between the anterior superior spinous process of the ileum and the crest of the pubis, and all the fasciæ connected to it are in their natural state and sufficiently relaxed; but if the thigh is strongly extended or the body bent backward, the ligament then becomes tense and is arched backward toward the thigh. The effect of the general tension of the limb in this position would be to convert the arch formed by the hernia into an angle, against the hollow of which the edge of Hey's ligament would be firmly compressed, and a sufficient degree of resistance thus created to the return of the venous blood to produce a congested condition of the viscus. The operation of such a cause as this can hardly be considered as permanent, but the mischief once commenced is not easily controlled, and an intestine might soon be placed in such a condition as to render incarceration at the ring inevitable.

The situations at which crural hernia may be strangulated have not been satisfactorily described, although there is no subject on which more anatomical labour has been bestowed. If

I was to speak from my own experience alone, I should say that though the hernia itself is superficial, the seat of the strangulation is always deep—somewhere at or in the immediate neighbourhood of the neck of the sac. I found the opinion partly on the dissection of subjects that had died of the disease, but more particularly on the phenomena I have observed during the progress of an operation on the living: still the experience of one individual can scarcely ever be sufficient to establish a great pathological principle, and there is authority that cannot be questioned for believing that crural hernia is frequently strictured at a far less depth from the surface. Besides the neck of the sac, by which this hernia is confessedly strictured in very many cases, Sir A. Cooper places the seat of strangulation, first in the crural sheath and semilunar or lunated edge of the fascia lata, and secondly in the posterior edge of the fascia lata.* Mr. Colles says that the neck or constricted part of crural hernia does not always appear at the same depth from the surface, and explains the circumstance thus: "The hernia having descended into the femoral sheath, it escapes through one of those apertures in it for transmitting the lymphatic vessels, and also passes through a corresponding opening in the iliac portion of the fascia lata. As it passes through a small aperture in each of these parts at nearly the same spot, it must there be liable to great constriction; for these two layers of fascia will be compressed together, and thus their strength and resistance be considerably augmented. Hence we should find the seat of stricture in strangulated femoral hernia frequently to be at some distance below and to the pubic side of the crural ring."† The descriptions of Hey and Burns I cannot profess clearly to understand, and I fear they were taken rather from sound subjects than from those in which herniæ were actually present. Scarpa does not distinctly point out the anatomy of the seat of stricture, but from the general bearing of his descriptions, and above all from the anxiety he expresses relative to the danger of wounding the spermatic artery in operation, which vessel, if present, must lie close to the neck of the sac, I would hazard an opinion that he believed the seat of strangulation to be always deeply seated.

In dissecting this rupture from without, or in operating upon it in the living, it will be found to lie at a different depth from the surface, and to possess variety in the number of fascial coverings according to its position with reference to the parts already described. Thus it may be placed within the crural canal, within that triangular space formed by the fascia lata; or having passed beyond its inferior opening or falciform edge, it may present more superficially. In the former case, after the division of the common integuments, the skin and fat, the superficial fascia is exposed and may consist of many layers—at all events of two: next is the dense and resisting fascia lata of the thigh; and deeper still, the funnel-shaped fascia in which the crural ring is situated. Between this latter and the sac another fascia has been described under the name of the fascia propria, which may be supposed to be formed by a condensation of that cellular tissue already described as occupying the crural ring; but I have never been able to satisfy myself as to the existence of this as a distinct membrane, and I must again caution the young operator not to expect to meet with laminæ of fascia as described or demonstrated by the anatomist. A dexterous and careful dissector may make almost as many layers of fascia as he pleases.

After it has passed the inferior border of the crural canal and appeared more externally, the coverings of fascia to be expected must depend on the view taken of the anatomy of this part. If it is believed that the hernia having cleared this point merely swells out on being relieved from the pressure, without passing or pushing through any of the superincumbent structures, then in order to come down upon the sac it would be necessary to divide the skin and cellular tissue, the different laminæ of the fascia superficialis, the cribriform portion of the fascia lata, the anterior portion of the funnel-shaped fascia, and the fascia propria. If, on the other hand, it is supposed that the hernia has escaped through one of the openings in the femoral sheath, and a corresponding one in the iliac portion of the fascia lata, it will lie more superficial by the absence of these investments. In either case the last layer of fascia most adjacent to the sac is almost always remarkable for density and strength.

The general symptoms of this affection are the same with those of inguinal, such as the appearance of the tumour, its diminution or disappearance in the recumbent position, and the impulse imparted to it by coughing, sneezing, &c.: its peculiar symptoms are explicable by its anatomical relations. 1. The crural hernia is generally small and its increase slow: the size of the ring and the compression exercised on it by so many superincumbent layers of fascia will be sufficient to account for this, and also will shew why this rupture is almost always painful, and why position has so much effect on it, relief being constantly obtained by bending the thigh on the pelvis and rotating the limb inwards. 2. The peculiar manner of growth, its first passing downwards, then forwards, and then upwards and inwards, is caused by the attachment of the funnel-like fascia to the vessels at the superior part of the thigh, and by that of the fascia superficialis to the fascia lata near the entrance of the saphena vein; thus its shape is never pyramidal like that of inguinal; it is globular or oval, and its longest diameter is transverse. 3. I have already mentioned its prevalence amongst females advanced in life.

As the testicle is more subject to disease than any structure at the top of the thigh, there are more affections with which scrotal hernia may be confounded; but on the other hand, when a doubt arises on the subject of crural

* Cooper on Hernia, part ii p. 14.

† Colles' Surgical Anatomy, p. 77.

hernia, the diagnosis is vastly more difficult, and often the surgeon has to be guided by the general symptoms of peritoneal inflammation rather than by the results of local examination, however carefully performed. Mr. Colles* states that "this species of hernia is liable to strangulation even before it can be felt externally,"—an observation I was enabled to verify a few months since in a case where a very small knuckle of intestine had not passed the inferior aperture of the femoral canal, but was lodged in an absorbent gland, which seemed to have been hollowed out to receive it.† But the hernia may be much larger and still not discoverable in consequence of some unfortunate complication: I have seen a case of incarcerated hernia‡ in which an abscess was seated at the superior part of the thigh immediately in front of the sac; and after the pus had been evacuated, some time elapsed before decisive symptoms pointed out the existence of the more formidable disease behind. There is, in the Museum in Park-street, a preparation exhibiting a fatty tumour growing on the external surface of a hernial sac. The patient from whom it was taken was the subject of operation, and after the integuments and fascia had been divided and this tumour presented, some doubts were at first entertained as to the presence of a hernia beneath it; but on careful examination the operator discovered the hernial tumour, and cutting cautiously through the other, opened the sac, in which a knuckle of intestine was found incarcerated. The operation was successful, and the patient recovered. "In many instances," says Mr. Colles, "the difficulty of discriminating the disease is considerably increased by an enlarged lymphatic gland lying anterior to a very small hernia."

Perhaps there are no two affections more liable to be mistaken for each other than crural hernia and an enlarged lymphatic gland; and however apparently distinct the two affections may be, and however easy it may seem to form a diagnosis in theory, still the best surgeons speak of the difficulty of discriminating between them, and many acknowledge having fallen into the error themselves. It has happened that a patient has had a hernia on one side and an enlarged gland on the other, and when symptoms of strangulation became urgent, it was the gland that was considered to be the most pressing, and it was selected for the operation. I recollect two cases which occurred nearly at the same time; one in which there was a very minute hernia at the left groin, which had been regarded as a swelled gland, and the patient died of the effects of its strangulation; the other a case of pure peritoneal inflammation, in which the patient happened to have a swollen gland in the groin, which was actually cut down upon and exposed, but the operation did not much injury, for the patient subsequently recovered. It has been said that a diagnosis can be established by attention to the following circumstances. The hernia follows on some sudden exertion, on a blow or a fall, and appears suddenly and at once; whereas the gland in the commencement is very small, perhaps like a moveable kernel, and increases slowly and by degrees. Besides, this diagnostic will be greatly assisted if there is a chancre or other sore to account for the irritation and inflammation of the gland; but on the other hand the hernia does not always assume its given size at once, it is often so small at the beginning that the patient is not aware of its existence, and so far from appearing suddenly after a violent exertion it may have been present for months without being perceived. The hernia receives an impulse from coughing or sneezing, and retires or becomes smaller in the recumbent posture, which are not observed to happen with the gland; but then an enlarged gland may be complicated with a hernia, and the symptoms so mixed and confused that a diagnosis may be very difficult. It is said that a gland may be moved about and withdrawn from its situation in a slight degree, and if it can there is no great danger of mistaking it; but when it has arrived at the size or occupies the place which could make it resemble a hernia, then it does not admit of being moved under the fascia, and the diagnosis is almost impossible. Fortunately, a crural hernia does not often consist of omentum, but when it does there is nothing more likely to exhibit the characters of a gland in a state of chronic disease, and I know not how the two cases can be accurately distinguished. Here the physical evidence derived from a gentle percussion (as already noticed) is utterly and completely valueless.

Lumbar or psoas abscess is another affection that may be confounded with femoral hernia, and Mr. Colles states that he had known the mistake to have been committed. These diseases resemble each other in the following circumstances. Both present very nearly in the same situation at the bend of the groin, are firm and elastic; coughing gives to each the same or a similar impulse; and there are cases on record in which psoas abscess disappeared under pressure or by the patient assuming the recumbent posture. Yet I think the two cases not very difficult of distinction. Psoas abscess is a disease of youth; it does not often occur in the adult except as a critical abscess after fever, or in connexion with caries and curvature of the spine, in either of which cases the collateral circumstances will point it out; whereas femoral hernia is the disease of married women, and of course will not be likely to occur at the same period of life with the abscess. A sense of fluctuation is generally perceptible in psoas abscess; not so with hernia. The abscess is preceded by pain and weight in the loins and by shivering. It is a scrofulous complaint, and there will probably be other indications of the diathesis, such as the transparent skin, the thickened upper lip, or perhaps ill-conditioned scars about the neck. Any of these symptoms

* Op. citat. p. 83.

† This curious case occurred in the Meath Hospital in the summer of 1835.

‡ I use this term in the sense hitherto employed, not implying perfect strangulation.

taken singly may prove but an indifferent diagnostic, but in the aggregate they establish such distinction that it must be the result of sad inattention or of actual ignorance if any serious mistake is committed.

It has been stated that a varix of the saphena vein may present symptoms and appearances strongly resembling crural hernia, inasmuch as the tumour disappears under pressure or in the horizontal posture, and returns again immediately on these influences being removed, and also as it receives a certain degree of impulse from coughing or sneezing. From anatomical considerations it would almost seem impossible that such an error could be committed, and at first sight the observation seems to have been made for the purpose of creating nice distinctions and rendering the subject apparently complete rather than for any practical utility. A case, however, is related by Petit, who distinguished the real nature of the tumour by its dark-coloured appearance and by the general varicose state of the remainder of the vein. If difficulty is experienced in any particular case, it may be easily resolved by making pressure on the trunk of the iliac vein above Poupart's ligament, when the tumour will re-appear, even although the patient maintains the horizontal posture.

"Fatty tumours are not unfrequently found on dissection occupying the exact situation of crural hernia. I have not had an opportunity of seeing any case of this kind in the living body, but have had occasion to remark at least five or six instances of it every season in the dissecting room, from which I presume such tumours are more common than is generally suspected. In all those instances the fatty tumour was connected with or rather seemed to grow from the outer surface of the peritoneum lining the crural ring; and the inner surface of this membrane when viewed from the abdomen had a contracted, wrinkled, and thickened appearance, resembling very closely the appearance of a reduced hernial sac. Whether the peritoneum had been protruded in these instances I cannot pretend to say; nor can I venture to lay down the symptoms which should guide us in our diagnosis in the living body. This much at least is obvious, that these steatomatous tumours will not be accompanied by symptoms of strangulation."*

Umbilical hernia.—The navel is the remnant of an aperture that had been situated nearly in the centre of the front of the belly, but nearer to the pubis than to the ensiform cartilage: it is placed in the linea alba, and of course its edges are tendinous. During fœtal life it serves for the transmission of the umbilical vein and arteries, but its size is greater than would merely suffice for the passage of these vessels, in order that the circulation of the blood through them should suffer no interruption by accidental compression; and in a fœtus of seven months the edge of the aponeurotic opening is still thin, weak, and unresisting. After birth, when the navel string (as it is called) has dropped off, the umbilical aperture begins to close, until finally that puckered cicatrix is formed, the appearance of which is so familiar; but the periods at which this process commences and is completed, and the circumstances that may occur to interfere with it, are of some importance with reference to the phenomena of hernia. Scarpa says that it begins immediately, and that if the finger is passed up the peritoneal wall of the abdomen in a child two months after birth, not only will the navel be found firmly formed and completely cicatrised, but there will be a knot or elevation felt at this spot, shewing that it is then really stronger than most other parts of the abdominal parietes. Lawrence states that the contraction commences about the third or fourth month after birth, and thence inculcates the necessity of an infant being tolerably accurately bandaged anterior to that period in order to prevent the occurrence of umbilical rupture from its struggles or its cries. It is not of much consequence which of these opinions may be correct: probably both are so to a certain extent, for the opening is larger in some infants than in others, and will require a longer time to close, and the process of obliteration does not commence in all exactly at the same period after birth. Whatever variety may exist in this respect, when the process is complete the umbilicus can never afterwards be called an aperture; it never again re-opens; and when ruptures are observed in after-life seeming to occupy this situation, it will be found on examination that some neighbouring parts of the linea alba have given way, and the disease more strictly belongs to the ventral than to umbilical hernia.

It appears then that by the salutary provisions of nature the front of the abdominal parietes is well supported, and the contained viscera protected from protrusion; and even if the operations by which the umbilicus is closed should be accidentally suspended or interfered with, (as by the presence of a hernia for instance,) the disposition is not lost, and the aperture preserves its tendency to close and become obliterated for the first five or six years of childhood. Thus at any time within that period there may be a reasonable probability of obtaining a permanent cure of umbilical hernia; whereas after the age of ten or twelve years this disposition ceases to operate, or at least is greatly impaired, and there is little or no chance of so fortunate an occurrence.

The condition in which the umbilicus exists at and after birth divides the herniæ that occur in this situation into different orders according as they may appear at the period of birth or afterwards. Scarpa considers the disease to consist of only two species, the congenital and the adventitious—the congenital being that which appears in the infant when born, and the other occurring at any subsequent period. Lawrence speaks of three kinds, the congenital, that which appears at birth, and in which the protruded viscera are lodged in the umbilical cord; the umbilical hernia of children occurring after the navel has been formed, but pro-

* This passage is copied from Colles's Surg. Anatomy, p. 84.

truding through the original deficiency in the linea alba; and the hernia of adults, which has some peculiarities that shall be noticed hereafter.

The congenital umbilical hernia seems to depend rather on a deficiency of the anterior walls of the abdomen than on any other cause, and in the cases in which it is observed, the aperture at the navel is much larger than it should naturally be, and its tendinous edges excessively thin and weak. The deficiency of the abdominal parietes ranks amongst natural malformations, and it is astonishing to what an extent it has been observed. The entire of the tendinous front of the belly has been found imperfect, and nearly the whole of the viscera displaced, thus forming an immense rupture covered at its base and for some extent farther by the skin and superficial investments of the body, and in its remaining part by the transparent spongy substance of the umbilical cord. The contents of these ruptures are greatly varied: the liver or a portion of it, the spleen, the stomach, the greater and the lesser intestines have all been occasionally found thus circumstanced, but more particularly the omentum, which, as might be anticipated from its situation, is observed to constitute a part of almost every umbilical hernia both in the old subject and in the young. Whenever there is such a deficiency in the abdominal parietes, the pressure an infant undergoes in coming into the world materially contributes to the production of hernia, and accordingly it is observed most frequently after a protracted and difficult labour; and if it is large, and the contents of the abdomen extensively deranged or displaced, it is in general fatal, the infant seldom surviving beyond two or three days, and perhaps not so long. In this affection there seems to be a want of correspondence between the size of the viscera and that of the abdominal cavity, the former appearing enlarged and swollen; and there is seldom a possibility of returning the rupture, or of maintaining it so if reduced. There is in general also in these cases some other malformation or incomplete development to account for the fatality that so uniformly attends them. But if, on the other hand, the hernia is small, the case is by no means necessarily attended with danger: the rupture may be reduced, but it has a tendency to return whenever the child cries or makes any other exertion, and it is extremely difficult to restrain it by a bandage; but if it can be kept up for a few months, the umbilical aperture closes as it would have done if there had been no protrusion, and the cure is permanent and complete.

If, before the navel has become cicatrized and closed, a portion of any viscus should happen to be protruded through it, and its progress towards obliteration thus interrupted; or if the contraction has been delayed longer than usual, and an aperture thus left ready to favour the escape of a part of intestine from its natural situation, the rupture will be of the second form mentioned, namely, the umbilical hernia of the child. This differs from that of the infant inasmuch as it is covered by the skin and the cicatrized knot of the navel, and does not lie within the cord; and from that of the adult, so far as, if replaced and prevented from again protruding, the aperture will gradually contract, and thus a permanent cure be obtained, which is scarcely to be expected at a more advanced period of life. It has been already mentioned that Scarpa considered the perfect contraction of the umbilicus to be completed in about two months, and at the end of that time that it is even firmer than other parts: he moreover seemed to think this part materially strengthened by the remains of those vessels which before birth made up a part of the cord. The umbilical vein passing from the navel upwards towards the liver, and the hypogastric arteries passing downwards, are at the umbilicus united by a cicatrix to the skin and to each other, and contribute to prevent the yielding of the part as soon as they become ligamentous. The point of union of these vessels must be pushed forwards as well as the integuments in adventitious hernia, and hence it happens that when the umbilical aperture is only of its natural size, the rupture that takes place (if any) is small; and in cases where it is large and the abdominal parietes deficient in this point, the tumour is flatter and more compressed than might have been otherwise expected, and some of these vessels are found lying on it and forming a part of its covering.

In persons more advanced in life in whom the opening in the tendon had been perfectly closed, Scarpa denies that it ever becomes relaxed again, and therefore states that the ruptures which occur from over-distension, from pregnancy, or as the sequelæ of dropsy, are not situated in the original umbilical canal, but in some part of the linea alba that has more recently given way, and of which the umbilicus happens to form a part. He states further that the linea alba is not equally strong and firm in all its parts; that above the navel it becomes gradually thinner, and in women who have borne many children it is uneven in consistence, and in some parts so weak as to be liable to yield and tear on a very slight exertion. Hence it happens that these ventro-umbilical ruptures generally occur rather above the navel; and the almost obliterated remains of this cicatrix (for by the distension it becomes nearly smooth) is scarcely ever observed to occupy the centre of the tumour, but is found to one side and almost placed inferiorly. In the dissection of these tumours a laceration or fissure is constantly met with in the linea alba, sometimes transverse, but more generally longitudinal, and this is one reason why the umbilical ruptures of old persons are not susceptible of a radical cure, for there is a great difference between a natural opening, the tendency of which is to contract and close, and one made by the yielding and laceration of part of the linea alba or other tendinous portion of the abdominal parietes, which certainly cannot be supposed to be endowed with strong reparative properties.

There was a question formerly raised as to whether umbilical hernia possessed a peritoneal sac, and it was generally believed that no such investment had any existence in the disease. Garengeot in his paper on singular species of herniæ expressly states that ruptures of this kind were deficient in this particular, and he was followed by Petit and almost all the elders of our profession, who, to spare themselves the labour of investigation, copied from each other errors as well as truth. It is really curious to observe how a mistake could have so long maintained its ground that could have been set at rest by half-an-hour's dissection; and indeed it is in some respects surprising how such an opinion came to be entertained at all. In every case of umbilical hernia there must of necessity be a sac, because the peritoneum is not deficient at the navel, and the vessels that pass within the cord do not enter the cavity: they lie anterior to it, and are partly invested by the membrane, which is entire and complete behind the navel, and neither intestine nor omentum can be protruded without pushing it out before it, and thus constituting a proper hernial sac. It may be that in large umbilical herniæ the peritoneum shall have become very thin, so that the peristaltic motions of the intestines may be easily perceived through it from without; or it may have been burst accidentally, and in either of these cases there will be an appearance as if there had been in reality no sac. And moreover, the peritoneum immediately behind the navel is not connected to it by the same loose and distensible cellular tissue that unites it to other parts: it is here very closely joined, and consequently in small ruptures only occupying this spot there will be no appearance of a separate and distinct sac, although the peritoneal covering is really there notwithstanding. It must be borne in mind, however, that investments of umbilical ruptures are always very thin, and a proportionate degree of caution is requisite in cutting through them during operation. There are no distinct layers of fascia here as in other ruptures, no laminæ to separate one by one and one after another. In the congenital species the contents of the sac are merely covered by the peritoneum and the sheath of the cord. In the infantile, the coverings are the skin and cicatrix of the navel and the peritoneum; and in the adventitious kind or ventro-umbilical we meet the skin, then the superficial fascia, which is very thin and weak on this part of the abdomen; next the cellular tissue that had united the peritoneum to the adjacent structures, and which may have become condensed so as to form a kind of fascia propria; and lastly, the peritoneum or hernial sac itself.

In almost every case of umbilical hernia occurring in the adult, omentum has formed part of the contents of the sac, at least the observation has been so universally made that the rule may be considered as established. In general it lies before the intestine in such a position as to conceal it altogether and make it appear as if no other viscus was engaged; but sometimes the intestine makes a passage through it and presents first when the sac is opened; or both these structures may be coiled and twisted together in such wise as to render it difficult to unravel and separate them one from another, and highly perilous to return them in that condition into the cavity lest strangulation should take place within. From the circumstance also of containing omentum, umbilical ruptures frequently become irreducible, this structure, when protruded, becoming thickened and enlarged and occasionally loaded with fat, so as to preclude the possibility of its being again returned through the tendinous opening. Or adhesions may have formed between the omentum and the intestine, or between either or both of these and the sac: in short, the rupture may become irreducible from any of the causes already mentioned as capable of producing such a condition of parts, but the one first alluded to, namely, the thickening and alteration of the omentum, is the one most generally observed.

This altered condition of the omentum has also a paramount influence on the case even at a more remote period. Let it be supposed that symptoms of strangulation have supervened, and an operation been deemed necessary to preserve existence, the presence of this mass will be likely to prove extremely troublesome. Every surgeon is conversant with the different opinions that have been entertained as to the manner in which irreducible omentum should be dealt with. Some* speak boldly enough of cutting it off and returning any part that might remain, or allowing it to slip back into the abdomen without feeling any apprehension from the possibility of hæmorrhage. Some have tied a ligature around it to cause it to slough, and Mr. Hey† employed a ligature in another way and with a different view, namely, by applying it so tight as gradually to cut through the omentum by the process of absorption, but without entirely destroying the circulation through the included part. Scarpa‡ left the omentum, merely covering it with the sides of the hernial sac and dressing it lightly until suppuration appeared, when, he said, the pedicle by which it hung might be safely tied and the mass cut away. I notice this diversity of opinion not for the purpose of inculcating any one line of practice, but to shew that the omentum cannot be left there with safety. It is at all times and under every circumstance not very highly organized or able to sustain disease; still less so is it when altered from its natural arrangement, converted into an unwieldy mass of fat, and exposed to the influence of the atmosphere in an open wound. Sometimes it runs into tedious and unhealthy suppurations with profuse and wasting discharges; more generally, if the patient is old and debilitated, into mortification, which may (if the subject lives sufficiently long) pass on to the unaltered omentum within the abdomen, nor cease until it has reached the stomach.

* Pott, op. citat. p. 16. Petit and Ponteau, Mém. de l'Acad. Royale de Chir. tom. vii. p. 338. Colles's Surgical Anatomy, p. 100.

† In this he was anticipated by Moreau, Mém. de l'Acad. Roy. de Chir. t. vii. p. 344.

‡ Op. citat. p. 420.

The symptoms of umbilical hernia are easily understood by referring to those points in which it differs from ruptures situated elsewhere. In the infant the tumour appears long and thin, according to the quantity of viscera protruded through the aperture of the navel, and projects downwards on the belly: its coverings are almost transparent. In the more adult subject, if the patient is thin the tumour is of a pyriform figure, and when permitted to increase without restraint becomes very large and hangs pendulous towards the pubes. If he is fat it may form a less circumscribed swelling, broad and flat, apparently extending in every direction round the umbilical aperture. The sensation imparted to the finger is of a soft and doughy tumour slightly moveable under the skin, but sometimes in consequence of the presence of intestine in the rupture it may possess some elasticity. Occasionally, after an omental hernia has remained for years without producing much inconvenience, it suddenly enlarges towards the centre and assumes a conical chape, the apex being soft and elastic, the base hard and more solid: in this case there has probably been a fresh protrusion of intestine which has burst through the omentum and requires instant attention, as so circumstanced it is extremely liable to fall into a state of strangulation. The collateral symptoms, such as nausea, flatulence, colicky pains, &c., are more severe and more frequent in umbilical than in any other form of hernia, a circumstance that has often given rise to the idea that the stomach formed some part of the protrusion, but perhaps it is unnecessary to resort to such a supposition, for probably the herniæ of the linea alba that have been described as containing part of the displaced stomach were in no wise different from ordinary umbilical ruptures as to their contents, for the omentum being protruded will be sufficient to account for every aggravation of symptom.

When the hernia is strangulated, it is said that the symptoms are less severe and less urgent than in other species of ruptures, a circumstance that has also been accounted for from its so often containing omentum alone. Sir A. Cooper states that more cases of strangulation occur in the seasons when green vegetables are plenty than in others, which would seem to favour the idea of its being often caused by the use of flatulent or indigestible substances. But (except with reference to prevention) it is of little consequence how it may be caused, or whether its progress is rapid or not. When once formed, it must be reduced; and it runs its course with sufficient rapidity to render it extremely alarming. It has destroyed a patient in less than eighteen hours, and although such severity is not generally to be expected, yet in this or in any other kind of hernia the smallest unnecessary delay can never be justified.

"Sometimes a small mass of indurated fat, situated between the peritoneum and its union with the aponeurosis of the abdominal muscles, makes its way insensibly through the separated fibres of the linea alba, and is at last elevated externally in form of a tumour which seems to have all the characters of an omental hernia. The existence of this species of tumour through the linea alba is not only a certain fact and demonstrated by several observations made on the dead body by Morgagni, by Klinkosch and several others, but it is also proved that it makes its appearance in other parts of the linea alba besides that to which the umbilical vein corresponds internally. It may occur that a person in whom a similar small tumour has existed for a long time in the course of the linea alba may be attacked from a quite different cause by violent colic, with nausea, inclination to vomit, and interruption to the alvine excretions. The surgeon, in similar circumstances, is easily led into error," (and Scarpa committed the mistake himself,) "presuming that the tumour is a true incarcerated hernia of the linea alba, subjecting the patient to an operation which has no connexion with the cause of the disease." Never having seen any similar tumour, I have copied the above passage from Scarpa: they are probably of the same nature with those described by Mr. Colles as occasionally presenting at the crural ring. The resemblance must be strikingly obvious to every reader.

(William Henry Porter.)

HIBERNATION; etym. *hiberno*, to winter, to pass the winter; syn. *lethargy*; erroneously, *torpor*; Fr. *sommeil hivernal*; Germ. *Winterschlaf* and *Sommerschlaf*; a term chiefly applied to express that condition in which certain animals pass the winter season.

How often have I been struck with admiration in observing how variously the Creator has provided for certain of the *insectivorous* tribes, the swallow and the bat, for example, against the period when the sources of their daily food are cut off, when spring and summer yield to autumn and winter, and *insects* disappear! The first emigrates to a more genial climate where its nutriment still abounds; the second sinks into a deep sleep, in which food is unnecessary, and which continues through the dreary season of cold and famine.

It has not hitherto been distinctly ascertained to what extent the state of hibernation prevails in the animal kingdom; the bat, the hedgehog, and the dormouse, are the genera which present us with the most marked examples of this singular physiological condition in this country; to these the elegant authoress of "Sketches of Natural History" has added the water-rat and the wood-mouse, observing of the former—

"And when cold winter comes and the water-plants die,
And his little brooks yield him no longer supply,
Down into his burrow he cozily creeps,
And quietly through the long winter-time sleeps."

But before we proceed to discuss this question of natural history, we must consider that of the physiology of hibernation.

There is, in my opinion, an ultimate *law* of animal existence, which seems to regulate the different forms in which the different classes of animals present themselves. The quantity of respiration is inversely as the degree of irritability of the muscular fibre, the former being marked by the quantity of oxygen consumed in a given time, ascertained by the pneumatometer,* the latter by the force of galvanism necessary to demonstrate its existence. The bird tribes have a high respiration and a low irritability; the reptiles have a high degree of irritability and little respiration. This law obtains not only in the different tribes of animals, but also in the different stages or states of the same individual, the *structural* changes from one stage to another being always a change from a lower to a higher respiration, and from a higher to a lower degree of irritability, and the change of state, a change in the opposite direction: thus the changes from the egg to the bird, from the tadpole to the batrachian form, from the larva to the chrysalis and the insect condition, are changes in which, whilst a due ratio is constantly maintained, the quantity of respiration is augmented and the degree of irritability diminished; on the other hand, the *physiological* changes in the degree of activity in animals, during sleep, for example, but especially in that remarkable change which is the subject of this article, the respiration is diminished whilst the degree of irritability is, *pari passu*, augmented.

On what this susceptibility of change depends, and especially on what the power of taking on an augmented irritability depends, is at present unknown. But I think I may affirm that it is upon this power that the capability of passing into the state of hibernation reposes. I suppose that all animals have the faculty of sleeping; during sleep the respiration is slightly diminished, the irritability probably proportionately augmented—probably one ultimate object of this state of repose; but the phenomenon has its appointed limit which it cannot pass. In certain animals, that limit is not so confined,—the quantity of respiration is still further diminished, the degree of irritability still further augmented, and the deeper sleep, or lethargy, of hibernation takes place.

During this lethargy, the law of the inverse ratio of the respiration and of the irritability still prevails, and the animal merely puts on a reptile state in these respects. Were the respiration to be diminished without the appointed augmentation of the irritability, the heart would cease to be stimulated, and the animal would die, as in the cases of torpor and slow asphyxia; were the respiration augmented without the proportionate diminution of the irritability, the heart would be over-stimulated, and death would alike ensue, as in the case of a hibernating animal too suddenly roused from its lethargy, and as (probably) in the case of an animal placed in pure oxygen gas.

The difference between the hibernating and all other animals then is, an ultimate faculty of assuming an augmented degree of irritability of the muscular fibre—a power possessed by all animals within certain limits, but by the hibernating animal beyond the usual limit.

* See Phil. Trans. for 1832, p. 323.

Sleep, however inscrutable in itself, is the connecting link between the two physiological states; a disquisition on hibernation is, therefore, a disquisition on sleep—on profound sleep. It will shortly appear that one eminent philosopher has fallen into the error of assimilating different physiological phenomena by neglecting to take this fact into his consideration. Sleep and hibernation are similar *periodical* phenomena, induced by similar causes, leading to similar effects, and differing only in *degree*. Hibernation appears more extraordinary only because less familiar than sleep. Most animals are, in fact, naturally awake and asleep every revolving day, some being diurnal, others nocturnal. But in summer the bat actually hibernates, loses its respiration, and with its respiration its temperature, acquires vastly augmented irritability, and presents the other phenomena of *complete* hibernation, regularly and periodically every twenty-four hours; and the hedgehog and the dormouse present similar phenomena, only after other intervals.

Sleep then is the first stage of hibernation. The faculty of passing into the second is identical with that of assuming a greatly augmented irritability of the muscular fibre. Such are the results of my long attention to this interesting physiological question. Much error has arisen from viewing hibernation as a simple effect of cold. The influence of cold in inducing hibernation is merely its well-known influence in inducing sleep, concurring with the other causes of this condition. The direct effect of cold on the animal frame is, as I shall shortly have occasion to state particularly, totally different from hibernation. Hibernation is a physiological condition; the direct effect of cold, or *torpor*, is, on the contrary, a pathological and generally a fatal one.

The term hibernation has usually been applied to designate what its etymology implies, the condition in which certain animals pass the *winter* season. An error is, as I have already stated, involved in this view of the subject; for the condition termed hibernation is not confined to the winter season. Cuvier observes, in speaking of the Tenrecs, "ce sont des animaux nocturnes qui passent trois mois de l'année en lethargie, quoique habitants de la zône torride. Burguière assure même que c'est pendant les grandes chaleurs qu'ils dorment."* Hence the term *Sommerschlaf* employed in Germany. It is plain too, from this circumstance, that the state of hibernation is not necessarily connected with a low degree of external temperature, and we are surprised to find this celebrated naturalist, whom I have just quoted, observing, "la seule condition de la lethargie est le froid et l'absence des causes irritantes."†

I must repeat that hibernation is, in every respect, but the parallel of ordinary sleep, varying only in force and duration. It is equally marked by an inexplicable periodicity; it is equally modified by cooperating or opposing

* Règne Animal, ed. 1829, t. i. p. 125.

† Histoire des Sciences Naturelles, 1829, t. i. p. 280.

causes; and it is equally manifested in its peculiar effects, only varying in degree and intensity.

In giving a distinct idea of hibernation we must extend our views to the altered condition of each function in the animal economy, for this peculiar state is not limited to any special function or organ. It is, in fact, a treatise on physiology which should be written, comparing the state of each function and of each organ, in the hibernant or lethargic and in the active condition, a disquisition on *sleep*, indeed, in its various degrees, and in its effects in modifying the various functions.

The first question then is,—*what is sleep?* a question difficult, perhaps impossible, to answer, if we mean by it what is its *nature* or *essence*, but highly interesting to prosecute, if we mean what are its special phenomena and their mutual relations.

In order to treat of sleep properly, I must first observe that, of the nervous system, of which it is primarily a modification, formerly divided into *the cerebro-spinal* and *the ganglionic*, the first division must now be subdivided into *the cerebral* and *the true spinal*, the former being the exclusive seat of sensation, volition, &c.; the latter, the special source of certain actions now designated *excito-motory*, and observed in the orifices, the ingestors, the expulsors, the sphincters, &c. Now it is the *cerebral* system which sleeps, the *true spinal* retaining all its energies.

From this enunciation of the primary fact in sleep, we may trace the whole of the phenomena of this singular condition. In the state of activity, the cerebral system exerts a peculiar and continual influence over the true spinal, which ceases during sleep. In this manner the functions of the latter appear impaired; the respiration especially, and with the respiration the circulation, with which it always maintains a certain relation, becomes slower, irregular, and suspended at intervals. These phenomena observable in ordinary sleep are still more remarkable in the deep sleep or lethargy of hibernation or diurnation.

In order that the effects of hibernation may be traced in relation to all the functions of the animal economy, I must enter into a few brief details relative to the *arrangement* of these functions and the *order* in which I propose to notice them. The most simple and natural arrangement of the functions appears to me to be the following:—

I. Sanguification.

1. The ingestion and } of food.
2. The digestion .... }
3. The formation.... { *a.* of chyme. / *b.* of chyle.
4. Absorption ...... { *a.* by the lacteals. / *b.* by imbibition.
5. The organization of the blood.

II. Respiration.

1. The absorption .. { *a.* of oxygen. / *b.* of nitrogen, &c.
2. The exhalation .. { *a.* of carbonic acid. / *b.* of nitrogen, &c.
3. The results { *a.* augmented temperature. / *b.* a direct ratio between the pulsations and respirations. / *c.* an inverse ratio between the respiration and irritability.

III. The Circulation.

1. The pulmonic.
2. The systemic.
3. The cardiac or coronary.
4. The hepatic.
5. The splenic.
6. The circulation as the carrier .... { *a.* of nutrition. / *b.* of temperature.

IV. Defœcation.

1. Re-absorption by the lymphatics.
2. Excretion........ { *a.* by the lungs. / *b.* by the skin. / *c.* by the liver. / *d.* by the kidneys. / *e.* by the intestines.

V. The Nervous System.

1. The cerebral, or the system of
   a. The sensations, the senses.
   b. Volition, *spontaneous* motion.
2. The true spinal or *excito-motory*, or the system of
   a. The orifices.
   b. Ingestion.
   c. Expulsion.
   d. The sphincters.
3. The ganglionic.

VI. The Muscular System.

1. The irritability.
2. The motility.

I proceed to trace the influence of sleep, and of the deeper sleep of hibernation upon these various functions, beginning with the former.

I. *Of sleep.*—It was first ascertained experimentally by Messrs. Allen and Pepys, that the quantity of respiration is diminished in ordinary sleep.* The acts of respiration are obviously less frequent and less regular, being frequently suspended for a moment and renewed by a deep inspiration. The animal frame becomes more susceptible of the influence of cold. It is most probable that, during this condition, the irritability of the muscular system is augmented, and that this is one of the *final* objects of sleep; experiments, however, are still wanting to establish a fact in reference to ordinary sleep, which is clearly proved in regard to the sleep of hibernating animals, and the deeper sleep or lethargy of hibernation. I shall now proceed to treat of the sleep of hibernating animals.

II. *Of the sleep of hibernating animals.*—In the sleep of the hibernating animal, the respiration is more or less impaired: if the animal be placed in circumstances which best admit of observation, the acts of respiration will be found to have greatly diminished; if it be placed in the pneumatometer, little alteration is

* Phil. Trans. for 1809.

induced in the bulk of the air; if its temperature be taken by the thermometer, it will be found to be many degrees lower than that of the animal in its active state; if it be deprived of atmospheric air, it is not immediately incommoded or injured.

These facts I have observed in the hedgehog,* the dormouse,† and the bat.‡ If other authors have not made the same observations, it is because they have not been aware how easily this sleep is disturbed. To walk over the floor, to touch the table, is sufficient, in many instances, to rouse the animal, to re-produce respiration, and to frustrate the experiment.

The bat, which is a crepuscular or nocturnal feeder, regularly passes from its state of activity to one which may be designated *diurnation*. The respiration and the temperature fail; the necessity for respiration is greatly lessened.

During the summer of 1831, I carefully observed a bat in this condition. If it were quite quiet, its respiration became very imperfect; its temperature was but a few degrees above that of the atmosphere; being placed under water, it remained during eleven minutes uninjured, and on being removed became lively and continued well.

I have more recently watched the habits of two hedgehogs, in a temperature varying from 45° to 50°. These animals alternately awake, take food, and fall asleep. One of them is frequently awake, whilst the other is dormant, and goes to sleep at a time that the other awakes, but without regularity. When awake, the temperature of each, taken by pressing the bulb of a thermometer upon the stomach, is about 95°; when dormant, it is 45°; that of the atmosphere being 42° or 43°. The duration of this sleep is from two to three days, according to the temperature of the atmosphere. On the 4th of February, 1832, the temperature of the atmosphere being 50°, both the hedgehogs were dormant,—the temperature of one was 51°, and that of the other 52°; on the succeeding day, the temperature of the atmosphere had fallen one degree, the temperature of one of the hedgehogs was 49°, whilst that of the other, which had become lively, had risen to 87°; on the succeeding day, the first had become somewhat lively, and its temperature had risen to 60°, that of the other being 85°, and that of the atmosphere 47°.

I have observed precisely the same alternations in the dormouse; except that this animal awakes daily in moderate temperatures, takes its food, and re-passes into a state of sleep, in which the respiration is greatly impeded, and the temperature little higher than that of the atmosphere.

On the day on which the observations were made on the hedgehogs, the atmosphere being 49°, that of two dormice was 52°; on the succeeding day, the external temperature being 47°, that is, lower by two degrees, the temperature of one of these dormice was 92°, and that of the other 94°; and only three hours afterwards, the temperatures were 60° and 70° respectively, with a slight appearance of lethargy.

The hedgehog and the dormouse appear, in fact, to awake from the call of hunger, then to eat, and then again to become dormant, in temperatures which may be termed moderate. The bat, which could not find food if it did awake, does not undergo these periodical changes, except in the summer season. It appears to me, from the most careful observation, that there is every degree between the ordinary sleep of these animals and the most profound hibernation.

It is quite obvious, from these observations, that the ordinary sleep of hibernating animals differs from that of others, by inducing a more impaired state of the respiration and of the evolution of heat, with an augmented power of bearing the abstraction of the atmospheric air. This sleep probably passes into true hibernation, as the blood which circulates through the brain becomes more and more venous, from the diminution of the respiration, and as the muscular fibre of the heart acquires increased irritability.

It is absolutely necessary, in comparing the powers of hibernating and other animals, of evolving heat, accurately to observe whether there be any tendency to sleep. Mr. Hunter's and M. Edwards's experiments are deficient for want of this attention. Mr. Hunter, comparing the common mouse and the dormouse, exposed to a very low temperature, observes, that the temperature of the former was "diminished 16° at the diaphragm, and 18° in the pelvis; while in the dormouse it gained five degrees, but lost on a repetition."* The explanation of these facts is afforded by the observation, that when the dormouse increased in temperature it was "very lively," but that on the "repetition" it had become "less lively;" the mouse was probably in a state of languor from apprehension or for want of food.

M. Edwards omits to mention whether the hibernating animals, in his experiments, were disposed to be lively or dormant, or whether they had recently recovered from the dormant state. He does not even mention whether the experiments on the bat were performed in the evening, its period of activity, or in the morning or day, its period of lethargy or diurnation. Without a particular attention to these points, no correct result could be obtained. The hibernating animal, in a state of vigour and activity, is a totally different being from the same animal disposed to become dormant.

In order to perform this experiment in a satisfactory manner, the bat, for example, should be employed in the evening, when it has naturally awoke from its deep day-slumber, the hedgehog when it has awoke spontaneously to take food; otherwise the disposition to sleep may explain the loss of temperature. We must hesitate, therefore, in subscribing to the following conclusion of M. Edwards: "Nous voyons

* Erinaceus Europæus.
† Myoxus avellanarius.
‡ Vespertilio noctula.

* Animal Œconomy, p. 114.

que les chauves-souris produisent habituellement moins de chaleur que les animaux à sang chaud, et que c'est principalement à cette cause qu'il faut attribuer l'abaissement de leur température pendant la saison froide. En comparant cette expérience sur la chauve-souris adulte avec celles que nous avons faites sur les jeunes animaux à sang chaud, on y aperçoit un rapport remarquable; ils ne produisent pas assez de chaleur pour soutenir une température élevée, lorsque l'air est à un degré voisin de zéro. Mais il y a cette différence, que c'est un état passager chez les jeunes animaux à sang chaud, et qu'il est permanent chez les chauves-souris.

"Il est évident que les autres mammifères hibernans doivent participer plus ou moins de cette manière d'être. Les faits que j'ai exposés suffisent pour nous faire considérer ce groupe d'animaux sous le point de vue suivant; qu'au printemps et en été, dans leur état d'activité et de veille, lorsque leur température est assez élevée pour ne pas différer essentiellement de celle qui caractérise les animaux à sang chaud, ils n'ont pas la faculté de produire autant de chaleur; et tout en admettant que d'autres causes peuvent influer sur leur refroidissement pendant leur hibernation, il faut cependant l'attribuer en grande partie à cette particularité de leur constitution." *

There are, in fact, these differences between the *young* and the *hibernating* animal: 1. the former cannot, when exposed alone to severe cold, maintain its own temperature; if the latter appears to be in the same case, it is only because it has become affected with its peculiar lethargy; in its state of wakefulness and activity it maintains its usual elevated temperature in the same manner as other adult animals; 2. the young animal, in losing its temperature, becomes affected, not, like the hibernating animal, with *lethargy*, but with *torpor*, a totally different and a pathological condition which generally proves fatal. I must conclude these remarks by observing that I think the eminent physiologist whom I have quoted has assimilated the condition of the very young animal and the adult hibernating animal erroneously. The mere phenomenon of loss of temperature is the same; but the rationale of this phenomenon, its causes and its effects, are totally different.

III. *Of perfect hibernation.*—I now proceed to treat of perfect hibernation, of its causes, and of its effects on the various functions which I have enumerated. My observations will consist principally of a detail of a series of observations and experiments made in the course of the year 1831–1832, compared with the results obtained by other inquirers.

I consider that there is *one* special cause of hibernation,—that law imposed by the Creator, according to which *all* animals become affected with sleep at some period of each revolving day, and the hibernating animal at some period of the revolving year. We have thus presented to us the phenomena of diurnal and nocturnal animals, and the winter-sleep and the summer-sleep of hibernating animals.

Exposure to cold, not too severe, disposes to hibernation, as it disposes to ordinary sleep. Severe cold, on the contrary, first rouses the hibernating animal from its lethargy, and then plunges this and all animals into a state of fatal torpor.

The absence of every kind of stimulus or excitant, and a somewhat confined atmosphere,* also conduce to hibernation.

Every excitement, on the contrary, that of hunger, that of the sexes probably, tend to disturb this peculiar lethargy. It is in this manner that we explain the periodicity of sleep and hibernation, though there is probably also some hidden influence of the seasons, of the day or of the year, influences which have been traced by Dr. Prout and by M. Edwards in regard to the quantity of respiration.

I now proceed to treat of the condition of the several functions in hibernation.

The process of *sanguification* is, in some hibernating animals, nearly arrested; in others, it is entirely so.

There is much difference in the powers of digestion, and in the fact of omitting to take food, in the hibernation of different animals. The bat, being insectivorous, would awake in vain; no food could be found: the hedgehog might obtain snails or worms, if the ground were not very hard from frost: the dormouse would find less difficulty in meeting with grain and fruits. We accordingly observe a remarkable difference in the habits of awaking from their lethargy or hibernation, in these different animals.

I have observed no disposition to awake at all in the bat, except from external warmth or excitement. If the temperature be about 40° or 45°, the hedgehog, on the other hand, awakes, after various intervals of two, three, or four days passed in lethargy, to take food; and again returns to its state of hibernation. The dormouse, under similar circumstances, awakes daily.

Proportionate to the disposition to awake and take food, is the state of the functions of the stomach, bowels and kidneys. The dormouse and the hedgehog pass the fæces and urine in abundance during their intervals of activity. The bat is scarcely observed to have any excretions during its continued lethargy.

In the dormouse and the hedgehog, the sense of hunger appears to rouse the animal from its hibernation, whilst the food taken conduces to a return of the state of lethargy. It has already been observed, that there are alternations between activity and lethargy in this animal, with the taking of food, in temperatures about 40° or 45°. Nevertheless, abstinence doubtless conduces to hibernation, by rendering the system

* Des Agens Physiques, p. 155.

* M. de Saissy observes, "la marmotte, que j'ai engourdie par deux fois différentes, ne l'a été, je crois, que parceque je me suis avisé, quand la respiration a été bien affaiblie, de boucher le trou du couvercle. Ce n'a été que de cette manière que je suis parvenu à l'engourdir; car toutes les tentatives que j'avais faites avant ont été vaines."

more susceptible of the influence of cold, in inducing sleep and the loss of temperature. The hedgehog, which awakes from its hibernation, and does not eat, returns to its lethargy sooner than the one which is allowed food.

The *respiration* is very nearly suspended in hibernation. That this function almost ceases, is proved, 1st, by the absence of all detectible respiratory acts; 2dly, by the almost entire absence of any change in the air of the pneumatometer; 3dly, by the subsidence of the temperature to that of the atmosphere; and 4thly, by the capability of supporting, for a great length of time, the entire privation of air.

1. I have adopted various methods to ascertain the entire absence of the acts of respiration. I placed bats in small boxes, divided by a partition of silk riband, the cover of which consisted of glass, and in the side of which a small hole was made to admit of placing a long light rod or feather under the animal's stomach. The least respiratory movement caused the extremity of this rod to pass through a considerable space, so that it became perfectly apparent.

Over the hibernating hedgehog I placed a similar rod, fixing one extremity near the animal, and leaving the other to move freely over an index. During hibernation not the slightest movements of these rods could be observed, although they were diligently watched. But the least touch, the slightest shake immediately caused the bat to commence the alternate acts of respiration, whilst it invariably produced the singular effect of a deep and sonorous inspiration in the hedgehog. It is only necessary to touch the latter animal to ascertain whether it be in a state of hibernation or not: in the former case there is this deep sonorous inspiration; in the latter, the animal merely moves and coils itself up a little more closely than before. After the deep inspiration, there are a few feeble respirations, and then total quiescence. The bat makes similar respirations without the deep inspiration, and then relapses into suspended respiration.

2. As the acts of respiration are nearly suspended during hibernation, so are the changes induced in the atmospheric air.

On January the 28th, the temperature of the atmosphere being 42°, I placed a bat in the most perfect state of hibernation and undisturbed quiet, in the pneumatometer, during the whole night, a space of ten hours, from 1h. 30m. to 11h. 30m. There was no perceptible absorption of gas.

Having roused the animal a little, I replaced it in the pneumatometer, and continued to disturb it from time to time, by moving the apparatus. It continued inactive, and between the hours of 1h. 20m. and 4h., there was the absorption of one cubic inch only of gas.

Being much roused at four o'clock, and replaced in the pneumatometer, the bat now continued moving about incessantly; in one hour, five cubic inches of gas had disappeared. It was then removed. A further absorption took place of ·8 of a cubic inch of gas.

Thus the same little animal, which, in a state of hibernation, passed ten hours without respiration, absorbed or converted into carbonic acid, 5·8 cubic inches of oxygen gas in one hour when in a state of activity. In an intermediate condition, it removed one cubic inch of oxygen in two hours and forty minutes.

I repeated this experiment on February the 18th. A bat, in a state of perfect hibernation, was placed in the pneumatometer, and remained in it during the space of twenty-four hours. There was now the indication of a very slight absorption of gas, not, however, amounting to a cubic inch.

On February the 22d, I repeated this experiment once more, continuing it during the space of sixty hours; the thermometer descended gradually, but irregularly, from 41° to 38°; the result is given in the subjoined table.

Date		External Temperature.	Absorption.	Duration.
Feb. 22	11 P.M.	41°		
23	11 A.M.	38½	·8	12h
	11 P.M.	39½	·75	12
24	11 A.M.	38	·5	12
	11 P.M.	39	·75	12
25	11 A.M.	38	·6	12
			3·4	60

From this experiment it appears that 3·4 cubic inches of oxygen gas disappeared in sixty hours, from the respiration of a bat in the state of lethargy. It has been seen that in a state of activity, an equal quantity of this gas disappeared in less than half that number of minutes. The respiration of the hibernating bat descends to a sub-reptile state; it will be seen shortly that the irritability of the heart and of the muscular fibre generally, is proportionably augmented.

In this experiment it is probable that the lethargy of the animal was not quite complete. Should the temperature of the atmosphere fall, and continue at 32°, I shall again repeat it under these circumstances. The respiration will probably be still more nearly suspended.

It is important to remark, that the registration of the quantity of absorption in these experiments was not begun until several hours after the animal had been inclosed within the jar of the pneumatometer, so that the absorption of the carbonic acid always present in atmospheric air was excluded from the result.

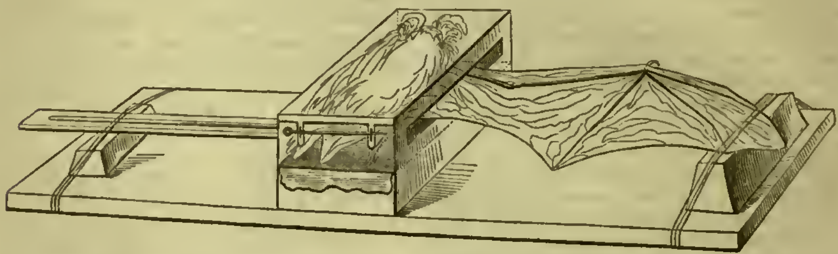
It may be a question whether the slight quantity of respiration I have mentioned be cutaneous. The absence of the acts of respiration would lead us to this opinion. But it may be observed, that these acts have not been watched, and can scarcely be watched continuously enough, to determine the question of their entire absence. Some contrivance to ascertain whether the rod has moved along the index during the absence of the observer would resolve every doubt upon this interesting point. And I think it right to remark, that after the apparent total cessation of respiration, as observed by the means which have just been described, there is probably still a slight diaphragmatic breathing. I am led to this conclusion, by having observed a slight movement of the flank in a favourable light, unattended by any motion of the thorax or epigastrium.

3. Much precaution is required in ascertain-

ing the comparative temperature of the animal with that of the atmosphere. The slightest excitement induces a degree of respiration, with the consequent evolution of heat.

The plan which is best adapted to determine this question in regard to the bat, and which I have adopted, together with every attention to preserve the animal quiet and undisturbed, is the following: a box was made of mahogany, with a glass lid, divided horizontally at its middle part, by a fold of strong riband, and of such dimensions as just to contain the animal. The bat was placed upon the riband, and inclosed by fixing the lid in its place. Being lethargic, it remained in undisturbed quiet. A thermometer, with a cylindrical bulb, was now passed through an orifice made in the box on a level with the riband, under the epigastrium of the animal, and left in this situation. This arrangement is made obvious by the subjoined wood-cut, (*fig.* 306,) which also displays the mode of examining the circulation.

Fig. 306.



It was only now necessary to make daily observations and comparisons between this thermometer and another placed in the adjacent atmospheric air. The layer of silk, and the portion of air underneath, protected the animal from the immediate influence of the temperature of the table, on which the box was placed.

The following table gives the result of observations made during many days, in very varying temperatures.

Date.		Temperature of the Atmosphere.	Temperature of the Animal.
		°	°
Jan. 6	11 P.M.	40	40½
7	8 P.M.	43	43
8		41	41½
9	11 P.M.	47	46
10	10 A.M.	46	46
—	12 midnight	47	47
11	10 P.M.	45	45
12	11 P.M.	45	45
13	11 P.M.	37	37½
14	11 A.M.	37	37
—	11 P.M.	40	40
15	2 P.M.	37	37
—	11 P.M.	35	35
16	11 P.M.	37	37
17	11 P.M.	42	42
18	11 A.M.	40	40
19	10 P.M.	36	36
20	11 P.M.	39	39
21	11 P.M.	40	40
22	11 P.M.	44	44
23	10 A.M.	42½	42½
—	11 P.M.	40½	40½
24	11 P.M.	43½	43½
25	10 P.M.	42	42
26	10 P.M.	41	41
27	10 P.M.	37	37
28	11 A.M.	34½	34½
—	11 P.M.	37	37
29	11 A.M.	42	42
—	11 P.M.	43	43
30	11 P.M.	42	42
31	11 P.M.	39½	39½

From this table it is obvious that the temperature of the hibernating animal accurately follows that of the atmosphere. When the changes of temperature in the latter are slight, the two thermometers denote the same temperature. If these changes are greater and more rapid, the temperature of the animal is a little lower or higher, according as the external temperature rises or falls; a little time being obviously required for the animal to attain that temperature.

Similar observations were made during the first three days of February. On the 4th, however, the temperature of the atmosphere rose to 50½°; that of the animal was now 82°, and there was considerable restlessness. On the 6th, the temperature of the atmosphere had fallen to 47½°, and that of the animal to 48°, whilst there was a return of the lethargy.

After this period there were the same equal alterations of temperature in the animal and in the atmosphere, observed in the month of January.

It is only necessary to add to these observations, that the internal temperature is about three degrees higher than that of the epigastrium. In two bats, the external temperature of each of which was 36°, a fine thermometer, with an extremely minute cylindrical bulb, passed gently into the stomach, rose to 39°.

The following experiments, made by the celebrated Jenner, illustrate this point:

" In the winter, the atmosphere at 44°, the heat of a torpid hedgehog at the pelvis was 45°, and at the diaphragm 48½°.

" The atmosphere 26°, the heat of a torpid hedgehog, in the cavity of the abdomen, was reduced so low as 30°.

" The same hedgehog was exposed to the cold atmosphere of 26° for two days, and the heat of the rectum was found to be 93°; the wound in the abdomen being so small that it would not admit the thermometer.*

* The animal had become lively. See Hunter on the Animal Œconomy, p. 113.

"A comparative experiment was made with a puppy, the atmosphere at 50°; the heat in the pelvis, as also at the diaphragm, was 102°.

"In summer, the atmosphere at 78°, the heat of the hedgehog, in an active state in the cavity of the abdomen, towards the pelvis, was 95°; at the diaphragm, 97°." *

There is an error in the admirable work of M. Edwards, as I have already stated, in relation to the present subject, which it is important to point out. M. Edwards first ascertained the interesting fact, that the very young of those species of animals which are born blind, lose their temperature if removed from the contact of their parent; and justly concludes that they have not sufficient power of evolving heat, to maintain their natural temperature when so exposed. M. Edwards then subjected hibernating animals to the action of cold, and observing that their temperature also fell, he concludes that they, like the very young animal, have not the faculty of maintaining their temperature under ordinary circumstances.†

It is remarkable that this acute physiologist did not perceive the error in this reasoning. In no instance does the young animal maintain its warmth, when exposed alone to the influence of an atmosphere of moderate temperature. Can this be said of the hibernating animal? Certainly not. In ordinary temperatures, the hibernating animal maintains its activity, and with its activity, its temperature. The loss of temperature in this kind of animal is an induced condition, occasioned by sleep.

There is a point unnoticed in M. Edwards's experiment. It is the condition of the bat in regard to activity or lethargy under the exposure to cold; and upon this the whole phenomena depend.

The differences between the young animal benumbed, and the hibernating animal lethargic, from cold, are both great and numerous. I purpose to point them out particularly on a future occasion.

4. It is in strict accordance with these facts, that the lethargic animal is enabled to bear the total abstraction of atmospheric air or oxygen gas, for a considerable period of time.

Spallanzani placed a marmot in carbonic acid gas, and makes the following report of the experiment in a letter to Senebier: "Vous vous ressouviendrez de ma marmotte qui fut si fortement léthargique dans l'hiver sévère de 1795; je la tins alors pendant quatre heures dans le gaz acide carbonique, le thermomètre marquant —12°, elle continua de vivre dans ce gaz qui est le plus mortel de tous, comme je vous le disais: au moins un rat et un oiseau que j'y plaçai avec elle y périrent à l'instant même. Il paraît donc que sa respiration fut suspendue pendant tout ce tems-là. Je soumis à la même expérience des chauve-souris semblablement léthargiques, et le résultat fut le même." ‡

* Ibid. p. 112.

† Des Agens Physiques, p. 155.

‡ Mémoires sur la Respiration, par Lazare Spallanzani, traduites en Français, d'après son manuscrit inédit, par Jean Senebier, p. 75.

A bat which was lethargic in an atmosphere of 36° was immersed in water of 41°. It moved about a little, and expelled bubbles of air from its lungs. It was kept in the water during sixteen minutes, and then removed. It appeared to be uninjured by the experiment.

A hedgehog which had been so lethargic in an atmosphere of 40° as not to awake for food during several days, was immersed in water of 42°. It moved about and expelled air from its lungs. It was retained under the water during 22½ minutes. It was then removed. It appeared uninjured.

It seems probable that the motions observed in these animals were excited through the medium of the cutaneous nerves.

The power of supporting the abstraction of oxygen gas, or atmospheric air, belongs solely to the hibernating state, and is no property of the hibernating animal in its state of activity. After having found that the dormant bat, in summer, supported immersion in water during eleven minutes, uninjured, I was anxious to know whether the active hedgehog possessed the same power. I immersed one of these animals in water. It expired in three minutes, the period in which immersion proves fatal to the other mammalia. Sir Anthony Carlisle has, therefore, committed an error, somewhat similar to that of M. Edwards, when he asserts that "animals of the class Mammalia, which hibernate and become torpid in winter, have at all times a power of subsisting under a confined respiration, which would destroy other animals not having this peculiar habit." * The power of bearing a suspended respiration is an induced state. It depends upon sleep or lethargy themselves, and their effect in impairing or suspending respiration; and upon the peculiar power of the left side of the heart, of becoming veno-contractile under these circumstances.

The *circulation* is reduced to an extreme degree of slowness, according to a law well-known, but hitherto, I believe, unexplained, according to which the respiration and the circulation are always proportionate to each other.

The wing of the bat affords an admirable opportunity of observing the condition of the circulation during hibernation. But it requires peculiar management. If the animal be taken from its cage, and the wing extended under the microscope, it is roused by the operation, and its respiratory and other movements are so excited, that all accurate observation of the condition of the circulation in the minute vessels is completely frustrated. Still greater caution is required in this case than even in the observation of the respiration and temperature.

After some fruitless trials, I at length succeeded perfectly in obtaining a view of the minute circulation undisturbed. Having placed the animal in its state of hibernation, in a little box of mahogany, I gently drew out its wing through a crevice made in the side of the box; I fixed the tip of the extended wing between portions of cork; I then attached the box and the cork to a piece of plate-glass; and lastly, I

* Phil. Trans. 1805, p. 17.

left the animal in this situation, in a cold atmosphere, to resume its lethargy. (See *fig.* 306.)

I could now quietly convey the animal ready prepared, and place it in the field of the microscope without disturbing its slumbers, and observe the condition of the circulation.

In this manner I have ascertained that, although the respiration be suspended, the circulation continues uninterruptedly. It is slow in the minute arteries and veins; the beat of the heart is regular, and generally about twenty-eight times in the minute.

We might be disposed to view the condition of the circulation in the state of hibernation as being reptile, or analogous to that of the batrachian tribes. But when we reflect that the respiration is nearly, if not totally, suspended, and that the blood is venous,* we must view the condition of the circulation as in a lower condition still, and, as it were, sub-reptile. It may, indeed, be rather compared to that state of the circulation which is observed in the frog from which the brain and spinal marrow have been removed by minute portions at distant intervals.†

In fact, in the midst of a suspended respiration, and an impaired condition of some other functions, one vital property is augmented. This is the irritability, and especially the irritability of the left side of the heart. The left side of the heart, which is, in the hibernating animal, in its state of activity, as in all the other mammalia, only arterio-contractile, becomes veno-contractile.

This phenomenon is one of the most remarkable presented to me in the whole animal kingdom. It forms the single exception to the most general rule amongst animals which possess a double heart. It accounts for the possibility of immersion in water or a noxious gas, without drowning or asphyxia; and it accounts for the possibility of a suspended respiration, without the feeling of oppression or pain, although sensation be unimpaired. It is, in a word, this peculiar phenomenon, which, conjoined with the peculiar effect of sleep in inducing diminished respiration in hibernating animals, constitutes the susceptibility and capability of taking on the hibernating state. On the other hand, as the rapid circulation of a highly arterialized blood in the brain and spinal marrow of birds probably conduces to their activity, the slow circulation of a venous blood doubtless contributes to the lethargy of the hibernating animal.

I need scarcely advert to the function of *defæcation*. It has already been briefly noticed under the head of sanguification, with which it proceeds *pari passu*.

In regard to the *nervous system*, I can only repeat that *sensation* and *volition* are quiescent. In my memoir upon the subject of hibernation,* I committed an error relative to this subject. But I am now satisfied that what I considered to be evidences of an unimpaired sensibility, were phenomena of the *excito-motory* kind. Thus I have observed that the slighest touch applied to one of the spines of the hedgehog immediately rouses it to draw that deep inspiration of which I have spoken. The merest shake induces a few respirations in the bat. The least disturbance, in fact, is felt, as is obvious from its effect in inducing motion in the animal.

It is from the misconception on this point that the error has arisen, that the respiration is not absolutely suspended in hibernation. This function has been so readily *re-excited*, that it has been considered as appertaining to the state of hibernation.

As I have already stated, the cerebral functions sleep, the true spinal functions retain their wonted energy; and if the respiration be nearly suspended, it is because little carbonic acid, the *excitor* of respiration, is evolved.

In the midst of a suspended or partially suspended respiration, the *irritability* of the muscular fibre becomes proportionately augmented.

The single fact of a power of sustaining the privation of air, without loss of life, leads alone to the inference that the irritability is greatly augmented in the state of hibernation. This inference flows from the law already stated, and the fact is one of its most remarkable illustrations and confirmations.

It might have been inferred from these premises, that the beat of the heart would continue longer after decapitation in the state of hibernation than in the state of activity in the same animal; an inference at once most singular and correct.

This view receives the fullest confirmation from the following remarkable experiment: on March the 9th, soon after midnight, I took a hedgehog which had been in a state of uninterrupted lethargy during 150 hours, and divided the spinal marrow just below the occiput; I then removed the brain and destroyed the whole spinal marrow as gently as possible. The action of the heart continued vigorous during four hours, when, seeing no prospect of a termination to the experiment, I resolved to envelope the animal in a wet cloth, and leave it until early in the morning. At 7 o'clock A.M. the beat of both sides of the heart still continued. They still continued to move at 10 A.M., each auricle and each ventricle contracting quite distinctly. At half-after 11 A.M. all were equally motionless; yet all equally contracted on being stimulated by the point of a penknife. At noon the two ventricles were alike unmoved on being irritated as before; but both auricles contracted. Both auricles and ventricles were shortly afterwards unirritable.

This experiment is the most extraordinary of those which have been performed upon the mammalia. It proves several interesting and important points: 1. That the irritability of the heart is augmented in continued lethargy in an

* M. Prunelle observes, "En comparant le sang de deux chauve-souris auxquelles j'avois ouvert les carotides, à l'une pendant son engourdissement et à l'autre dans l'état de veille, j'ai trouvé celui de la dernière beaucoup plus vermeil." Annales du Museum, tome xviii. p. 28.

† Essay on the Circulation, pp. 136-141.

* Phil. Trans. for 1832.

extraordinary degree. 2. That the irritability of the left side of the heart is then little, if at all, less irritable than the right,—that it is, in fact, veno-contractile. 3. That, in this condition of the animal system, the action of the heart continues for a considerable period independently of the brain and spinal marrow.

On April the 20th, at six o'clock in the evening, the temperature of the atmosphere being 53°, a comparative experiment was made upon a hedgehog in its state of activity: the spinal marrow was simply divided at the occiput; the beat of the right ventricle continued upwards of two hours, that of the left ventricle ceased almost immediately; the left auricle ceased to beat in less than a quarter of an hour; the right auricle also ceased to beat long before the right ventricle.

In further proof of the same fact, I may here adduce a remarkable paragraph from the paper of Mangili in the Annales du Muséum:* "J'observai à peu près les mêmes choses dans une autre marmotte en léthargie, que je décapitai le 22 de Mars 1807. Mais en ouvrant celle-ci, j'avois deux objets: le premier, d'examiner l'état des viscères les plus importans, comme le cœur, les poumons et le cerveau. Le second étoit de voir comment procédent les phénomènes de l'irritabilité musculaire; parce qu'ayant entendu dire à un célèbre naturaliste, que l'engourdissement avoit pour cause l'altération ou la suspension de cette irritabilité, il m'importoit de savoir si cette assertion étoit vraie. Dans la chambre où se trouvoit la marmotte, le thermomètre étoit à 6 degrés et demi: l'ayant introduit dans le bas ventre, il monta d'un degré, c'est-à-dire à 7 degrés et demi.

"Je trouvai les poumons dans leur état naturel. Le cœur continua à battre pendant plus de trois heures. Les pulsations, d'abord vives et frequentes, s'affoiblirent et se ralentirent peu-à-peu. J'en avois compté de seize à dix-huit par minute au commencement de la première heure; à la fin de la troisième je n'en comptois plus que trois dans le même temps. Les veines du cerveau me parurent gonflées de sang.

"La tête unie au cou ayant été séparée du tronc, je la mis dans un vase avec de l'esprit-de-vin, et j'y remarquai, même après une demi-heure, des mouvemens assez sensibles. Ce fait prouve, ainsi que plusieurs autres dont je parlerai bientôt, que si dans l'état de léthargie conservatrice la vie est beaucoup moins énergique, le principe vital répandu dans les diverses parties, a beaucoup plus de tenacité, et tarde bien plus à s'éteindre.

"Je séparai du corps de l'animal plusieurs morceaux des muscles qui obéissent à la volonté, et je vis avec étonnement que, trois heures après la mort, ils se contractoient fortement chaque fois que je les soumettois à l'action galvanique. Ces mouvemens convulsifs ne se ralentirent qu'au bout de quatre heures.

"Il suit de là que les marmottes tuées pendant qu'elles sont en léthargie, présentent, relativement à l'irritabilité, à peu près les mêmes phénomènes qu'on remarque dans plusieurs animaux à sang froid.

"Pour savoir ensuite si les phénomènes d'irritabilité étoient les mêmes dans l'état de veille et dans celui de léthargie, le 25 de Juin, j'ai fait périr, précisément de la même manière, une seconde marmotte qui étoit éveillée depuis deux mois, et qui faisoit de frequentes courses dans le jardin. Mon thermomètre marquoit ce jour-là 18 degrés: l'ayant introduit dans le ventre de la marmotte au moment où je venois de la décapiter, il s'éleva à 29 degrés.

"Ayant mis le cœur à découvert, comme je l'avois fait dans mon expérience du mois de Mars, je comptai d'abord vingt-sept ou vingt-huit pulsations par minute. Ce nombre n'étoit plus que de douze au bout d'un quart d'heure, et de huit, au bout de demi-heure: dans le dix minutes suivantes, il n'y eut plus que quatre pulsations très-foibles par minute, et elles cessèrent totalement dans les dix dernières minutes, c'est-à-dire cinquante minutes après la mort de l'animal; tandis que le cœur de la marmotte tuée dans l'état de léthargie, donnoit encore quatre légères pulsations par minute, trois heures après que la tête avoit été séparée du corps. Cette grande différence prouve que le principe de l'irritabilité s'accumule pendant la léthargie conservatrice.

"Les chairs musculaires me semblirent plus pâles que celles de la marmotte en léthargie: elles étoient d'abord très sensibles à l'action galvanique; mais ses signes d'irritabilité s'affoiblirent et disparurent bien plus rapidement. En effet, les chairs musculaires de cette marmotte étoient peu sensibles au bout de deux heures, tandis que dans la marmotte tuée en hiver elles se contractoient fortement au bout de trois heures, et que l'irritabilité ne s'affoiblit notablement que quatre heures après la mort.

"Les chairs des muscles intercostaux et abdominaux conservèrent leur sensibilité au stimulus électrique quelques minutes de plus que celles des membres; d'où l'on peut conclure que le principe de l'irritabilité se conserve d'avantage dans certaines parties du même animal. Mais ce qui est prouvé jusqu'à l'évidence, c'est que ce principe a bien plus de ténacité dans les chairs de l'animal tué pendant l'état de léthargie, que dans celles de l'animal tué pendant l'état de veille."

This author does not appear to have had any apprehension of the extreme importance of this extraordinary change in the irritability, but merely states it as a fact. Its due value can only be known by observing the dependence of the functions of life on that law of the inverse condition of the respiration and of the irritability, of which so much has already been said. In the hibernating animal the respiration is nearly suspended; had not the irritability become proportionately augmented, the actions of life must have ceased!

I must add one remark upon the *motility* of the muscular fibre in hibernation; it is unimpaired. Those physiologists who have asserted the contrary, have, as will be shown shortly, mistaken the phenomena of torpor from cold, for those of true hibernation.

* Tome x. p. 453-456.

If the hedgehog in a state of the most perfect lethargy, uncomplicated with torpor, be touched, its respiration is resumed, and it coils itself up more forcibly than before. The dormouse, in similar circumstances, unfolds itself; and the bat moves variously. Not the slightest stiffness is observed. The hedgehog, when roused, walks about, and does not stagger, as has been asserted. The bat speedily takes to the wing, and flies about with great activity, although exhaustion and death may subsequently result from the experiment. The phenomena are similar to those of awaking from natural sleep. Impaired motility, stiffness, lameness, &c. belong to torpor, and not to true hibernation.

III. *Of reviviscence.* — Not the least interesting of the phenomena connected with hibernation are those of reviviscence. Hibernation induces a state of irritability of the left side of the heart, which, with high respiration and an arterialized blood, would be incompatible with life. Respiration suddenly restored, and permanently excited, is, therefore, as destructive as its privation in other circumstances.

All those bats which were sent to me from distant parts of the country died. The continued excitement from the motion of the coach keeping them in a state of respiration, the animal perished. One bat had, on its arrival, been roused so as to fly about. Being left quiet, it relapsed into a state of hibernation. The excitement being again repeated the next day, it again flew about the room; on the succeeding day it was found dead.

It is in accordance with this law, that we observe hibernating animals adopting various measures to secure themselves from frequent sources of disturbance and excitement. They choose sheltered situations, as caverns, burrows, &c. secure from the rapid changes and the inclemencies of the weather and season. Many form themselves nests; others congregate together. The hedgehog and the dormouse roll themselves up into a ball. The common bat suspends itself by the claws of its hinder feet, with its head dependent, generally in clusters; the horseshoe bat *(ferrum equinum)* spreads its wings so as to embrace and protect its fellows.

All these circumstances are obviously designed to prevent disturbed hibernation.

In the depth of caverns, and other situations sheltered from changes of temperature in the atmosphere, the calls of hunger are probably the principal cause of reviviscence in the spring. The other causes of reviviscence are the return of warmth and external excitements: it is interesting to observe and trace the gradual return of respiration in the former case, and of the temperature of the animal in the latter.

If the hibernating hedgehog be touched even very gently, it draws a deep breath, and then continues to breathe for a short time. If this excitement be repeated, the animal is permanently roused, and its temperature raised. If the temperature of the atmosphere be augmented, the respiration is gradually excited, and the animal is gradually restored to its state of activity.

If a hibernating animal be excited in a very cold atmosphere, its temperature rises variously, and then falls. A bat was perfectly lethargic in a temperature of 36°. A fine thermometer, with a cylindrical bulb, was introduced into its stomach; it rose to 39°. One hour afterwards, the animal not being further disturbed, the respiration was rapid, and the temperature in the stomach 95°. Shortly afterwards the temperature was 90°. The minute circulation was pretty good, and pulsatory in the arteries, the heart beating from twenty-eight to thirty-six times in the minute.

In another bat, in an atmosphere of the temperature of 36°, the thermometer in the stomach rose to 39°. The animal being continually excited, the temperature rose to 65°, but speedily fell to 60°.

The animal excited and revived in this manner is in a state of exhaustion and inanition. It is incapable of maintaining its temperature if exposed to cold, and will die unless it repass into the state of hibernation. It may be compared to the case of the mouse deprived of food in the following experiment of Mr. Hunter. "A mouse was put into a cold atmosphere of 13° for an hour, and then the thermometer was introduced as before; but the animal had lost heat, for the quicksilver at the diaphragm was carried only to 83°, in the pelvis to 78°.

"In order to determine whether an animal that is awakened has the same powers, with respect to preserving heat and cold, as one that is vigorous and strong, I weakened a mouse by fasting, and then introduced the bulb of the thermometer into its belly; the bulb being at the diaphragm, the quicksilver rose to 97°; in the pelvis to 95°, being two degrees colder than the strong mouse: the mouse being put into an atmosphere as cold as the other, and the thermometer again introduced, the quicksilver stood at 79° at the diaphragm, and at 74° in the pelvis.

"In this experiment the heat at the diaphragm was diminished 18°, in the pelvis 21°.

"This greater diminution of heat in the second than in the first, we may suppose proportional to the decreased power of the animal, arising from want of food."*

But extreme cold alone, by a painful effect induced on the sentient nerves, rouses the hibernating animal from its lethargy, as has been remarked already, and is illustrated by the following experiments of Hunter. "Having brought a healthy dormouse, which had been asleep from the coldness of the atmosphere, into a room in which there was a fire, (the atmosphere at 64°,) I introduced the thermometer into its belly, nearly at the middle, between the thorax and pubis, and the quicksilver rose to 74° or 75°; turning the bulb towards the diaphragm, it rose to 80°; and when I applied it to the liver, it rose to 81½°.

"The mouse being placed in an atmosphere at 20°, and left there half an hour, when taken out was very lively, even much more so than when put in. Introducing the thermometer into the lower part of the belly, the quicksilver

* Animal Œconomy, pp. 114, 115.

rose to 91°; and turning it up to the liver, to 93°.

"The animal being replaced in the cold atmosphere at 30°, for an hour, the thermometer was again introduced into the belly; at the liver it rose to 93°; in the pelvis to 92°; the mouse continuing very lively.

"It was again put back into an atmosphere cooled to 19°, and left there an hour; the thermometer at the diaphragm was 87°; in the pelvis 83°; but the animal was now less lively.

"Having been put into its cage, the thermometer being placed at the diaphragm, in two hours afterwards was at 93°." *

In these experiments the animals appear to have been roused partly by the state of the wound in the abdomen, but chiefly by the extreme cold. They can scarcely, however, be considered as experiments upon hibernation, however interesting they may be in reference to reviviscence from that state.

The fact of the fatal influence of excited respiration during the augmented irritability of hibernation, contrasted with the similar fatal effect of suspended respiration, during the diminished irritability of the state of activity, will illustrate many of the causes, kinds, and phenomena of death. Do not these resolve themselves, in fact, into irritability insufficiently or excessively excited?

IV. *Of torpor from cold.*—It is highly important, and essential to the present investigation to distinguish that kind of torpor which may be produced by cold in any animal, from true hibernation, which is a property peculiar to a few species. The former is attended by a benumbed state of the sentient nerves, and a stiffened condition of the muscles; it is the direct and immediate effect of cold, and even in the hibernating animal is of an injurious and fatal tendency; in the latter, the sensibility and motility are unimpaired, the phenomena are produced through the medium of sleep; and the effect and object are the preservation of life.

Striking as these differences are, it is certain that the distinction has not always been made by former observers. In all the experiments which have been made, with artificial temperatures especially, it is obvious that this distinction has been neglected.

True hibernation is induced by temperatures only moderately low. All hibernating animals avoid exposure to extreme cold. They seek some secure retreat, make themselves nests or burrows, or congregate in clusters, and, if the season prove unusually severe, or if their retreat be not well chosen and they be exposed in consequence to excessive cold, many become benumbed, stiffen, and die.

In our experiments upon hibernation we should imitate nature's operations. Would any one imagine that the following detail contained the account of an experiment upon this subject? "Le 31 Janvier," says M. Saissy, "à trois heures du soir, la température atmosphérique étant à 1°·25 au-dessous de zéro, celle d'un hérisson engourdi profondément à 3°·50 au dessus, j'enfermai ce quadrupède dans un bocal de verre entouré de toute part d'une mixtion de glace et de muriate de soude. L'excès du froid le réveilla d'abord, mais trois heures ont suffi pour le replonger dans une profonde torpeur.

"J'avais placé l'animal de manière que je pouvais répéter, autant que je le jugeais nécessaire, les expériences thermométriques. Dès que sa température eut baissé jusqu'à zero, (ce ne fut qu'à 2 heures du matin) je le retirai du bocal et le placai dans une température de 12° et plus au dessus de la glace; mais l'animal était mort." *

To induce true hibernation, it is quite necessary to avoid extreme cold; otherwise we produce the benumbed and stiffened condition to which the term torpor or torpidity may be applied. I have even observed that methods which secure moderation in temperature, lead to hibernation: hedgehogs, supplied with hay or straw, and dormice, supplied with cotton-wool, make themselves nests and become lethargic; when others, to which these materials are denied, and which are consequently more exposed to the cold, remain in a state of activity. In these cases, warmth or moderated cold actually concur to produce hibernation.

When we read of insensibility, of a stiffened state of the muscles, and of a cessation of the circulation, as obtaining in hibernation, we may be certain that a state of torpor has been mistaken for that condition. The actually hibernating animal exposed to continued severe cold is, as M. Saissy correctly observes, first roused from this state of ease and preservation into a painful activity, and then plunged into a fatal torpor.

This subject will come to be considered in a subsequent part of this inquiry, in which I purpose to trace the effects of cold in changing the relative quantity of respiration and degree of the irritability in animals of different ages which do not hibernate; in the meantime, the accurate distinction between mere torpor, which may occur in any animal, and which is a destructivestate, from true hibernation, which is preservative, and the peculiarity of certain animals, will enable us to correct many inaccuracies into which Legallois,† M. Edwards,‡ and other physiologists have fallen. (See IRRITABILITY.)

In conclusion, one of the most general effects of sleep is to impair the respiration, and with that function the evolution of animal temperature. The impaired state of the respiration induces a less arterial condition of the blood, which then becomes unfit for stimulating the heart; accumulation of the blood takes place in the pulmonary veins and left auricle; a sense of oppression is induced, and the animal is either roused to draw a deep sigh or awakes altogether.

* Animal Œconomy, pp. 111, 112.

* Recherches sur les Animaux hibernans, par M. J. A. Saissy, pp. 13, 14.

† Œuvres de Legallois, Paris, 1824, p. 282.

‡ Agens Physiques, pp. 148, 292.

Such are the phenomena in animals in which the heart has not the faculty of taking on an augmented state of irritability, with this lessened degree of stimulus. But in those animals which do possess this faculty, a property which constitutes the power of hibernation, the heart continues the circulation of the blood, more slowly indeed, but not less perfectly, although its arterial character be diminished and its stimulant property impaired. No repletion of the pulmonary veins and of the left auricle, no sense of oppression is induced, and the animal is not roused; the respiration continues low, the temperature falls, and the animal can bear, for a short period, the abstraction of atmospheric air.

All the phenomena of hibernation originate, then, in the susceptibility of augmented irritability. The state of sleep, which may be viewed as the first stage of hibernation, induces an impaired degree of respiration. This would soon be attended with pain, if the irritability of the heart were not at the same time augmented, so as to carry on the circulation of a less arterial blood, and the animal would draw a deep sigh —would augment its respiration or awake. Occasional sighs are, indeed, observed in the sleep of all animals, except the hibernating. In these, the circulation goes on uninterruptedly, with a diminished respiration, by the means of an augmented irritability. There is no stagnation of the blood at the heart; consequently, no uneasiness; and the animal becomes more and more lethargic, as the circulation of a venous blood is more complete. This lethargy is eventually interrupted by circumstances which break ordinary sleep, as external stimuli or the calls of appetite.

It still remains for me briefly to discuss the question,—what are the hibernating animals? I must first advert to the fact, on which I have already insisted, that hibernation does not present itself in an equal degree in all the hibernating tribes. All animals *sleep* periodically, in the night or in the day. Some sleep for several days together, especially after taking food, and in the cool seasons of the year, as the hedgehog. Perhaps the bat may be the only animal which sleeps profoundly the winter through, without awaking to take food.

These remarks prepare us for a more just view of hibernation and of hibernating animals than is, as I believe, usually taken.

Of the hibernating animals the most unequivocal are the bat, the hedgehog, the marmot, the hamster, the dormouse. It has been said that the bear and beaver belong to the number, but this is extremely doubtful. It has been said also that the swallow belongs to the hibernating class, but this is incorrect. The cold-blooded animals, the Chelonian, the Saurian, the Ophidian, and the Batrachian tribes, all, however, indubitably pass the winter in a state of apathy and lethargy. Some of the fishes also become lethargic during the cold season. The same remark applies to some of the molluscous and insect tribes.

BIBLIOGRAPHY.—*Hunter*, An. Œconomy, Owen's edition, p. 131. Lond. 1837. *Spallanzani*, Mém. sur la Respirstion, par Senebier. Genev. 1803; or Eng. translat. Edinb. 1804. *De Saissy*, Recherches exp. sur les Anim. Hivernans., Lyons, 1808. *Mangili*, Essai sur la Léthargie periodique. Milan, 1807. *Edwards*, sur les Agens Physiques. Paris, 1824, or Dr. Hodgkin's English transl. *Prunelle*, Recherches sur les phénom. et sur les causes du sommeil hivernal. Ann. du Mus. t. xviii. *Berthold*, Müller's Archiv. 1837, p. 67. Müller's Physiology, passim.

(Marshall Hall.)

HIP-JOINT, NORMAL ANATOMY OF (in human anatomy).—Fr. *articulation ilio-femorale*; Germ. *Huft gelenk*.—This joint belongs to the class of enarthrodial or ball and socket joints, being formed by the adaptation of the head of the femur to the acetabulum of the os innominatum. These bones are connected by a very powerful capsular ligament, which again is completely covered by strong and thick muscles, under the influence of which the various motions of the joint are performed. We propose to examine *seriatim* the several textures entering into the formation of this joint, and lastly to consider the motions of which it is susceptible.

The bones.—Of the two bones which in the adult enter into the formation of this joint, the os innominatum contributes by the acetabulum, and the femur by its head.

The acetabulum (cotyloid cavity: Germ. *die Pfanne)* is the cup or socket which receives the head of the femur, and is admitted to be the deepest articular cavity in the body. Prior to the adult period of life this cavity serves as the centre of union for the three bones of which the os innominatum is formed, viz., the ilium, ischium, and pubis. These, however, do not enter equally into the acetabulum, inasmuch as the ischium contributes in the proportion of rather more than two-fifths, the ilium of about two-fifths, whilst the pubis yields rather less than one-fifth.

Although the acetabulum is situated nearly in the centre of the separated os innominatum, it has a different position in relation to the entire pelvis. The union of the ossa innominata at the symphysis pubis, and the completion of the pelvis by the addition of the sacrum posteriorly, place the acetabular cavities on either side upon the antero-external aspect of the pelvis, so that a line drawn horizontally from the one to the other would pass through the union of the anterior with the two posterior thirds of the antero-posterior diameter of the pelvis. The aspect of each acetabulum is outwards and very slightly forwards as well as downwards.

Each cavity is surrounded for about four-fifths of its circumference by a sharp but strong lip or margin *(supercilium acetabuli)*, leaving opposite the obturator foramen a notch of considerable extent *(incisura acetabuli)* directed from without downwards, forwards, and inwards, the deepest part of which is smooth and gives passage to nerves and vessels. This notch corresponds to the junction of the pubis and ischium; and we may here observe that the margin of the acetabulum exhibits a slight concavity superiorly, corresponding to the junction of the pubis and ilium, and a similar one inferiorly and externally, corresponding to the junction of the ilium and ischium. These concavities are separated by intervening convexities, and hence the margin of the acetabulum has the appearance of a waving line. Immediately within the margin of the acetabulum we perceive a broad band of smooth bone *(facies lunata)* covered in the recent state by articular cartilage, about seven-eighths of an inch wide at its lower portion, or opposite the ischium, an inch and a quarter to an inch and a half superiorly and externally, where it corresponds to the ilium, and from a quarter to half an inch internally and superiorly at the pubis. This band terminates at each extremity of the notch already described in a process *(cornu)*, the superior of which looks downwards, outwards, and backwards, whilst the inferior, more prominent than the superior, projects towards the notch, forming a kind of gutter between its superior margin, and the deepest part of the notch. Internal to this band, there is a depression, as it were a cavity within the acetabulum, rough and uneven, uninvested by cartilage in the recent state, being continuous with the notch leading towards the obturator foramen. This is the *fovea* or *sinus*, and lodges a quantity of fatty cellular tissue formerly termed *glands of Havers*, from their having been first described by that anatomist. On the upper and lower portions of this inner cavity, various inequalities and foramina are seen, the latter being for the passage of the nutritious vessels of the bone, which is very thin at this point, so much so indeed, that if held up to the light, it will be found transparent. The depth of the acetabulum is not uniform in its different regions. This variety corresponds in a great measure to the breadth of the smooth band of bone *(facies lunata)* already described. Where this is broadest, the cavity possesses the greatest depth, and where it is entirely absent, the cavity is very superficial, as opposite the notch.

The non-articular circumference of the lip of the acetabulum is rough and marked by foramina for the passage of nutritious vessels, and also for the attachment of the capsular ligament.

The head of the femur, representing about three-fourths of a sphere, is supported and connected to the shaft of that bone at an angle varying with age, by a constricted and flattened process termed the neck. A waving prominent line surrounds the head at its junction with the neck, and may be regarded as the boundary line between these two parts, leaving on its inner side the articular surface of the head of the femur, which is smooth, having in the adult its greater convexity directed upwards and inwards. At one point, however, the articular character of this surface is interrupted by a depression, which is not covered with cartilage in the recent state. This depression, situated immediately behind and below the point through which the axis of the head of the bone would pass, gives insertion to the ligamentum teres.

2. *The cartilage.*—That portion of the surface of the acetabulum which corresponds to the facies lunata is alone invested by articular cartilage. This cartilaginous layer is thickest at its external circumference, becoming gradually thinner as it proceeds internally. The head of the femur, on the other hand, is nearly entirely incrusted with cartilage, which, as is usual on convex surfaces, is thickest towards its centre, where it is interrupted by the depression for the ligamentum teres, and becomes progressively thinner towards the circumference.

3. *Fibro-cartilage.*—Immediately surrounding the margin of the acetabulum is a fibro-cartilaginous ring about three lines broad, triangular in shape, having its base attached to the brim of the cavity, whilst its apex is free. This is the so-called *cotyloid ligament (ligamentum cotyloideum, fibro-cartilagineum, labium cartilagineum acetabuli.)* It clearly belongs to the fibro-cartilages of circumference, and is the counterpart of the glenoid ligament in the shoulder-joint (see FIBRO-CARTILAGE), and as it completely removes the irregular character of the margin of the acetabulum, it will be found to be deepest where it corresponds to the concavities of the acetabular border. Its free border is sharp, and directed inwards, *i. e.*, towards the centre of the joint, narrowing the orifice of the acetabulum, at the same time that it increases the depth of that cavity. Its fixed margin constitutes its base, and is connected to the brim of the acetabulum; its external surface covered by synovial membrane corresponds to the capsular ligament, whilst its internal, also covered by synovial membrane, embraces the head of the femur. Having arrived at the notch, it is continued over each cornu of the facies lunata, retaining somewhat of its form, but much diminished in dimensions, and having assumed much more the appearance of pure cartilage than of fibro-cartilage. It ceases at the point at which the concave margin of the facies lunata becomes blended with the convexity of each cornu. It is not stretched across the notch as some anatomists erroneously describe it. The whole extent of this fibro-cartilage, then, corresponds exactly to the convex margin of the facies lunata.

4. *Ligaments.*—The notch of the acetabulum is converted into a foramen, strengthened and in a great degree closed by ligamentous fibres arranged in two layers, and extended from the superior to the inferior cornu. The whole forms the *ligamentum transversale acetabuli* of Winslow. Of these the external and deepest arises from the superior, and is inserted into the inferior cornu of the acetabulum. The external surface of this layer, directed obliquely backwards towards the cavity of the acetabulum, corresponds and gives attachment to the ligamentum teres. Its internal surface is applied to the external layer; its external margin is attached to the capsular ligament, and its internal superiorly to the pubis, but inferiorly it is

free, and bounds a foramen for the passage of vessels. The internal layer of the transverse ligament is attached below to the inferior cornu, and above to the superior, where it appears to blend with the cotyloid ligament. By its external surface it is in apposition with the external layer of the transverse ligament, and its internal surface is directed towards the obturator ligament and external obturator muscle. Some fibres pass from its upper margin to the obturator ligament; but in greatest part this margin contributes to form the foramen already described for the passage of vessels. Its inferior margin affords attachment to the capsular ligament.

Round ligament. (*Ligamentum teres capitis femoris seu ligamentum inter-articulare.*)— This ligament, which was first described by Vesalius, has very improperly received the epithet *round*, inasmuch as in point of fact it is a triangular fasciculus, about an inch and a half in length, having its base attached to the acetabulum and its apex to the depression on the head of the femur. It is most advantageously placed for escaping injury in the various motions of the joint, as, independently of its corresponding to the soft cushion contained in the excavation of the acetabulum, its direction and attachments completely remove it from all danger on this score. It is attached by the superior portion of its base to the upper cornu of the notch, and to the external layer of the tranverse ligament; and by the inferior and larger portion of its base to the lower cornu, as well as to the external layer of the tranverse ligament; from these points of attachment its direction in the quiescent state of the limb, i. e. the femur being placed vertically under the pelvis, is upwards, outwards, and backwards, to its insertion into the head of the femur.*

When the joint is cut into in the recent state, there are processes seen extending from this ligament towards the circumference of the excavation; these should not be mistaken for portions or attachments of the ligamentum teres; they are folds of the synovial membrane proceeding from that ligament over the surface of the acetabulum. Situated in the rough excavation of the acetabulum, and forming a cushion for the ligamentum teres in the several motions and positions of the head of the femur, is the soft pulpy mass of fatty cellular tissue, covered by synovial membrane, already alluded to as the glands of Havers, first described and figured by that anatomist in his Osteologia Nova.

Capsular ligament.—The hip-joint is completed by a strong fibrous investment, termed capsular ligament (*capsula fibrosa ossis femoris*). This is by far the strongest and largest capsular ligament in the body. However it is by no means uniform in its strength and thickness, these being greatly increased by super-imposed fibres in those situations upon which a considerable force is exercised in certain motions of the joint. It not only embraces the articulation, but also includes the neck of the femur, to the base of which it extends from the os innominatum. Its fibres are variously directed from the os innominatum, to which they are firmly attached from the margin of the acetabulum to a considerable distance on the dorsum of that bone. Superiorly and externally they may be traced as far as the inferior anterior spinous process of the ilium in front, whilst posteriorly the great sciatic notch marks their boundary, and an arched line drawn from the inferior anterior spine of the ilium to the spine of the ischium denotes with tolerable exactness their attachment in this direction. Inferiorly and externally they are attached to that portion of the ischium situated between the cotyloid cavity and the external lip of the tuber ischii, and to this latter itself by very strong dense fibres. Superiorly and internally they arise from that portion of the ilium situated between its anterior inferior spine and the ilio-pectineal eminence, and from the pubis as far as the superior cornu of the acetabulum. Inferiorly and internally the capsule is attached to the transverse ligament of the cotyloid cavity.

By this description we perceive that the capsular ligament is firmly attached to the os innominatum; that with the exception of the portion arising from the transverse ligament its origins at all points are from an inch to nearly two inches in extent. Passing in various directions, according to their several situations, the fibres run to be inserted into the base of the neck of the femur, anteriorly into the anterior inter-trochanteric line, superiorly and externally into the surface of the bone close to the digital fossa at the root of the great trochanter, inferiorly and internally to the line leading from the lesser trochanter to the anterior inter-trochanteric line, and posteriorly it is partly reflected upwards, so as to become continuous with the periosteum of the posterior part of the neck of the bone; this reflection taking place along the posterior inter-trochanteric line, and partly inserted into that line, especially at its internal and external extremities. The reflected portion is derived from the deep fibres of the capsule, which in passing upwards to be inserted into the bone at the circumference of the head, contribute to form those bands of fibrous membrane, which are manifest on the posterior aspect of the neck of the femur on opening the capsule, being covered only by synovial membrane. These bands are sometimes of considerable strength, and they are well described and figured by Weitbrecht,* by whom they were designated *retinacula*.

We have already observed that the capsular ligament is not uniform in thickness at all points. At the outer part of its anterior surface its thickness is very considerable, being strengthened and increased by a band of fibres

* [Weber states that, in the erect posture, the direction of the ligamentum teres is vertical. See Mechanik der Menschlichen Gehwerkzeuge, p. 143, and pl. ii. fig. 1.—Ed.]

* Syndesmologia, Petrop. 1742.

of some magnitude (*accessory ligament*), arising from the inferior anterior spine of the ilium and the space beneath, from which they descend, diverging to be inserted into the anterior intertrochanteric line; these fibres are so much developed in some instances as almost to resemble a distinct ligament. At this point the capsule is nearly half an inch thick. Externally its thickness is considerable, though somewhat less than at the point last described. From the pubis a smaller and thinner band of accessory fibres may be traced towards the lesser trochanter, strengthening the capsule in this situation; between the two accessory bands in the centre of the anterior surface, the capsule is extremely thin, and sometimes wholly destitute of fibrous tissue, being altogether composed of synovial membrane, and a little cellular tissue, by which it is separated from the bursa that lies under the tendon of the psoas muscle: this bursa, moreover, sometimes communicates with the cavity of the joint through an opening in this situation.

The internal surface of the capsule invested by its synovial membrane corresponds to the cotyloid ligament, to the neck and a portion of the head of the femur. The external is covered anteriorly by the rectus femoris, psoas, and iliacus muscles, internally by the obturator externus and pectineus; posteriorly it lies upon the quadratus femoris, gemelli, pyriformis, and obturator internus, and superiorly the glutæus minimus adheres very closely to it.

The capsule of the hip-joint, although stronger, is not so long or so loose as that of the scapulo-humeral articulation, neither is it pierced by any tendon.

Synovial membrane.—To facilitate description, let us commence at the greatest circumference of the head of the femur. From this point the synovial membrane passes outwards over the neck of the bone as far as the attachment of the capsular ligament; from the bone it is reflected on to the deep surface of this ligament, along which it passes to the line of its attachment to the os innominatum and transverse ligament: along that line it is reflected again on to the margin of the acetabulum over the cotyloid ligament into the cavity, which it completely lines, and from which it is carried by the round ligament, which it invests, to the head of the femur.

Arteries.—The hip-joint is supplied with blood by branches from the obturator artery, derived from the internal iliac or from the internal circumflex branch of the femoral. These are distributed, some in the fat and cellular tissue, filling the excavation at the bottom of the acetabulum, whilst others ramify on the ligamentum teres, and are conducted by it to the head of the femur. It not unfrequently occurs that the joint receives blood from both these sources.

Nerves.—These are derived from the obturator, which uniting with the deep division of the anterior crural cause the pain to be referred to the knee in some diseases of the hip-joint.

Motions.—The motions of this joint are mostly performed by the femur upon the os innominatum, and consist of flexion, extension, abduction, adduction, circumduction, and rotation.

In slight flexion the head of the femur revolves upon its axis in the cotyloid cavity; the anterior portion of the capsular ligament being relaxed, whilst the posterior is rendered proportionally tense. If this motion be augmented to any considerable extent, the capsular ligament is relaxed to a greater degree anteriorly, whilst posteriorly, in consequence of the distance between its two points of attachment being increased, it is very tense, and rendered convex by being stretched over the head of the femur, which is now very prominent in this situation, resulting from the altered relations between it and the acetabulum. The anterior part of the head of the femur is placed against the deepest portion of the acetabulum, whilst its broad articulating surface situate above the depression for the round ligament is directed backwards, where the acetabulum is too shallow to receive it completely; it therefore forms a projection in this situation, a projection which, in my opinion, ought rather to be attributed in this instance to the natural formation of the parts than to any displacement of the head of the bone.

When excessive flexion is combined with adduction, the head of the femur glides from before backwards, and from within outwards in the acetabulum; its anterior portion is concealed in this cavity, whilst its posterior emerging lies against the capsular ligament, considerably increasing its tension. To produce these motions muscles of great power are employed; in some these agents are not confined merely to one joint, but have two opposite functions to perform, being flexors of one joint at the same time that they extend another.

In abduction, when the lower extremity of the femur is separated from the median line, its head is naturally directed downwards, its inferior portion being forced against the capsular ligament; therefore when the motion is carried to any great extent the ligament is liable to rupture, and allow the head of the femur to escape over the internal lip of the acetabulum into the obturator foramen.

In adduction the same occurs as in abduction, but in an inverse direction, with this exception, that as the motion cannot be carried so far, and as in this case the head of the femur is opposed to the deepest portion of the acetabulum, dislocation cannot occur. Simple adduction, unaccompanied by any flexion of the joint, is very limited. Let any one, while standing in the erect posture, approximate his knees, it will be found that the utmost he can do is to bring them very near to each other, but that he cannot press them against each other; if, however, the hip-joints have been previously very slightly flexed, then the knees may be easily pressed against each other, and the adduction may be carried to a much greater extent, so as to cross the legs. It is limited by the ligamentum teres and the external and anterior part of the capsular ligament.

Circumduction combining the four preceding is a compound movement, in which the inferior extremity describes a cone, the apex of which is at the joint; the head of the femur in the course of this motion successively assumes the several situations already described.

In rotation outwards the head of the femur is directed forwards and inwards, the anterior surface of the neck looks outwards, the posterior inwards resting on the brim of the acetabulum; the capsular ligament is put upon the stretch on its inner side. Any sudden jerk or violence when in this position is liable to produce dislocation upwards upon the pubis.

In rotation inwards the bone assumes the contrary direction, and the capsular ligament and ligamentum teres are equally put upon the stretch. In this case dislocation may occur either upon the dorsum of the ilium or into the sciatic notch. For this motion we have but few muscles, this position being produced merely by the tensor vaginæ femoris and anterior fibres of the gluteus medius muscles. The disparity between the number of muscles influencing the motions of rotation outwards and inwards is very striking, but this may be attributed to the direction of the acetabulum from within outwards and forwards naturally tending to produce rotation inwards. Consequently before the opposite motion can be effected there is this inequality to be overcome, and hence the disparity between the muscles.

(H. Hancock.)

HIP-JOINT, ABNORMAL CONDITIONS OF THE.—In this article we shall adopt an arrangement similar to that which we have followed in our former observations on the abnormal conditions of particular joints, and consider these states under the heads of, 1. congenital malformations; 2. the effects of disease, and, 3. the results of accident.

SECTION I. *Congenital malformation of the hip-joint.*—The peculiar affection termed by the continental surgeons congenital or "original luxation" of the hip-joint, has not in our islands attracted the notice that it seems to us to merit. When we reflect upon the very valuable additions which have been made to our knowledge of the pathology of the articulations by British writers, and observe their silence upon this abnormal state of the hip-joint, we might be led to infer that this malformation had no existence in these islands; this, however, unfortunately is not true.

In the very valuable museums in London we can easily recognise many unquestionable specimens of this congenital malformation of the bones of the hip-joint. In Dublin we know some living examples of it, and our museums contain preparations shewing some of its varieties and most of its usual anatomical characters.

At the meeting of the British Association in Dublin in the year 1835, Dr. Hutton made some interesting observations on this affection to the section of medical science, and gave an account of a well-marked example of it affecting one hip-joint. On that occasion Dr. Handyside observed that he had met with a case of congenital luxation of *both* hip-joints, in a subject which had been brought into his anatomical rooms at Edinburgh; and he added that the appearances of the joints corresponded very closely with those noticed by Dr. Hutton. The Professor of Anatomy and Surgery to the University of Dublin, Dr. Harrison, laid before the Surgical Society last winter the results of two accurate post-mortem examinations which he had made of this malformation of the hip-joint. The history of these cases, as far as Dr. Harrison could make it out, shewed that the subjects of them had during life presented the ordinary signs of the infirmity in question. In one of them, one hip-joint only was affected; in the second, not only was the arrest of development such as to leave the acetabulum a plane surface by depriving it of border of any kind, but the ligamentum teres, the head and greater part of the cervix femoris were also deficient on both sides, so that the femora at their upper extremity presented a rude resemblance to the ossa humeri. In this case (*fig.* 307) the capsular ligament was of an extraordinary length, and permitted the rudiment of a head and neck, with the trochanter major, to ascend and descend on each side on the dorsum ilii, and to pass backwards on the ischium to the very edge of the ischiatic notch, in the different movements of the patient.

The case of congenital malformation of the hip-joint has not escaped the notice of continental surgeons,* although perhaps the nature of the affection had not fully attracted the attention of the profession until Dupuytren† gave the results of his observations of twenty-six cases of this malformation which were presented to him in the course of his public and private practice. He seems to have met with the affection more frequently in the female than in the male, in the vast proportion of twenty-two females to four males, and from his description it would appear that he has usually found, in the same individual, both hip-joints affected. In the cases we have witnessed, we have not observed this very great preponderance of female over male cases; and although we have noticed the defect to be double in the same individual, we have more frequently observed but one joint engaged. This is of importance to be recollected, as mistakes in our diagnosis are more likely to occur when only one joint is affected, than in those cases in which the defect is double in the same individual.

The characters, says Dupuytren, of this "original luxation" are nearly similar to all those we notice belonging to the ordinary luxation upwards and backwards on the dorsum of the ilium: the limbs are shortened and inverted; the superior extremities of the femora are carried upwards, backwards, and outwards, into the external iliac fossa, where a considerable prominence can be seen, caused by the unusual elevation of the great trochanter; the thighs, unusually slender, are obliquely directed down-

* Palletta, Lafond, Callard, Bellomeir.

† Repertoire d'Anatomie, Leçons Orales.

wards, forwards, and inwards, and this obliquity is greater in proportion as the pelvis is broader; hence the deformity in the female increases about the age of puberty: there is, in consequence of this breadth of the pelvis, a tendency of the limbs to cross each other inferiorly, and the movements they are found to enjoy are very limited, particularly those of abduction and rotation; hence the individual finds great difficulty in performing the different functions belonging naturally to the inferior limbs. When we examine a person with this double defect standing, we are struck at once with the apparent want of proportion between the superior and inferior parts of the body, with the imperfection of the lower limbs, and with the peculiar attitude of the patient. The trunk is fully developed, says Dupuytren, whilst the inferior limbs, short and slender, seem as if they were suited only to an individual of smaller stature. When we view the patient laterally, we observe that the chest and superior part of the body are carried very much backwards, while the anterior part of the abdomen is thrown very prominently forwards, and at the same time we notice there is a corresponding hollowing posteriorly in the region of the loins, and that the nates jut out backwards most conspicuously. A very characteristic circumstance relative to the standing position of these malformed individuals is, that they rest on the ground only by the anterior part of their feet; most of the peculiar circumstances relating to the attitude of these persons follow as the necessary consequence of their hip-joints (or in other words the centre of motion of the lower extremities) being placed behind their ordinary situation with respect to the pelvis.

If a patient so unhappily constituted wish to walk, we see him incline the superior part of his body towards the limb which is now intended to support the weight of the body; he as it were balances himself on the anterior part of the foot of this side; he next raises from the ground the opposite foot, and transfers laboriously his weight from one side to the other—indeed each time this motion takes place, the head of the femur which receives the weight of the body, ascends upon the external iliac fossa, and is sustained by its ligaments and muscles; the pelvis is at the same time depressed, and all the signs of displacement become more obvious on this side, while they diminish sensibly on the other; in a word, progression thus becomes an awkward and waddling movement.

It may appear singular that running and leaping should be executed by these patients with more facility than walking, yet such is the fact; for in those exertions the energy of muscular contraction, and the rapidity with which the weight of the body is transferred from one limb to the other, are such, that the want of a true acetabulum is not so much felt as in walking. Any of these exercises, however, very soon induce fatigue, which we can readily account for when we recollect the friction which the head of the femur must undergo against the side of the pelvis, and the great efforts which the muscles have to sustain in supporting the weight of the body, during the balancing or waddling motion described. When persons afflicted with this malformation lie down horizontally on their back, the signs of their infirmity become so slight as to be scarcely perceptible, because in this situation of complete repose the muscles do not draw upwards the lower limbs, nor does the weight of the body depress the pelvis. Dupuytren found that in this situation of the body he could elongate or shorten the affected limbs of the patient; to elongate them, he says, it was merely necessary to pull slightly downwards at the knee or ankle, and to shorten them, to push them upwards; the head of the femur will undergo in such experiments a displacement of one, two, or even three inches (Dupuytren), and all these displacements will be affected without causing any pain and with the greatest ease, convincing us that no proper cavity exists fit to receive and retain the head of the femur.

It is of importance that this congenital malformation of the hip-joint should be well understood, not only that dangerous errors in diagnosis may be avoided, but that this defect, when it really exists, may be recognized early, so that timely and proper treatment may be resorted to. It presents to the superficial observer many of the signs which belong to a disease of the hip-joint; and of the cases seen by Dupuytren, few, he says, had been recognized by the surgeons previously consulted: almost all these unfortunate patients had been subjected to painful and worse than useless treatment. Many individuals afflicted with original luxation of the hip-joint have been, in consequence of the errors or ignorance of their medical attendants, condemned to keep their beds during many years. "I have seen others," says be, "whom they had forced to submit to numberless applications of leeches, blisters, issues, and moxas; among others I remember the case of a young girl, who suffered the application of twenty-one moxas around the hip, without this barbarous treatment having effected any favourable change in the situation of this unfortunate patient."

We can easily distinguish this original luxation from disease of the hip-joint, as there is no pain felt by the patient either in the hip or knee; there is neither heat, swelling, nor abscess, no evidence of inflammation chronic or acute, nor is there any cicatrix; consequently nothing exists which can induce us to believe that heretofore there ever existed any abscess or fistula, consequences so very usual in cases of disease of the hip-joint, when this disease has arrived at the stage of luxation.

Dupuytren's description of this condition of the hip-joint seems to apply altogether to the case in which both joints are engaged; when one articulation only is affected, so far as it is concerned, the features of the congenital defect are just as well marked as those above alluded to. The usual signs of the dislocation upwards and backwards on the dorsum ilii, and the same range of ascent and descent of the head of the femur on the ilium and towards the ischiatic notch, is noticed as in the former case; as, however, the weight of the body is almost entirely thrown on the unaffected limb, the latter becomes much larger and stronger than usual, while the malformed limb falls into a state of more or less of atrophy from want of use; its circulation in general seems more languid, and its nervous energies and temperature are less than those of the well-formed extremity; add to this, as we have already noticed (what might be expected,) that in consequence of the centre of gravity being so uniformly thrown on the sound limb, a lateral curvature of the spine takes place, and a great mobility of the sacro-lumbar articulation exists.

Anatomical characters of this affection.— Opportunities for ascertaining the anatomy of this congenital defect, whether both hip-joints be implicated or one only affected, are very rare. Although Dupuytren has seen so many patients afflicted with this malformation, he has had very few opportunities, he says, of studying its anatomy, because the affection is not a disease, but an infirmity which has no tendency to shorten life. With respect to the *muscles* he has remarked, that some of them around the joint are found to be well developed, while others are in a state of atrophy: the first are those which have still preserved their functions, the second are those whose action has been restrained by changes induced in the position and form of the parts: some of these latter, he says, are reduced to a sort of yellow fibrous tissue, in which we can scarcely discover muscular fibre.

The cotyloid cavity of the os ilii in some cases scarcely can be said to exist, so irregular are the traces of it; sometimes an irregular bony eminence occupies its place, having no cartilaginous covering, no rudiment of cotyloid ligament; it is merely surrounded by resistant cellular tissue, and covered by muscles which pass by it to be inserted into the little trochanter. Sometimes, says Dupuytren, I have found the ligamentum teres of the articulation much elongated, flattened superiorly, and worn as it were in certain points by the pressure and friction of the head of the femur; the latter is lodged in a cavity analogous enough to that which we find formed in cases of luxation upwards and outwards, which have been left for a long time unreduced. This cavity (if such it can be called) is situated in the external iliac fossa, above and behind the usual situation of the cotyloid cavity, at a height proportioned to the shortening of the limb, or degree of ascent of the head of the femur. The superior portion of the femur preserves in all its parts, its form, its dimensions, and its *natural relations*, only the internal side, and the anterior part of the head of this bone has sometimes lost its rounded form, a circumstance which would appear to result from the friction which it has been subjected to by its frequent contact with parts which have not been organized to receive it.

The writer's observation does not entirely correspond with this account of the superior portion of the femur preserving its form and natural relations with the rest of the bone. He has usually noticed that the head of the femur has lost its spheroidal shape, and presents somewhat of a conical appearance, as Dupuytren well describes; but two other circumstances he has observed in almost all the cases he has examined, whether in the recent dissections he has himself witnessed, or in the macerated bones he has seen in Dublin or elsewhere:— 1st, that the neck of the femur, instead of having its axis directed, as it naturally is, from behind forwards, upwards, and inwards, has in this malformation lost its usual relation with the shaft of the thigh-bone, and the axis is directed upwards, and almost directly forwards. This alteration in the direction of the axis of the neck of the thigh-bone did not escape the observation of Dr. Hutton, in his remarks on his case already alluded to; he expressed his idea of the altered direction of the axis by saying that the axis of the neck in this case fell *directly* on the *anterior* part of the upper extremity of the shaft: "the relative position of the neck and shaft appeared as it might be supposed to do if, the lower portion of the femur being fixed, the upper portion were twisted *forwards*, the head moving through one fourth of a circle." 2dly. The other circumstance which the writer has noticed must be viewed in connection with this altered direction of the usual axis of the neck of the femur just alluded to; it is that in all the cases he has as yet seen of this original luxation of the femur, the head of the thigh-bone, instead of being directed *backwards*, as it is in the ordinary luxation on the dorsum ilii, on the contrary has been directed *forwards*, and has been placed beside the anterior inferior spinous process of the ilium, while the trochanter major has been directed backwards on the dorsum ilii.

It is rather strange that a relative position of the bones of the hip-joint, so different from what has been observed in the ordinary dislocation upwards on the dorsum ilii, and one so usually met with in the case of original luxation of the hip-joint, should have heretofore escaped observation.

In one of the specimens of malformation of the hip-joint preserved by Mr. Harrison in the Museum of the University of Dublin, this relative position of the femur and the anterior inferior spine of the ilium can be noticed, while the trochanter major is placed posterior to both. And in two preparations preserved in the Richmond Hospital Museum, the same observation can be made,—the atrophied heads of the thigh-bones are directed forwards; the great trochanters lie behind these heads on the sides of the pelvis.

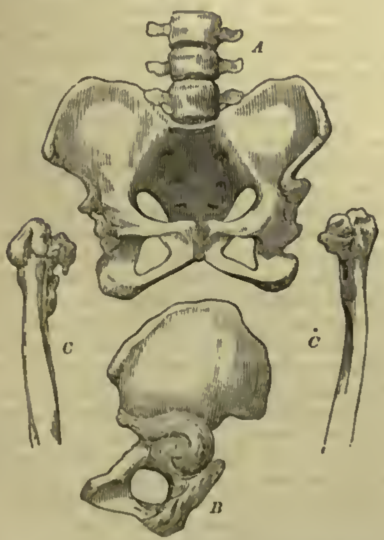
These are circumstances important for us to keep in mind, when we are considering the diagnosis of the various affections of the hip-joint.

We say that such a remarkable circumstance demands notice from us, because in the cases of this affection we have as yet observed in the living subject, the thigh, leg, and foot of the malformed limb has not been so much inverted as it always is in the ordinary luxation upwards and backwards on the dorsum ilii; indeed in the case of a lad, named Hannon, whom the writer has frequently examined, (*fig.* 308,) the thigh, leg, and foot were by no means inverted, the ordinary aspect of the front of the femur, patella, &c. was directed as much forwards as it naturally is; the shortening and other signs of luxation upwards on the dorsum ilii existed, and, in consequence of the emaciated state of the limb, the relative position of the head and neck of the femur, above adverted to, was easily recognized, when the hand was laid upon the head of the bone, and a strong movement of rotation outward was communicated to the malformed extremity.

We do not mean to assert that in all cases this relative position of the head and neck of the femur will be found to exist; in this, as in other congenital defects, much variety may be expected to be found. When in these cases the soft parts are removed, the bones of the pelvis present appearances which are remarkable enough, although we believe that these appearances have heretofore escaped the observation of anatomists, who seem to have confined their attention to the abnormal condition of the head of the os femoris and the acetabulum.

The anterior spines of the ilium, particularly the inferior, we have usually found to be directed very much inwards, towards each other (*fig.* 307); the external iliac fossa to be more convex, and the internal iliac fossa more concave than usual: beneath the anterior inferior spine we notice a deep groove directed outwards, through which the united tendon and fibres of the psoas and iliacus pass to the lesser trochanter of the femur, which process is always in these cases placed so much behind as well as above its normal situation. The sub-pubic angle is remarkably obtuse, the rami of the pubes and ischia are very oblique, and the tuberosities of the ischia greatly everted.

Fig. 307.



Many of these which we would call characteristic features of the double congenital defect now under consideration have heretofore escaped the notice of all those who have written on "the original luxation" of the hip-joint. Sandifort in his Museum Anatomicum has, however, given a delineation of a pelvis belonging to a subject in which he says both hip-joints were found dislocated: what this author has there drawn was probably not understood in his day, but any one who has seen many specimens of the deformity we are now endeavouring to describe, will agree with us, we are sure, in considering Plate LXIV a true representation of congenital luxation in both hip-joints.

When only one of the hip-joints is affected we find a lateral curvature of the spine to exist, and the bones of the pelvis to be in a state of atrophy on the malformed side. The portions of the os pubis and ischium which circumscribe the thyroid foramen are generally long and slender, and the tuberosity of the ischium is at a greater distance from the symphysis of the pubis on the malformed than on the opposite side.

Many of the anatomical characters we have here stated may be supposed to be the gradual result of causes acting from early infancy on bones as yet soft and cartilaginous. The weight of the body so constantly acting unfavourably on badly-formed bones and over-distended ligaments, the efforts of muscles by their repeated exertions endeavouring to supply the deficiencies in the ligaments and in the articular surfaces of the bones, are so many causes which must act on and alter the direction of the head and neck of the femur, distort the tuberosities of the ischia, and draw towards the middle line the spines of the ilium; but we may inquire does the first fault in these cases consist in the arrest of development in the bones? in the muscles? or should we look to the nervous system for the primitive source of these intra-uterine defects? These are inquiries which cannot, we believe, in the present state of our knowledge, be satisfactorily replied to. Andral remarks that in almost all cases in which one of the cerebral hemispheres is atrophied we find the limbs of the *opposite* side less developed than natural; but he does not venture to express an opinion as to whether the imperfect development of the brain is the cause of the malformed extremity, or the repose and want of use of the latter the reflected cause of the atrophy of the brain. No doubt we have, in one solitary instance already quoted,* shewn that a congenital malformation of the left hip-joint coincided with a deficiency of the cerebral convolutions of the right hemisphere of the brain, but this coincidence we have reason to believe must be exceedingly rare.

Some surgeons of eminence, whose opinions must have considerable weight with the profession, have stated it to be their belief† that "a simple paralytic condition of the muscles of the lower extremity, as a consequence of the irritation from teething arising during infancy," is the starting point of disease in these cases,

* Dr. Hutton's case, Dublin Journal, volume viii
† See Lancet for 1825-6.

and would of course consider all the phenomena of the malformation we have dwelt on, as the mere consequences of the paralytic condition of the muscles. With such a doctrine we are not at all disposed to agree; in no other instances do we find paralysis produce similar results; besides, the muscles of the hip-joints in many of these cases seem in the exercise of running and leaping endowed with very energetic powers of action. It is perfectly clear that to refer all in these cases to a paralysis of the muscles is quite unsatisfactory, because the abnormal conditions of the several structures around the affected joints are in these cases so varied and numerous that we feel that they never can be rationally referred to this single source. In some instances we find a very well marked oval eminence on the side of the pelvis for articulation with the malformed head of the femur, while no trace of cotyloid cavity exists; in some the defect is slight, in others the deformity is great; thus the ligamentum teres may be a long and slender thread without vascularity or strength in some cases, in others we have seen it four inches long, and at the same time of considerable breadth; while in others again no trace of ligamentum teres or head of the femur existed, the imperfect representation of a head being retained by a lengthened capsular ligament, supported by the smaller muscles around the malformed articulation.

These observations satisfy us that we cannot refer to "paralysis of the muscles of the lower extremity as a consequence of irritation from teething arising during infancy," the phenomena that this affection termed congenital malformation of the hip-joint presents.

We have no doubt seen some instances in which a certain paralytic tendency and other congenital defects seemed combined with the malformation of the hip-joint; but again we have seen many others in which there was no paralytic tendency, and in which no other defect than a double congenital luxation of the hip-joint existed; and in Dupuytren's twenty-six cases no mention is made of paralysis, nor of atrophy of the cerebral convolutions.

We confess we are glad to feel ourselves able successfully to oppose the hopeless idea of paralysis of the muscles being in fault, because we have reason to believe that mechanical treatment of the malformed hip-joint has succeeded, when early applied, in lessening the infirmity. The idea of paralysis of the muscles being the root of the evil, precludes all hope of mechanical treatment being at all serviceable to these unfortunate individuals.

History of a case of congenital malformation of the left hip-joint, with the anatomical examination of the articulation.—A man named John North, æt. 31, of weak intellect, was admitted under the care of Dr. Hutton, July 1835, into the Richmond Hospital; he was afflicted with a most severe form of inflammation of the larynx, trachea, and lungs. I was asked to visit him, and report my opinion as to whether the operation of tracheotomy should be performed, or whether such a measure would be calculated to relieve the urgent symptoms of dyspnœa which seemed in this case to threaten suffocation. While I was examining the patient he wished to get out of his bed, and then I noticed that besides having an atrophied and contracted state of the left forearm and wrist, his left lower extremity was deformed, and seemed much shorter than the opposite limb. Upon even a very superficial view of this left hip-joint and the position of the limb, all the more obvious features of a dislocation upwards and backwards on the dorsum ilii, were recognized. Upon inquiry it was ascertained, as far as could be from such a patient and from his ordinary attendants, that the hip-joint had never suffered any accident, and that, although he had issues inserted, he never had had any acute disease or suffering in the deformed hip, which deformity, with the contraction of the upper extremity, was coeval with their earliest recollections of him.

I agreed with those in consultation on the case that the state of the lungs would speedily bring about the death of the patient, and that no operation, such as tracheotomy or laryngotomy, should be resorted to. I also expressed my conviction that the left hip-joint presented a very fine illustration of the abnormal state of this articulation, which Dupuytren and others had described as a congenital or original luxation of the hip. The next day the patient died of the inflammatory affection of the chest, and a post-mortem examination was made by Dr. Hutton, at which Mr. Smith and the writer were present. There were observed the same appearances of luxation on the dorsum ilii as before noticed; the body being held up and maintained in the erect posture, the pelvis was seen to be very oblique and elevated towards the malformed side, the left lower extremity seemed three inches shorter than the right or perfectly formed limb, but on measurement it was plain that the deformed limb was not really shortened, but had merely ascended on the dorsum ilii. The trochanter major (naturally on a level with the horizontal ramus of the pubis) was elevated two inches above this bone. In the prominence and elevation of the great trochanter, in the semiflexion and adduction of the limb, in the circumstance of the motions of rotation and abduction being limited,—in all these the case nearly resembled the ordinary luxation on the dorsum ilii, whether produced by accident or the result of an old caries; but the history of the case was opposed to either of these conjectures, and the marks of issues placed there through ignorance were not to mislead us, or induce us to alter our opinion already expressed, as we were well aware that in almost all the cases seen by Dupuytren similar evidences of surgical ignorance of the true nature of the affection had existed. Besides the unusual prominence and elevation of the trochanter major already mentioned, the head of the femur could itself be plainly enough felt, when a movement of rotation outwards was given to the shaft of the bone; but when the limb was forcibly elevated or extended, even now in the dead subject, its range of movement of ascent and descent was not more than half an inch; in this particular this case differed from those given by Dupuytren, because in his cases the range of motion of ascent and descent of the head of the femur on the os innominatum, which could be communicated, amounted to two inches.* The body having been placed on its face, and the integuments removed from the glutæus maximus, this muscle looked somewhat paler in its colour than natural, its lower margin (which in the natural state has a descent of obliquity amounting to three inches) was placed nearly transversely. When this muscle was removed, the trochanter major presented itself; it lay on the dorsum of the ilium, near to the ischiatic notch, above the pyriformis and below the range of the glutæi (medius et minimus), which were in a state of atrophy. The head of the femur, smaller than usual, was in advance of the great trochanter, and was placed immediately external to the anterior inferior spinous process of the ilium, and was here covered immediately by the capsular ligament and some scattered fibres of the lesser glutæi: the tensor vaginæ femoris lay in front of the head of the bone.

The pyriformis and quadratus were very oblique in their course, passing upwards and outwards: all the muscles in the front of the thigh, such as the pectinalis and other adductors, passed from the os pubis outwards with a degree of obliquity three or four inches less than natural. The psoas magnus was drawn a little outwards, and its edges were twisted so that the internal edge was directed backwards and its external edge forwards. All the muscles of this extremity were smaller and less developed than those of the other; but with the exception of part of the obturator externus which looked fatty, their fibres had a natural appearance. There were no marks of previous violent injury or chronic disease.

The capsular ligament was attached as usual to the circumference of the acetabulum on one part, and to the base of the neck of the femur on the other; it was strong and at the same time elongated, so as to allow the head of the femur to rest on the dorsum of the ilium, but ligamentary bands passed from this part of the ilium to the external surface of the capsule, where it invested the head of the femur; these must have served to strengthen and fix the capsule and thus prevent any great range of motion over the ilium. When this capsule was cut into, the head of the femur was found somewhat conical in its form and much smaller than usual; the cartilaginous covering, thin and of an azure hue, did not form a very uniform or perfect covering for the head of the bone; there seemed no deficiency of synovial fluid within the joint. The inter-articular ligament or ligamentum teres, as it is called, presented a very remarkable appearance; it was of unusual dimensions, being more than four inches long; of a yellowish colour like tendon, and as thick as the tendo Achillis near the os calcis; instead of being firm, round, and thick, it was soft and could be easily spread out to the breadth of an inch: its fibres were connected by means of a thin transparent membrane like a synovial structure. This substitute for the normal ligamentum teres was continuous with the cotyloid ligament, or arose from that part of it which completes the notch of the acetabulum within. From this origin or attachment, the ligament passed, as it were, from within outwards and upwards to be attached to the head of the femur, presenting in its course an inverted arch, the cavity upwards and inwards, the convexity downwards and outwards. On its inferior surface it corresponded to the head of the femur, where it was hollowed out from before backwards, so as to accommodate itself to the head of the bone, for which it formed a kind of cup which followed the movements of the femur, affording it always a receptacle as the inter-articular cartilage does for the condyle of the lower jaw. This broad ligament had no connexion by synovial folds or fibrous productions with the bottom of the acetabulum. The cotyloid ligament was flattened out round the brim of the acetabulum, and was otherwise imperfect: the fatty and vascular cellular structure named Haversian gland existed in rather large quantity.

When a comparative view of the bones of the pelvis and lower extremity of each side was taken, it was manifest that the left lower extremity was in a state of atrophy, that the thigh-bone was straight and slender, and that the atrophy extended downwards to the bones of the leg, and included also the whole of the left os innominatum; the anterior spines and crest of the ilium were inverted, the internal iliac fossa was much deepened, and the external surface of the ilium rendered more convex than usual. The rami of the os pubis and ischium seemed more attenuated and slender than those of the opposite side, and the foramen ovale wider. The circumference of the acetabulum of this side included nearly as large a space as usual, but the upper and outer portion of its brim or its supercilium was deficient. This cavity was shallow, its surface scabrous or uneven, and was no where invested with cartilage; a flattened surface above it marked the point of habitual contact of the head of the femur and ilium: the bone was not excavated in this situation to receive the head of the femur, which was retained here, as already mentioned, by ligamentous bands, which extended from this part of the ilium to the external surface of the capsular ligament. The femur, it has been said, was atrophied at this side and slender, but it was of the same length as the opposite bone, diminished only in the circumference of the shaft. The axis of the head and neck was directed from the shaft of the bone upwards and inwards, but it was straighter, and its direction was by several degrees more forward than natural.

As we have detailed this case merely as an illustration of the congenital malformation of the hip, and do not wish here to enter into minute particulars as to the morbid appear-

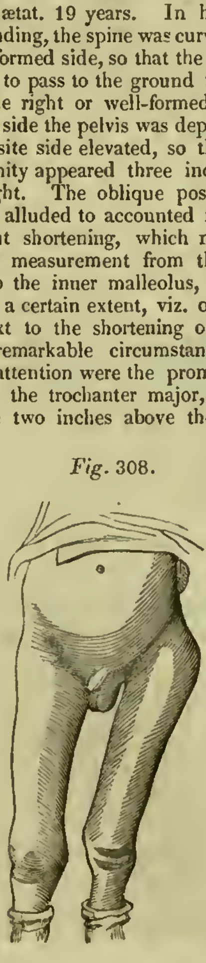
* See Dr. Hutton's account in the Dublin Journal, vol. viii.

ances which the post-mortem examination further disclosed, we merely state that evidences of diffuse inflammation of the mucous and submucous tissues of the pharynx and larynx, with purulent infiltration in the submucous tissue, existed with extensive bronchitis, as well as splenization of the lungs. It was moreover discovered that the right hemisphere of the brain was deficient, and that a cyst five inches in length and between two and three in its transverse diameter occupied the interval (which was an inch in depth) between the surface of the atrophied brain and interior of the calvarium; this cyst was filled with limpid serum.

The whole of the left upper extremity was in a state of atrophy, flexed at the elbow and wrist-joints, and the forearm and hand were rigidly pronated.

A case of congenital luxation of the left hip-joint very similar to the foregoing was under the writer's observation for some time as an out-patient of the Richmond Hospital. This lad was on different occasions seen and prescribed for by Dr. Hutton, who first recognized the nature of the case, and the other surgeons of the institution. His name was Martin Hannon; he was a labourer, ætat. 19 years. In his ordinary attitude, standing, the spine was curved laterally to the well-formed side, so that the line of gravity seemed to pass to the ground through the centre of the right or well-formed thigh and leg: on this side the pelvis was depressed, and on the opposite side elevated, so that the left lower extremity appeared three inches shorter than the right. The oblique position of the pelvis above alluded to accounted for much of this apparent shortening, which nevertheless, by accurate measurement from the spine of the ilium to the inner malleolus, was proved to be real to a certain extent, viz. one inch and a half. Next to the shortening of the limb, the most remarkable circumstances which caught our attention were the prominency and elevation of the trochanter major, which was found to be two inches above the horizontal

Fig. 308.



ramus of the pubis. The trochanter major was also behind its usual situation (*fig.* 308). The hip-joint possessed a certain degree of the motions of flexion and abduction, and when the patient was directed to extend the thigh backwards, the motion about the sacro-lumbar articulations seemed preternaturally free. When the hand was placed on the left hip-joint, the head of the femur could be felt plainly to be situated in a very unusual position, namely, forwards and upwards, close to the anterior inferior spine of the ilium, and in advance of its neck and the great trochanter, which lay towards the ischiatic notch: if now a motion of rotation outwards were communicated to the femur, the trochanter major moved backwards, while the head of the femur rolled forwards and outwards; and so very thin was the patient that the head of the bone could be seen and easily felt moving in this novel situation. The deformed thigh was at its upper part thrown much outwards (*fig.* 308), and to recover, as it were, this deviation outwards above, it passed much inwards towards its lower extremity; the thigh and leg were cold and atrophied, and the poor lad had also that malformation of the ankle called valgus.

He walked with the assistance of a stick, and in consequence of the double defect of the left hip-joint and ankle very imperfectly.

The sound limb, which seemed, in standing, to bear the whole weight of the body, was very muscular, and was larger in proportion than to be expected, when compared with the left or deformed leg, thigh, chest, and upper extremities, which last presented no peculiarities.

Such were the notes the writer had taken of this case in December 1837, when the lad applied to him at the hospital to be relieved of an indolent ulcer he had on the weak limb. In the beginning of the spring of this year he became affected with phthisis, and died of that disease in the Whitworth Hospital on the 12th June, 1838. Mr. Smith had a cast taken of the lower part of the body, pelvis, and lower extremities, which is preserved in our Museum. The interior of the thorax presented the usual effects of phthisis.

Left hip-joint.— The muscles around the joint were remarkably pale and greatly attenuated; they held the same position relatively to the head of the bone, as in the preceding case of North, but they were more atrophied; in many places all appearance of muscular fibre was lost, and its place supplied by a yellow fatty fibrous tissue. The muscles of the rest of the extremity, particularly the gastrocnemius and solœus, were in a similar condition. The sciatic nerve had not a very healthy aspect; it was yellowish; and its fibres, though firm, were more loosely connected than usual.

The capsular ligament was remarkably thick, and was lined on its interior or synovial surface with a very red vascular membrane, like scarlet cloth. The internal ligament of the joint or ligamentum teres was fully three inches long, and much stronger than usual (*fig.* 309); it

Fig. 309.

grew to the cotyloid ligament at the notch, as is usual, and had no other connexion with the acetabulum, which contained no Haversian gland, and was not lined by cartilage. The cotyloid ligament was very flat and imperfect.

Bones.—In the general aspect of the bones of the pelvis and of the femur, there existed a very striking resemblance between this case and the former detailed. The os innominatum of the left or deformed side, together with the femur and other bones of the left lower extremity, were much smaller than the os innominatum and bones of the right lower extremity; the former, besides being deformed, were also in a state of atrophy in circumference and length, while the latter were evidently larger and better nourished than one would expect to find them in so delicate an individual. In a word, there was a compensatory growth of the skeleton on the right side, as it were to make up for the deficient growth of the left or malformed side. The head of the right femur and the corresponding acetabulum were both very large, the right half of the pelvis too, in all its bony prominences, was well marked, and the anterior spines of the ilium were inverted; the inter-vertebral substance intervening between the last lumbar vertebra and base of the sacrum was much thicker than usual.

Section II. *Disease.*—The abnormal appearances we notice in the articulation of the hip, produced by disease, are usually the result of inflammation, which may have been either acute or chronic; arising either in the synovial membrane, the cartilage, or the bone. Indeed, in modern works on the diseases of the joints, we have laid down for us rather positively the symptoms and anatomical characters of synovitis, chondritis, and osteitis; but much as we would wish to adopt an arrangement that the pathology of Pinel and Bichat would suggest, and which comes commended to us by the experience of Brodie, we do not think that this arrangement can be strictly adhered to. In acute rheumatic arthritis, we have the synovial or fibro-synovial structures of the articulation engaged, with little, if any, implication of the cartilage or bone, but in any of the cases commonly denominated "disease of the hip," the inflammation, as far as our experience has gone, never long confines itself to any one structure entering into the composition of the joint. In a work, however, like this, the opinions of the highest authorities on such a question must be quoted. According to Sir Benjamin Brodie,* synovitis coxæ, or inflammation of the synovial membrane of the hip-joint, may take place in different degrees of intensity; but for the most part it has the form of a chronic or slow affection, which, while it impairs, does not destroy the functions of the articulation. In the hip, less frequently than in other joints, is the fluctuation of the effused fluid perceived, but the existence of swelling is sufficiently evident beneath the muscles: there is fulness of the groin and pain, which is not "referred to the knee, as in cases of ulceration of cartilage, but to the upper and inner part of the thigh, immediately below the origin of the adductor longus; the weight can be borne on the affected limb, and pressure against the heel gives no pain; this (the pain) is often severe, yet it does not amount to that excruciating sensation which exhausts the powers and spirits of the patient, in whom the cartilages of the hip are ulcerated."

The following case Sir B. Brodie adduces as an example of inflammation of the synovial membrane of the hip, terminating in dislocation.

Master L.,† being at that time about eight years of age, was attacked towards the end of September, 1824, with what was believed at the time to be inflammation of one of the parotid glands, attended with a good deal of fever; after six or seven days, and apparently in consequence of the application of cold lotions to the cheek, the inflammation left the parotid gland, and attacked one shoulder and arm; and at the end of two or three days more it left the shoulder and attacked one of the hips. For six or eight weeks he suffered most severely from pain referred to the inside of the thigh, extending from the pubes as low down as within two or three inches of the inner condyle of the femur, and attended with a great deal of fever. There was no pain in the knee. The surgeon who was then in attendance applied leeches to the hip, lotions, &c. &c., and afterwards made an issue with caustic behind the great trochanter. The fluctuation of fluid was perceived at the posterior part of the hip; and it was supposed that an abscess had formed; however, no puncture was made, and the fluid gradually became absorbed. In March, 1825, Master L. was sufficiently well to be able to walk about, but it was discovered that the limb was shortened. In November, 1825, Sir B. Brodie was consulted respecting him; at this time there were all the marks of a dislocation of the hip upwards and outwards, the limb was shortened, the toes turned inwards, and the head of the femur was distinctly to be felt on the posterior part of the ilium, above the margin of the acetabulum.

Now, if we may be permitted to give an

* On Diseases of the Joints, 3d edit.

† Case XI. Brodie, page 51, 3d edition.

opinion as to this case, we would certainly question much the correctness of the conjecture, that the inflammation of the hip-joint was altogether limited to the synovial membrane: no doubt, so far as the hip was concerned, the inflammation began in the synovial structures; but who can doubt that in this case the cartilages became secondarily engaged, that the acetabulum itself was after a time implicated, and that an abscess had formed? For our parts, we have little doubt that all the structures entering into the composition of the articulation were implicated in the inflammation of the joint.

It has been above stated, as the opinion of the author now cited, that synovitis has for the most part the form of a chronic affection, but as a proof that a disease, apparently slight, and of a part no way concerned in the vital functions, may produce such a degree of disturbance of the constitution as rapidly to occasion death, he adduces the following case.* Sir B. Brodie considers it a case of inflammation of the synovial membrane, (synovitis coxæ,) which ran its course to a fatal termination in the short space of a week.

A young lady, nine years of age, being at play on the 1st of January, 1808, fell and wrenched her hip; she experienced so little uneasiness, that she walked out on that day as usual; in the evening she went to a dance, but there was seized with a rigor, was carried home, and put to bed. Next morning she was much indisposed, and complained of pain in the thigh and knee; on the following day she had pain in the hip, and was feverish. These symptoms continued; she became delirious, and died just a week from the time of the accident. On inspecting the body on the following day, the viscera of the thorax and abdomen were found in a perfectly healthy state. The hip-joint on the side of the injury contained about half an ounce of dark-coloured pus, and the synovial membrane, where it was reflected over the neck of the femur, was destroyed by ulceration for about the extent of a shilling. This was an awful case, and such, fortunately, are rare; however it has been our lot to witness some very similar in their course and unhappy termination, and we have always looked upon them as specimens of that terrible disease "diffuse inflammation."

The next case, No. XVI. in Sir B. Brodie's work,† we look upon exactly in the same light. The following the writer saw under the care of his lamented friend, the late Dr. M'Dowel.

Synovitis coxæ with periostitis succeeding to a fall on the hip—death in eight days.—Peter Neale, æt. 12, admitted into the Richmond Surgical Hospital, January 11, 1833. Four days previous to admission he fell from a wall of moderate height, on the left hip, which was so much contused, that he was unable to stand upon the limb, and was carried home. The pain and constitutional disturbance increased daily; on admission it was found that the left hip-joint was very tense and swollen; the pain was so excruciating that he was unable to move in bed without assistance; his countenance anxious, sunken, and expressive of intense suffering, tongue furred, black sordes on his teeth; he was delirious, and screamed without intermission; his hip became more tender, tense, and swollen; he also now complained of pain in the right shoulder and elbow. To these symptoms succeeded drowsiness, tendency to coma, occasional muttering delirium; he now had a peculiarly wild and frightened look. He died on the morning of the 15th; the fourth from his admission into the hospital, and the eighth from the time of the fall on the hip. The post-mortem examination took place four hours after death. On cutting through the left glutæal muscles, matter issued from numerous small points; the muscular fibres were of a deep red colour; the periosteum was detached from the entire of the ilium by a quantity of dark brown pus, which passed through the great sciatic notch, and separated the membrane from the whole concavity of the bone, which was of a pink colour; the fluid had passed through a small ulcerated opening in the capsule of the joint from the cotyloid cavity; small portions of lymph were found on the head of the bone, and the synovial membrane, covering the fatty mass at the bottom of the acetabulum, bore evidences of acute inflammation having existed here; and the surface of the synovial membrane was also covered with lymph. There was no ulceration of the cartilages. The right shoulder-joint healthy. In the right elbow-joint a fluid in small quantity, resembling that which was contained in the hip-joint.*

Cartilage.—The inflammation and ulceration of the cartilages of the hip-joint are said by Sir B. Brodie to be most frequently met with in those who have passed the age of puberty, and who are under thirty or thirty-five; but that they are sometimes seen in young children, and occasionally in those advanced in life: when the cartilage covering the bones which enter into the articulation of the hip-joint are affected, the progress of the case is slow; the pain is at first trivial, the degree of lameness slight; but as there is no effusion of pus or increased secretion of synovial fluid, there is no appreciable external swelling; but the pain, the wasting of the limb, and lameness gradually increase, with the spasmodic startings, and abscess and dislocation follow, as in cases in which the inflammation originated in other tissues. To exhibit the disease of the cartilage where this structure alone is engaged, we must have some opportunity of witnessing it in an individual who has died of some other complaint. The following case well illustrates the opinion of the first authority on such a subject.

John Catmah, 44 years of age, was admitted into St. George's Hospital on the 29th of September, 1813, with pains of the lower limb of

* Case XV. p. 64, 3d edit.
† Page 65, 3d edition.

* See Dr. M'Dowel's observations in the 3d and 4th volume of the Dublin Journal, on Synovitis, &c.

the right side, extending from the hip to the knee, and resembling the pains of rheumatism. He attributed these pains to his having caught cold about a month before his admission. He laboured also under a complaint of his bowels, of which he died on the 4th of December. On dissection, no preternatural appearances were discovered, except in the right hip. The capsular ligament and synovial membrane were in a natural state, the cartilages covering the head of the femur and lining the bottom of the acetabulum were destroyed by ulceration in about one-half of their extent, and wherever the cartilage was destroyed an ulcerated surface of bone was exposed; the round ligament was readily torn in consequence of ulceration having extended to it at the part where it was inserted into the acetabulum. The bones possessed their natural texture and hardness; there was no pus in the joint. It was observed that the ulcerated surface of the acetabulum corresponded to that of the femur, these surfaces being exactly in contact in the position in which the patient had remained since his admission into the hospital.

Mr. Aston Key, from the cases he had an opportunity of examining of ulceration of the cartilage of the hip-joint in the early stage of the disease, is of opinion that the ulceration of the cartilage is preceded by inflammation of the ligamentum teres. He adduces the following interesting case.

A young female, who, for six months prior to her death, had laboured under the usual symptoms of chronic inflammation of the hip-joint, and when the symptoms had nearly yielded to the treatment employed, was attacked with another disease, of which she died.

The ligamentum teres was found much thicker and more pulpy than usual from interstitial effusion; the vessels on its investing synovial membrane were distended and large, without being filled with injection. At the root of the ligament where it is attached to the head of the femur, a spot of ulceration in the cartilage was seen commencing, as it does in other joints, by an extension of the vessels in the form of a membrane from the root of the vascular ligament. The same process had also begun on the acetabulum, where the ligamentum teres was attached.*

Bone.—The scrofulous affection of the hip-joint or morbus coxæ of Ford is, according to modern writers, a specimen of strumous osteitis. The disease, as far as the hip-joint itself is concerned, commences deep in the cancellous structure of the bones, and in general is remarkably slow in its progress.

While the disease goes on in the cancellous structure of the bones, before it has extended further, and while there is no swelling, the patient experiences some degree of pain, which, however, is never so severe as to occasion serious distress; it is often so slight, and increases so gradually as scarcely to be noticed; after a time the external parts sympathize with those within, and serum and coagulated lymph being effused into the cellular membrane, the joint appears swollen: should the patient be a child, it not unfrequently happens that this swelling first attracts the attention of the nurse or parents. The swelling is puffy and elastic, with blue veins meandring over its surface, but though usually more in degree than in those cases in which ulceration of the cartilage occurs as a primary disease, it is not greater in appearance, because the muscles of the limb are not equally wasted from want of exercise; the pain increases, but is not severe until matter has formed, and the parts over the abscess have become distended and inflamed, but then it is immediately relieved upon the abscess bursting. The skin, under these circumstances, assumes a dark red or purple colour, the abscess is slow in its progress, and when it bursts or is opened it discharges a thin pus, with portions of a curdy substance floating in it; afterwards the discharge lessens in quantity, becomes thicker in consistence, and at last nearly resembles the cheesy matter which is found in scrofulous absorbent glands. In most instances several abscesses take place in succession, but at various intervals, some of which heal, while others remain open, assuming the form of fistulous sinuses, at the bottom of which carious bone may be distinguished by means of a probe. The principal difference which is to be observed between the symptoms of this affection and that in which the cartilage is primarily the seat of inflammation, is in the degree or amount of pain which the patient endures, and which is much greater in the latter than in those cases where the disease exists in the cancellous structure of the bones. A girl laboured under an affection of the hip-joint, in which the nates were flattened, and an abscess had broken on the outside of the thigh, but it was observed she had suffered comparatively little pain. Under these circumstances she died, and when, says Sir B. Brodie, I was about to examine the body, I observed to those who were present, that there was little doubt but that the origin of the disease would be found to have been, not in the cartilages, nor in the bony surfaces to which they are connected, but in the cancellous structure of the bone. The appearances verified this remark: the cartilages were ulcerated and the bones destroyed to some extent; the latter were soft, so that they might be cut with a scalpel, and on dividing the articulating extremity of the femur longitudinally, a considerable collection of thick pus was found in the neck of that bone below the head, which either had not escaped at all, or had escaped in very small quantity by oozing through the cancelli which were interposed between it and the cavity of the joint. The hip-joint wears externally the peculiar aspect of a white swelling, and internally the anatomical structure will be found similar. In this disease of the joints the cancellous structure of the bones is the part primarily affected, in consequence of which ulceration takes place in the cartilages covering their articulating surfaces. The cartilages being ulcerated, the subsequent progress of the disease is in many respects the

* See Medico-Chirurgical Transactions, vol. xviii.

same as where the ulceration takes place in them in the first instance. Rust is of opinion that, under the influence of the disease in question, the head of the bone becomes more voluminous than in the normal state, and that from its gradual increase the cavity destined to receive it can no longer contain it; that the centre of the eminence becomes very vascular and softened, and presents evident traces of inflammation, which Rust thinks always begins in the membranous medullary tissue which occupies the interior of the cancelli of the head of the bone. Roche and Sanson, from whom we have taken this account of Rust's opinion, add that sometimes the articular head of the bone is not changed in volume, but that the cavity for receiving the head is filled by a swelling of the cartilage which clothes it, and by that of the cellular flocculi or Haversian glands.

Having stated the opinions of those who would wish to arrange and distinguish from each other the different morbid affections of the hip-joint according to the different structures they originate in, we regret to feel obliged here to express our dissent from this arrangement, as we find the greatest difficulty in adhering to it practically.

We have no doubt but that the disease of the hip, whether acute or chronic in its attack, may begin by an inflammation of the synovial membrane of the joint, and that occasionally, particularly in scrofulous subjects, the cancellary structures of the bones may be the first seat of the local disease; we might even yield an assent to the opinion of some, that the cartilages may in rare cases be the structures first engaged; but if we seek for facts to convince the mind of the truth of all such speculations, we shall find but little that is satisfactory to guide us. Post-mortem examinations seldom reveal to us the state of the joint, until the disease has made great ravages, and until several structures have been implicated; the external signs of synovitis, chondritis, and osteitis, cannot, in our judgment, be distinctly recognized in all cases in an articulation so covered by muscles and so remote from the surface as the hip-joint is. We feel convinced, therefore, that in the present state of our knowledge the effects of disease on the articulation of the hip may be best considered under the following heads: 1. acute arthritis coxæ; 2. chronic strumous arthritis coxæ; 3. chronic rheumatic arthritis coxæ.

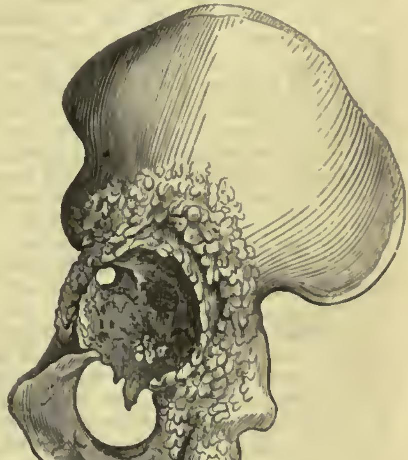
1. *Acute Arthritis coxæ.*—The following case presents an example of an ordinary case of acute arthritis coxæ. Daniel Reddy, æt. 18, a labourer, was admitted into the Richmond Hospital on the 11th of October, 1838. He now had all the symptoms of a very severe attack of acute inflammation of the hip-joint. He stated that he had always been remarkably healthy until about four weeks ago, when in consequence of having lain for some hours on damp grass, he had a shivering, which was succeeded by fever; on the following morning he had severe pain deep behind the great trochanter; he became so very lame and unable to walk from the pain in his left hip-joint, that he was compelled to keep his bed; he also complained of pain in the groin and startings in the limb. When the patient was supported as far as it was possible in the erect position, we observed posteriorly that there was a remarkable flatness and breadth of the nates of the affected hip, and that its lower fold had disappeared; there was a gradual pyriform tapering down of the hip into the thigh, which was already much wasted; the pelvis itself was rotated on the spine, the left side being directed backwards, and the spinal column much curved forwards, rendering the abdomen very prominent in this direction. There was at first an apparent elongation of the limb, which soon became flexed on the pelvis, and so strongly adducted as to cross the median line, if the term adduction can be so applied. There was great heat all around the hip-joint; when pressure was made either on the great trochanter or in the groin, it caused great pain to the patient, and if the least movement was communicated it seemed almost insupportable. In bed he lay on the right or sound side, with the left side of the pelvis directed backwards, the left thigh and leg both much flexed and directed inwards, as already remarked, across the middle line; he kept the limb by holding it grasped with both hands near the knee. There was some fulness, fluctuation, and tenderness on pressure over the left iliac fossa, and shooting pain passed down to the knee. There was constitutional fever and much general heat of surface. To rest and active treatment by leeching, blistering, and calomel with opium, his symptoms yielded for a time, then he relapsed, and such alternations occurred thrice, and then all the urgent symptoms subsided. In March his fever and constitutional disturbance had disappeared, and from the recovery of his flesh and expression of countenance, we judged that this attack had passed over, but had left him liable to fresh and dangerous returns of inflammation from the most trivial causes, either local, such as injuries, or constitutional. In April there was a shortening of one inch and a half, the foot of the affected limb rested on the instep of the other in standing, and in lying the knee was supported by a cushion placed above the other knee; adduction extreme; and although the thigh, leg, and foot were habitually somewhat inverted, eversion was admissible; behind there was a great widening of the buttock and retraction of the trochanter major; no fluctuation of matter could be felt about the joint, nor had he any pain in the knee or hip.

Such, we imagine, is the more ordinary course of acute arthritis coxæ. In this case acute synovitis followed the lying on the damp grass; there was noticed an apparent elongation of the limb, which was of very short duration, and was succeeded by a shortening at first very trifling, scarcely appreciable, but after a month half an inch, and at last fully an inch and a half. In consequence of the very decided elevation on the dorsum ilii of the great trochanter, with the habitual inversion, flexion, and adduction of the whole limb, we might be led to infer that in this case the articular ligament and fibrous capsule had yielded from ulceration, and the muscles had dislocated the head of the femur from the acetabulum on the dorsum ilii; but the shortening was not sudden, as we have known it to have been in such cases, but gradual, nor by a careful examination of the dorsum of the ilium, and searching deeply behind the situation of the great trochanter, could we feel the head of the femur where it should be, were it really dislocated from the cavity of the acetabulum, nor by a forced rotation inwards of the whole limb could the head of the bone be rendered manifest. Our strongest reason, however, for concluding that the head of the bone is not really luxated on the dorsum ilii is, that although the foot may habitually be directed a little inwards, still the foot is susceptible of rotation outwards to a greater extent than is compatible with any idea of the head and neck of the femur being thrown, as in the ordinary luxation, on the dorsum ilii.

The following case of acute arthritis coxæ presents a remarkable example of this affection, in which the course of the disease was rapid, its symptoms obscure, and death occurred suddenly and unexpectedly.

On the 11th of January, 1829, I was requested by my friend Mr. Speedy, then one of my pupils at the Richmond School of Medicine, to assist him at the post-mortem examination of a grenadier, who died with a psoas abscess rather suddenly and unexpectedly. The man, aged 32, had been only one month complaining of pains about his loins and hip-joint, and was only a few days confined to bed. The body was thin, though not emaciated; in the inguinal region a large fluctuating swelling was perceived, which evidently extended into the abdominal cavity, and had assumed the situation and form of a psoas abscess. While cutting into the cavity of the abdomen, pus was noticed to issue from some of the veins which were divided, and particularly from the epigastric. When the abdomen was opened, we observed that the sheath of the psoas muscle was distended as high up as the diaphragm, and on puncturing it a quantity of purulent matter escaped. A second abscess was discovered in the true pelvis, which extended from the back part of the thyroid foramen to the sacrum, lying outside the bladder and rectum. We next laid fully open the sheath of the psoas muscle, which we observed had not been organized into the usual form of a cyst, and search was made for some point of diseased bone along the spinal column, but none was found here; we then directed our attention to the hip-joint; we found the capsular ligament perfect, except where it arises from the transverse ligament of the notch near the thyroid foramen. Here a large perforation existed in the capsular ligament, through which the finger could be passed on through the thyroid foramen into the interior of the abscess in the true pelvis; the sac of this last abscess we traced as high as the bifurcation of the aorta and junction of the common iliac veins with the vena cava; here this latter vessel was found firmly adherent to the sac, and on carefully removing both in connection, and slitting up the vena cava posteriorly, we had a view of a perforation in its anterior wall, close to its junction with the iliacs; this perforation was large enough to admit a goose-quill, and established a free communication between the vein and the cavity of the abscess, by which blood and purulent matter had an easy passage from one to the other. How long this communication had existed we could not ascertain; but thus was satisfactorily explained the extraordinary phenomenon which had attracted our attention in an earlier stage of the dissection, viz. the issue of pus from some of the veins of the abdominal parietes which were cut across. On prosecuting the examination still further, we found that close to the anterior inferior spine of the ilium and iliopubal eminence, where the united tendons of the psoas and iliacus muscles pass over this part of the horizontal ramus of the os innominatum, a vertical perforation of the brim of the acetabulum existed, half an inch deep, of a funnel shape, with its largest part towards the acetabulum, and capable of allowing at its smallest part a large sized bougie

Fig. 310.



to pass; through this the matter had passed up and elevated the psoas muscle or distended its sheath, which thus presented the ordinary characters of a psoas abscess, but which we learned had appeared suddenly and without having been preceded by the usual premonitory signs. There was no trace of cartilage, Haversian gland, or synovial membrane on the acetabulum; the round ligament was gone, and the cartilaginous covering of the head of the femur had been removed, as well as the synovial membrane of the neck of this bone. The exposed surfaces of the bones were carious, but the acetabulum had suffered more particularly; it was deeper, but not wider than usual; its fundus, where formed by the ischium, was thin as paper, but yet no perforation had taken place in this part of the cavity, as thickened periosteum supported the bone, while the ulcerative absorption was so active in the interior of this cavity, removing the bone, osseous spiculæ or stalactiform growths, such as we are familiar with as being produced around scrofulous joints, had been deposited around the entire circumference of the acetabulum; some of these had much narrowed the usual extent of the obturator foramen, at that point where matter had passed from the joint into the interior of the pelvis. The bones have been macerated and preserved in the Richmond School Museum, and verify many of the statements made relative to this very singular case.

What influence the communication between the cavity of the abscess and the interior of the vena cava had in producing the fatal result in this case, we do not feel ourselves called upon to determine, nor is this the place to dwell on this obscure subject. The usual phenomena of apparent elongation at first and real shortening of the limb afterwards, either did not exist or were so trifling as not to be appreciated in this case, and the disease ran its course rapidly to a fatal termination, the head of the bone remaining in its normal position in the acetabulum. It was probably from having witnessed such cases as the foregoing that that experienced surgeon, Boyer, was induced to make the following remark:—"On a observé un variété de la carie qui n'attaque que le fond de la cavité cotyloïde; de sorte que ce fond seulement est detruit, tandis que ces bords restent intacts; alors la matière purulente de mauvaise qualité, qui la remplit, se porte jusque dans le bassin, ou elle forme un foyer plus ou moins considérable; dans ce cas, la maladie fait perir le sujet, sans deplacement du femur."

We will adduce but one example more of the acute arthritis coxæ, with the post-mortem examination.

Alexander Clarke, æt. 17, on admission into the Richmond Hospital, it was observed that there was much swelling about the hip-joint; the integuments over it were tense and shining, the glands in the groin were swollen and very tender; he suffered from pain, shooting to the knee and spasmodic startings, which awoke him at night; he could not permit the slightest motion of the limb, which was shortened one inch and a quarter; it was habitually inverted and flexed on the trunk; the constitutional disturbance was considerable. From the treatment adopted he derived benefit, and a partial recovery resulted. He left the hospital, but soon returned, in consequence of an aggravation of all the former symptoms, caused by a fall on the diseased hip. A deep abscess formed in the groin and extended under Poupart's ligament; hectic symptoms showed themselves. There were alternate diarrhœa and attacks of vomiting. The abscess in the iliac fossa increased, the tumefaction around the joint diminished, the shortening and inversion of the limb became greater, and œdema of the foot and leg occurred; he now became suddenly insensible; his left arm was totally paralyzed, while the right was convulsed and constantly in motion; his face too was distorted by twitchings, and he passed his discharges involuntarily; he lay thus for several days and died, being in all eighty days ill.

Post-mortem examination.—Upon cutting down to the hip-joint the capsular ligament was found to have been extensively removed anteriorly; posteriorly and laterally it was not ulcerated, but seemed to have been greatly lengthened and widened; the synovial membrane was lined with a yellowish-green membrane, just like what we see investing the interior of the sac of an old chronic abscess; the ligamentum teres and cartilage, which invested the head of the bone, had been removed, the bones were rough, unusually red and vascular, and were coated with yellowish-green lymph; the acetabulum was much enlarged, and the head of the bone was drawn to the upper and outer part. The left iliac fossa was entirely filled by an immense abscess, lying between the muscle and bone, passing down under Poupart's ligament as far as the lesser trochanter. The iliac vessels and the anterior crural nerve were pushed forwards; half an inch below Poupart's ligament a process of the abscess had passed outwards and backwards, which communicated with the hip-joint, and having the muscles posterior to the joint, which were thinned and matted together, to form its wall in that direction. In the brain purulent matter was found on the arachnoid surface as well as between the several convolutions of the right hemisphere. The neighbouring portion of the brain was softened and vascular; there was no effusion into the arachnoid sac or into the ventricles.*

Sometimes the acute arthritis coxæ is an essential disease, and the only one present at the time in the constitution, being simple and confined to the one articulation, as in the case of Reddy before quoted. Sometimes, however, the acute inflammation of the hip-joint is a symptom of another disease. In acute rheumatic fever the hip-joint is, in its turn, sometimes severely visited. Finally, the cases yet published of acute periostitis and synovitis combined, and of acute puerperal rheumatism, in which the hip-joint became implicated, need not be discussed here. We are of opinion that such cases should be looked upon as true specimens of that almost intractable disease called diffuse inflammation.

Anatomical characters.—From the post-mortem examinations of cases of acute arthritis coxæ which have been hitherto made, we can collect that all the structures around the joint are in a state of active vascular congestion. The synovial membrane and subsynovial structure present the ordinary characters of active congestion and the results of acute inflammation. Sometimes there is an increased secretion of synovial fluid, and sometimes, in its stead, purulent matter distends the articulation. The synovial membrane, where it is reflected over the neck of the femur, has been found de-

* See Dublin Journal, vol. iii. and iv., also preparation in the Richmond Hospital Museum, which the writer has recently inspected.

stroyed by ulceration. Sometimes the purulent matter has been known to have escaped from the articulation by ulcerated openings in the capsule of the joint, and to have passed into the pelvis, and penetrated between the muscles. The fatty mass at the bottom of the acetabulum has been found swollen, inflamed, and covered with a membranous layer of lymph, at the same time in some of these cases the neighbouring periosteum has been found detached from the bone, which was redder than usual. These are appearances which have been noticed in those who have died of acute arthritic inflammation, whether it may have arisen from diffuse inflammation or simple acute disease confined to the one articulation. In acute cases, actual dislocation of the bones, we believe, has not been noticed, as the disease seldom arrives at its second or third stage under such circumstances, but the cartilage and synovial membranes have been altogether destroyed, and the porous structure of the bones has been exposed, digital depressions have been seen produced by acute caries in the acetabulum and head of the femur. The bones have then presented a rough vascular surface, and in many cases lymph has been found to cover the convexity of the head of the thigh-bone and to line the acetabulum. The head of the femur sometimes is but little altered, either as to form or position, but when the acetabulum is largely excavated by disease, the head of the thigh-bone will be found to be drawn by the muscles to its upper and back part. Even in acute arthritis coxæ in the young subject, the epiphysis of the head of the femur has been found detached.* The ligamentum teres is generally absorbed early, and the capsular ligament is usually ulcerated in some one part, so that, on the post-mortem examination, the bones are found to be very moveable on each other. They are usually observed to be highly vascular, and some imagine the head of the femur is enlarged. Hyperosteotic depositions or stalactiform productions, which are very friable, exist around the diseased joint.

2. *Chronic strumous arthritis coxæ.*—The scrofulous disease of the hip-joint is very generally slow in its progress, and is seldom seen, except in persons who bear other evidences of the strumous diathesis; there are examples of it occurring in individuals who have passed the age of thirty years, though generally seen in those of more tender years. This affection of the joint, although slow and insidious in its attack, yet is attended with the usual phenomena of an inflammatory or sub-inflammatory action. Many of the writers who have described the "disease of the hip-joint," have assigned to it three periods or stages, as Ford has done, while succeeding authors have added to the description of the three stages of Ford, a period which they call the period of the invasion of the disease. In this their first stage, there is pain in the thigh, extending to the knee, which appears and disappears alternately; a marked weakness in the thigh, and a sense of feebleness in the whole limb; the gait is limping, and some tension is felt in the groin. This period lasts sometimes but a few days, at other times many months. In the second period the limb is wasted, and apparently, though not really, elongated; the trochanter is placed lower down, and is more outward than that of the opposite side; the buttock is flattened, and its fold is lower than natural; the patient's lameness is characteristic; he moves the affected limb round with a shuffling motion, the foot scraping the ground, and he sometimes assists the elevation of the thigh with his hand. At this time the knee is painful, and not unfrequently a puffy swelling appears in it, both which circumstances often too much attract the attention of patient and surgeon, and divert it from the true seat of the disease. The third period is characterized by a real shortening of the limb; this is sometimes sudden, and the immediate consequence of caries of the brim of the acetabulum and luxation of the head of the femur upward and backward on the dorsum of the ilium. The shortening of the limb, however, is more commonly gradual, and the consequence of the slow ulceration and widening of the acetabulum.

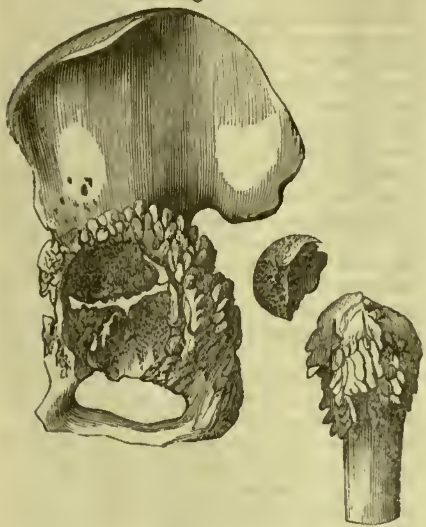
It has of late been truly observed, that the luxation is not so common as generally imagined, but when it does occur, it usually takes place in the direction upwards and outwards; when the fibrous capsule and other ligaments are destroyed by ulceration, the head of the femur escapes by the superior and posterior part of the acetabulum, and obeying the action of the glutæi muscles, it glides from before backwards and without inwards upon the convex surface of the ilium; the thigh is flexed, adducted, and turned with a strong rotation inwards; the great trochanter approaches the crest of the ilium, the muscles are raised up by the head of the femur, and the buttock is rounded, and becomes very protuberant posteriorly. Although this is the direction in which the luxation usually takes place, still it has been noticed to have occurred in a direction horizontally backwards towards the ischiatic notch (Earle). It has also been seen in the direction downwards and inwards towards the foramen ovale, in which case the limb is elongated and directed outwards. Still more rarely has it been thrown upwards and inwards on the horizontal ramus of the pubis. In one instance, says Brodie, I have seen the dislocation in the direction forwards, the head of the femur resting on the pubis, the knee and toes being turned outwards.

It would be wrong, however, to suppose that a true dislocation of the head of the femur from the ulcerated acetabulum is a very common occurrence; although all these cases, above alluded to, have been witnessed, we believe very frequently the shortening of the limb in the third and fourth stage of the disease arises from ulceration and widening of the acetabulum and destruction of the head of the femur. The head of the femur sometimes sepa-

* See a preparation in the museum of the College of Surgeons, Dublin, presented by the late Professor Todd.

rates at its epiphysis from the neck of the bone, and the latter is drawn up, (*fig.* 311,) and the

Fig. 311.



whole limb shortened greatly, and the toes are as much everted as when fracture of the neck of the femur occurs from accident. The shortening is usually, but not invariably, the precursor of abscess; when this occurs, the disease is in its fourth stage. This period, or that of of the formation of matter, is generally marked by an aggravation of the pain, by frequent spasms and startings of the muscles, by greater wasting of the limb, occasional œdema of the foot, (which is a very unpromising feature,) &c. These chronic symptomatic abscesses may present themselves in various directions; the matter may remain for months without undergoing any change, and even after this be rather suddenly absorbed, or the pus may escape through openings made by nature or by art; the external orifices of these abscesses frequently degenerate into fistulæ, from which exfoliations occasionally take place, and these exfoliations are sometimes so small as to be almost sabulous, sometimes larger pieces come away with pain; such are to be considered not unfavourable indications. The writer has known two examples of the head of the femur thus separated at their epiphysis from the neck of the bones; in these cases the patients recovered, with the usual deformity.* Of the numerous situations around the hip-joint, in which matter has been found deposited, there is one variety which demands the special attention of surgeons, in consequence of the difficulty which has been experienced in recognizing the disease, namely, the case in which the caries affects the bottom of the acetabulum, so that the fundus alone is destroyed. Sir B. Brodie met with one case, where in the bottom of the acetabulum there was an ulcerated opening, just large enough to admit a common probe, communicating with an abscess within the pelvis. Mr. Tagart* alludes also to a case in which this perforation exists. (*Figs.* 312 and 313.) Of such per-

Fig. 312.

Fig. 313.

* One of these was presented to him by Mr. Shaw, the surgeon to the Clonard Dispensary, and is preserved in the Richmond School Museum; the other was shewn by Dr. Carlile lately to the Pathological Society, Dublin.

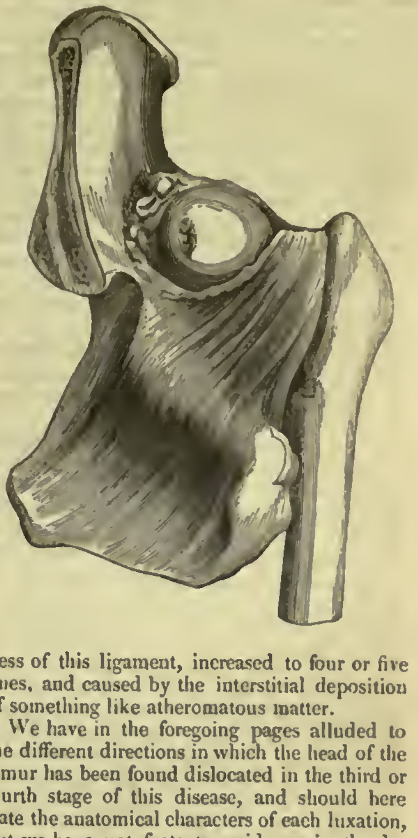
* Lancet, vol. i. 1835 and 6, Jan. 2.

forations the writer has seen in different museums a great variety: in many instances the opening is small, in others of sufficient size to admit easily the head of the femur. These cases are in the beginning obscure, and when abscesses form, they are concealed within the cavity of the pelvis.

Anatomical characters.—When opportunities have occurred of examining the interior of the hip-joint in those who have died of other complaints, this articulation being, at the time of death, in the early stages of the chronic disease we are now considering, the adipose cellular mass which occupies the fundus of the acetabulum, the cellular structure which connects the fibres of the inter-articular ligament, the subsynovial cellular tissue which surrounds the corona of the head of the femur, as well as the interior of the bones themselves, have been found to wear an unusually red appearance from increased vascularity. The cartilage has been found softened, to have lost its usual lustre, to be slightly elevated, and too easily torn from the subjacent bone; in some cases thinned, in others detached in flaps; in some it has presented a corroded appearance, and coinciding with these changes purulent matter has been found in the interior of the joint, the capsular ligament thickened, and the lymphatic glands in the groin enlarged. In the anatomical examination of those who have died in the advanced stages of the scrofulous disease of the hip, if the patient have not arrived at the age of puberty, we find that very frequently the original portions of the os innominatum are separated from each other for several lines, that the epiphysis of the head of the femur is completely detached from the shaft of this bone; the greater and lesser trochanters are sometimes in very young subjects removed by absorption, and evidence of devastating caries is found in the bottom of the acetabulum. (*Fig.* 311.)

In some cases the head of the bone has been found dislocated on the dorsum ilii, previous to which occurrence all the ligaments have been destroyed, the acetabulum has the superior and posterior part of its brim removed by caries, and the bone thus abandoned to the action of the muscles takes the position it ordinarily does in the common luxation upwards and backwards on the dorsum ilii. This complete dislocation is not so common an occurrence as generally imagined; there are, however, some specimens of it preserved in the museum of the College of Surgeons in Dublin. In one preparation, the cartilage of the head of the femur is perfect, the round ligament is gone; the further ascent of the head of the bone on the dorsum ilii seems principally restrained by the obturator muscles (*fig.* 314). The interesting circumstance in the preparation to be noticed is, that the acetabulum is occupied to the level of its brim with a very dense atheromatous matter or yellowish green lymph, apparently an unorganized substance resembling what we see contained in crude scrofulous tubercles: what remained of the capsular ligament around the neck of the femur has been cut crucially, and the everted edges of the flaps shew the thickness of this ligament, increased to four or five lines, and caused by the interstitial deposition of something like atheromatous matter.

Fig. 314.



We have in the foregoing pages alluded to the different directions in which the head of the femur has been found dislocated in the third or fourth stage of this disease, and should here state the anatomical characters of each luxation, but we have not facts to guide us in the description.

When a section is made of the bones entering into the composition of the hip-joint, when the patient has died of this disease in an advanced stage, they will be found to be softened in the interior, and to contain a fatty or a yellowish cheese-like matter in their cells; when opportunities have occurred for examination in an earlier stage of this scrofulous caries, these organs have been generally found preternaturally red and vascular, (as before stated,) with a deficient proportion of earthy matter, admitting not only of being cut with a knife without turning its edge, but yielding and being crushed under very slight pressure. A modern author,* after quoting the authority of Lloyd on scrofula as proof of the truth of some of the foregoing observations, adds his own opinion, " that in simple inflammation, uninfluenced by the scrofulous diathesis, particularly when it becomes of a chronic character, bone is secreted in abundance, but that the striking feature in this kind of inflammation is, the absence of all secretion or deposit of bone." With the latter doctrine we cannot at all agree, and must conclude we do not rightly apprehend the

* Coulson on the Diseases of the Hip-joint, Lond. 1837, 4to. p. 39.

author, as we have very generally found osseous growths exterior to the hip-joint in the os innominatum and femur, (*fig.* 310), as the result of scrofulous inflammation of the articulation. These growths are generally friable stalactiform productions which beset the bones, and are to be seen in the numerous specimens illustrating the morbid anatomy of morbus coxæ, which are contained in our museums in Dublin.* Notwithstanding these osseous productions or vegetations, the bones are found to have diminished much in their specific gravity. I have always found them float when thrown into water. These growths are, however, only met with in the post-mortem examination of such chronic cases as have manifested in their course various alternations of improvement and reverses; they are almost invariably found when the caries of the bones had been arrested, and an imperfect attempt at anchylosis had been made.

We have also opportunities of examining anatomically the hip-joints of persons who have had this disease in their youth, in whom it had been arrested in the second or third stage, and who had attained advanced life, and died of some other complaint. In some, besides the bony growths already alluded to, we find examples of anchylosis or of a false joint; indeed, although an absolute union and consolidation of the bones, viz. the os innominatum and the head of the femur may not have taken place, still in most cases there is very little real motion of the two bones upon each other; the flexor and adductor muscles of the thigh and hip-joint are usually in a state of spastic contraction; they admit of but little increase of flexion: whenever we attempt extension, we find the thigh is readily brought down from the abdomen, the lumbar vertebræ are arched forwards, and this portion of the spine and the sacrolumbar articulation are the seat of motion, which often is erroneously referred to the hip-joint. The os innominatum follows the head of the femur just as freely almost as the scapula accompanies the various changes of position impressed upon the humerus, when anchylosis of the shoulder-joint has taken place. I was called upon about eight years ago to examine the body of a woman, aged 26 years, who died in the Whitworth Hospital of an acute disease. This young woman had walked very lamely for many years, in consequence of her having had a most tedious and dangerous attack of hip-disease twenty years before her death, but after her recovery from the first attack she never had any pain or inflammation in the joint; there were no evidences of suppuration ever having occurred; marks of issues were on the nates. When making an examination of the structures around the articulation and of the joint itself, the muscles were found remarkably firm, but somewhat paler than usual; the ligamentous structures around the junction of the femur with the os innominatum were very strong, and so close was the union of the bones that on a superficial view we might easily imagine that true bony anchylosis had occurred. I removed the bones, and they are preserved in the Richmond School Museum. The whole head of the femur has been absorbed, and only one-fourth part of the neck of the bone remains; the place of the cotyloid cavity is supplied by a rough scabrous surface, of an oval form transversely, and about one inch and one line in this its longest diameter; the two rough bony surfaces with eminences and depressions confronted to each, and reciprocally adapted, were joined by a species of strong fibrous capsule; no motion whatever existed between these bones, yet when the ligamentous connexion between them was cut, it was evident that no bony union had taken place. In this case the false anchylosis had occurred in a very unfavourable direction; the thigh was flexed to so great a degree that the knee was really elevated above the level of the hip-joint, and so much adducted at the same time, that the knee crossed much the middle line. When she stood up straight on the right and perfect limb, the left heel did not approach within twelve inches of the ground: the texture of the bones was as hard as iron.

We find in a modern author the observation, which must be admitted to be correct, that true bony anchylosis of the hip-joint is rare; but, he adds, that many pathologists doubt that such an occurrence ever takes place: that the many specimens of true bony anchylosis of the hip we have witnessed, were all examples of union of bony surfaces in scrofulous cases, we would not wish to maintain, but we imagine many of them must have been the result of the ordinary hip disease cured, as it is called, by anchylosis. Sir Philip Crampton has shewn me a very fine specimen of anchylosis of the hip-joint, which very much resembles the preparation represented (*fig.* 312); the acetabulum had been the principal seat of the disease; it was much widened, and the head of the bone was drawn towards its upper and outer part, where firm anchylosis had taken place. In this case Sir P. Crampton assured me the patient had a constitution eminently scrofulous. He got well of the hip-disease by anchylosis, the thigh-bone having been judiciously preserved in a vertical direction during the progress of the cure. He walked afterwards tolerably well, but at the age of 26 became attacked with phthisis, and died. This case proves that true bony anchylosis can occur in the scrofulous subject, and that attention may occasionally overcome the disposition to excessive flexion and adduction of the limb.

The museum of the Richmond Hospital contains three specimens, in which the junction of the os innominatum with the femur is as solid as if they formed but one bone, and a vertical section through the united bones shews as free a communication of the cells of the cervix femoris and those of the os innominatum as if these bones had never been separately formed. These seem to have been examples

† These osseous vegetations we have already alluded to in this work, when speaking of the chronic strumous arthritis of the elbow: see p. 79, Elbow-joint, Abnormal Anatomy of.

of early affections of the hip-disease, in which little or no displacement of the head of the femur occurred.

The acetabulum, we know, is generally widened in this disease, and the head of the femur is drawn upwards and outwards; if at this period the inflammation be arrested, true bony anchylosis may occur; and if a happy direction can be given to the shaft of the femur, a very useful limb may remain, even though the hip-joint itself has lost all motion; the sacro-lumbar joint and the neighbouring intervertebral structures admit of much freedom of motion.

In examining anatomically the hip-joints of those who, having had the chronic scrofulous disease of this articulation in their youth, and have recovered and lived for years, though lame, in these, instead of anchylosis, we find a false joint is formed. Of this imperfect cure of hip disease we have seen some examples, and we possess one remarkable specimen of it. In this the acetabulum was altogether removed, and a triangular space, encircled by a rounded brim covered with a compact stratum of bone, existed. The removal of the neck of the femur was so complete that a plane or rather concave surface corresponded to the inner side of the trochanter major, from which the neck of the bone naturally arises.

It has been stated that luxation on the dorsum of the ilium sometimes happens as a consequence of chronic disease of the joint; sometimes the disease which carried away, in this instance, the borders of the acetabulum, seems, as it were, to have been transferred to the new surface of the os innominatum with which the head of the femur came in contact, and we find the process of ulceration has even continued its course; again it sometimes happens that anchylosis or a false joint has been formed.

Albers and Rust have described the change which the bones of the pelvis undergo in their form and situation. The pelvis, in those who have for a long time gone lame, is pushed upwards, and the sacrum is flat and straight. In a few cases, however, it is more curved than in the natural state; the coccyx is bent strongly forwards, and the connexion of the last lumbar vertebra with the sacrum forms a right angle; the ilium of the affected side stands higher, and has in general a perpendicular direction, and more of a triangular form; the external surface is smooth, whilst the iliac fossa appears more hollowed than usual; this hollowing probably depends on the action of the iliacus internus, which is greater than that of the glutæi. The horizontal ramus of the pubes often seems lengthened and lower than in the natural state, and the ischium is usually drawn outwards and forwards; the perpendicular direction of the foramen ovale is changed more to a horizontal one, and the opening assumes more of a triangular form, its base being turned towards the acetabulum. In consequence of the changed situation of the bones of the pelvis, its different diameters undergo an essential deviation from the natural state, the superior apertures of the pelvis are commonly somewhat oblique, and the pelvis is broader on the affected side from before backwards.*

The *muscles* in advanced cases are in a state of atrophy, of a greenish hue, and often matted together; sometimes they form the walls of scrofulous symptomatic abscesses, containing a thin serous pus mixed with flakes; sometimes the pus is inodorous, of ordinary character. Usually the contents of the abscess make their way to the skin, more rarely to the mucous surfaces. In more advanced cases these abscesses are found to contain fetid air and purulent matter of a very bad quality; in these latter circumstances we discover either an external or internal fistulous opening; the walls of the abscesses have collapsed, and have been converted into fistulous canals lined by false membranes; these have become, as it were, the excretory canals, through which the matter has been discharged from the interior of the diseased joint, and through which sabulous matter, small hard pieces of bone, or pieces as large as the epiphysis of the head of the femur, as elsewhere noticed, have made their way. The abscesses are found, on dissection of those who have died of morbus coxæ strumosæ, pointing or to have opened in various directions.

We have already stated that the capsular ligament has been found perforated by fistulous openings, and that in the advanced stage of the disease little or no vestige of the capsule is left. The abscesses, therefore, we meet with on dissection may be considered as reservoirs for the matter which proceeds from the carious bones; occasionally, no doubt, we shall find around the joint abscesses which have no communication whatever with the diseased articulation: not only in the soft parts around the joint have we met with such isolated collections of matter, but also in the body of the os ilii, and in the centre of the trochanter major of the femur.

We have given an account of an acute case of morbus coxæ, in which a psoas abscess was found to have originated in a carious hip-joint. The communication of the carious bones with the interior of the sheath of the psoas took place through a small perforation in the horizontal ramus of the os innominatum. In this case also an abscess existed in the true pelvis, and death was the consequence of it, having burst into the vena cava. In Mr. Liston's collection there is a specimen shewing extensive destruction of the acetabulum, head and neck of the femur, with several sinuses leading from the joint, and one in particular of large size, leading towards the rectum through the foramen ovale; there is also the rectum corresponding to this preparation, with a rounded opening sufficient to admit the point of the little finger, about an inch and a half above the anus. In this case the abscess lay across the pelvis; by one of its extremities it communicated with the diseased hip-joint through the foramen ovale and ulcerated capsular ligament, and by its posterior extremity with the rectum. The case of pelvic abscess I have so often adverted to was very similarly

* Coulson, p. 42.

situated, but instead of opening by its posterior extremity into the rectum, its fundus was elevated somewhat higher in the pelvis, and burst into the vena cava. The late Dr. M'Dowel, in the fourth volume of the Dublin Journal, says that in two cases of hip-joint disease he had seen several years since, the matter had passed into the pelvis through the bottom of the acetabulum, and there accumulated in such quantity as to compress the bladder and cause retention of urine, requiring the daily use of the catheter. He also adds, that this route for the matter is not uncommon, and in its progress that it may form a tumour of considerable size by the side of the rectum, and occasionally burst into the cavity of this intestine. Sir A. Cooper mentions the latter occurrence in one instance. Dr. M'Dowel adds, I had an opportunity of witnessing it. Abscesses take their course from the diseased joint into the pelvis, and open into the vagina. Sir B. Brodie mentions a case of this kind in a child aged 11 years; and in Dr. Kirby's collection, which he presented to the College of Surgeons, is a similar example. Dr. M'Dowel, in the paper already alluded to, observes that he is not aware of its being recorded that an iliac abscess may result from a caries of the hip-joint, yet in four cases, he adds, I have found it to occur. The fluid escaping through an opening on the inside of the capsular ligament, passes upwards behind the psoas and ascends into the iliac fossa, detaching the muscles from the bone. In such cases we have considerable fulness in the groin, which can be traced upwards behind Poupart's ligament; from the stretching of the filaments of the anterior crural nerve more neuralgic pain attends this case than we usually find in disease of the hip-joint. The iliac vessels are displaced, become flattened and adherent to the sac; from the compression of the vein much more œdema of the limb is present than in ordinary cases. The cœcum or the sigmoid flexure of the colon may be considerably displaced or united to the sac.* Sometimes it passes behind the vessels, and accumulating, it may compress the bladder and rectum, which then form the inner wall of the abscess.

In a very interesting case of iliac abscess which was treated in the year 1833 in the Richmond Hospital, ulceration of a portion of the ilium adhering to the wall of the abscess occurred, and its contents, after being poured into the abscess, escaped externally through a fistulous opening near the spine of the ilium; ulceration also of the external iliac artery took place about an inch and a half above Poupart's ligament, and sudden death resulted from the blood escaping in large quantity into the cavity of the abscess. The preparation is preserved in the museum of the Richmond Hospital. The anterior and crural nerves are often found on the stretch. We have already mentioned a case of this kind, (Clarke,) and Sir B. Brodie mentions one in which he found two enlarged lymphatic glands, each the size of a walnut, immediately below the crural arch in the fore part of the joint, and these lay in contact with and immediately behind two branches of the nerves, so as to keep the latter on the stretch, like the strings passing over the bridge of a violin.

We must not forget that the diseased action in these cases of chronic strumous arthritis is not confined to the joint. We have seen examples in the living and specimens in museums, proving that at the same time both hip-joints may be engaged in the same individual. In acute cases we have given an example of the membranes of the brain having been affected, so also in chronic cases; tubercles have also been found in the lungs, the mesenteric glands extensively enlarged, and ulcers in the intestines, and tubercular accretions in the peritoneum.

3. *Chronic rheumatism.* — (*Morbus coxæ senilis, or chronic rheumatic orthritis of the hip.*) By these terms we would wish to designate a very peculiar disease of the hip-joint, the morbid results of which are now pretty well known to pathological anatomists; but it must be confessed that very little has been done to make the profession acquainted with its symptoms or appropriate treatment.

History of the disease.—We will venture to assert that there cannot be a more graphic illustration given of this disease and its consequences than those to be found in the Museum Anatomicum of Sandifort, who has not confined his delineations to the head and neck of the thigh-bone, but has also shewn the various alterations of form which the acetabulum undergoes.* For many years this disease has been accurately described in the clinical lectures delivered in the different hospitals in Dublin, and the importance of distinguishing it from the other affections of this articulation has been pointed out. Mr. Benjamin Bell, in his work on the bones, has, under the head of "interstitial absorption of the neck of the thigh-bone," alluded to this disease, and detailed many of its external signs, as well as the morbid changes which the neck of the bone suffers; and in the sixth volume of the Dublin Journal, Mr. Smith, in a paper on the diagnosis of injuries of the hip, has given a very good and concise account of this remarkable affection of the hip-joint.

The writer of this article long ago, in his lectures, gave the name of *morbus coxæ senilis* to the disease in question, but as he has since met with many instances of it occurring so early as at the age of thirty or forty, he is now disposed to substitute for this name that of *chronic rheumatic arthritis* of the hip-joint, and he considers it as the same disease precisely as he has elsewhere in this work described as affecting other articulations. (See Elbow, Hand, Knee, Shoulder.)

As to the cause of this chronic disease of the hip-joint, we believe little is known. We have heard it frequently attributed to the effects of cold and wet; and an acute attack of rheu-

* The matter, which is generally prevented from passing down into the true pelvis by the connexion of the fascia iliaca, sometimes makes its way into this cavity by ulceration of this fascia.

* Mus. Anatom. Lugduni Batavorum, 1793, vol. ii. tab. lxix. ad lxxiii.

matic arthritis of the hip-joint produced by cold, we can easily conceive may occasionally merge into the chronic affection we wish to describe. We have also reason to think that falls upon the great trochanter have given rise to the first symptoms of this disease; but in many cases no satisfactory cause can be assigned by the patient for the origin of the affection.

Symptoms, &c.—The patient complains of stiffness in the hip-joint and about the great trochanter; also of a dull boring pain which extends down the front of the thigh to the knee. The stiffness is most felt in the morning when the patient commences to walk; but after exercise the movements of the joint become somewhat more free. In the evening of a day the patient has had much walking exercise, the pain is always more severe. The uneasiness, however, gradually subsides after he has retired to bed. The pain is always increased when the patient throws the weight of his body fully on the affected joint. But let the surgeon press on the great trochanter, or adopt any other expedient so as to push the head of the bone even rudely against the acetabulum, and these manœuvres are the sources of no uneasiness whatever to the patient. Although we can easily satisfy ourselves that no actual anchylosis exists, still it is evident enough that the motion of rotation is lost, and that the other movements, particularly flexion, are confined within very narrow limits. When we place the patient in a horizontal position, and endeavour to communicate any of these movements to the hip-joint, the patient complains of pain, and an evident crepitation can be heard and felt deep in the articulation. The limb is apparently shortened by from two to three inches; the apparent shortening arises from the obliquity of position of the pelvis relatively to the spine, and the elevation of the affected side is such that the crest of the ilium and the last short rib approach nearer to each other at this side in the ordinary attitude of standing by two inches than those of the opposite side. All these circumstances account for the apparent shortening of the limb, which however, on accurate measurement, will be found not to be really shortened more than an inch. The patient walks very lame, and with the foot and whole limb greatly everted. The nates of the sound side is unusually prominent, while that of the affected side is quite flat, and no trace of the lower fold of the glutæus is seen. The muscles of the thigh also seem somewhat atrophied, still they do not want for firmness; and we may uniformly observe that the calf of the leg of the affected limb is not inferior in size and firmness to the other. When we minutely examine the great trochanter, we find it larger and more prominent than usual; and about the situation of the acetabulum, horizontal branch of the os pubis, and lesser trochanter, bony protuberances can, upon careful examination, be recognized. This disease, when once fully established in the hip-joint, rarely or never extends itself to the other articulations. We have known, however, a few examples in which it affected both hip-joints in the same individual. The chronic inflammation of the various structures of the joint in which the disease consists, is never accompanied by any appreciable degree of heat or external swelling of the soft parts, and we have never heard of the inflammation going on to suppuration.

The following case will shew the necessity of making the profession fully acquainted with this disease, as it proves how very obscure are the early signs of the affection, and that even the morbid appearances may be confounded with those which are the result of accident. At the meeting of the British Association in Dublin, in the year 1836, one of its most distinguished members, Mr. Snow Harris of Plymouth, made the following communication to the medical section :—"Sir A. Cooper and many other eminent surgeons had doubted the possibility of union taking place in fracture of the neck of the thigh-bone, within the capsular ligament. A case had lately fallen under his (Mr. H.'s) notice, which he thought would tend to set the question at rest. It was that of a gentleman who had received an injury by being thrown from his gig ten years ago. He had got up and walked immediately after the accident, but continued lame from that period up to the time of his death. He had been attended by some of the most celebrated surgeons in London, but they had not been able to determine whether there was a fracture of the bone or not, but kept him lying on a sofa for nearly twelve months. The injured limb was shortened, the foot everted, the thigh wasted, and owing to the constant inclination of the body forward on one side, a lateral curvature of the spine took place. Some time ago the gentleman died of disease of the heart; and Mr. Harris, being anxious to examine the parts, removed the acetabulum and a portion of the thigh-bone, which he then presented for the inspection of the meeting. He had found the trochanter higher up than natural, and the neck of the bone shortened; a section of the bone had been made, and the line of union, in Mr. Harris's opinion, was clearly manifest." *

When Mr. Harris exhibited this specimen to the medical section of the British Association which met in Dublin, it excited much interest, first as the individual, the subject of the case, was the celebrated comedian Mr. Matthews, and secondly, as at the announcement of the case it was asserted that it settled in the affirmative the much agitated question, whether the intra-capsular fracture of the cervix femoris was or was not susceptible of osseous union. The writer was present at the communication of this case to the section, and upon the presentation of the specimen expressed his doubts that this case, either from its history or post-mortem appearances, was an example of the intra-capsular fracture, and rather held the opinion that it was one of this chronic rheumatic affection which he has been endeavouring to describe; in which opinion he was most decidedly confirmed upon inspecting the acetabulum, the widening of this cavity, the complete filling up

* See Dublin Journal, vol. viii.

of the fossa which is normally destined to contain the substance called Haversian gland, the shortening of the neck of the femur and depression of the head towards the lesser trochanter, and the ivory deposition on it. In this view Mr. Smith, who had so well described the disease in question, and the hospital surgeons around him, concurred, and Mr. Snow Harris himself quickly became a convert to our views, and we are satisfied from what we observed of his liberality, that we have his full permission to communicate this case in its present form to the profession. The sketch (*fig.* 315) is taken from the cast of the

Fig. 315.

Mr. Snow Harris's case.

head and neck of the femur presented by Mr. Harris to the College of Surgeons, Dublin. The upper part of the head of the femur was exceedingly rough on its surface, and of an oval form from above downwards; the axis of the neck was at right angles with the shaft, and seemed to run horizontally inwards and backwards, so that the length of the fossa which exists posteriorly between the corona of the head and the posterior inter-trochanteric line, was in this case less than a quarter of an inch, a fossa which we know naturally measures two inches. In viewing the oval form of the head, we conclude the movement of rotation must have been impossible; from the shortening of the neck posteriorly, we can infer that the toe and foot must have been greatly everted, and from the depression of the head, to the level of the trochanter, the femur must have been nearly one inch shorter than the other. The lamented individual had not suffered from the disease more than ten years, so that the morbid appearances were not to the same amount as we are accustomed to see as the result of this very slow disease.

The following case is that of an individual who has been, to the writer's knowledge, suffering for many years under this disease.

Patrick Macken, now aged seventy-seven years, was brought up as a postilion and groom, but for the last seventeen years has been quite unfit for service in consequence of his having been afflicted with a very severe pain in his right hip; from the first attack of which he became lame, and ever since the lameness has been slowly but gradually increasing. In every

Fig. 316.

Chronic rheumatic arthritis of the Hip.

other respect his health is excellent, except that he has some wandering rheumatic pains in other joints, particularly in the right shoulder.

He walks with great labour and pain, and now requires the assistance of a stick in each hand (*fig.* 316); in the morning his movements are stiff and confined, but they become freer on exercise; in the evening of a day he has walked much, the pain and stiffness are worse and increased in proportion to the excess of exercise and labour he had undergone in the day. While he remains in bed he rests on the affected hip, and suffers no pain whatever except he suddenly turns himself incautiously. As soon as he gets up and throws his entire weight on the diseased hip-joint, the pain commences; if asked in what particular part of the joint he feels most suffering, he points to the back part of the great trochanter and to a point which corresponds to the situation of the lesser trochanter; he says the pain shoots from these points down the front of the thigh to the knee. These pains are sometimes more severe, and sometimes less, without his being able to assign any cause for these alterations, and he cannot observe that the state of the weather has any influence on them whatever.

As he stands at rest, he throws the weight of his body on the left or unaffected limb, while the right leg hangs in front and slightly across the left, and seems to be at least three inches shorter; he leans slightly back and supports himself on two sticks: as he walks the right foot is considerably everted, and when he moves without sticks (which he accomplishes with the greatest difficulty) he places the whole sole of the foot flat upon the ground. He never, however, ventures of his own accord to move without the help of two sticks, by the assistance of which he is enabled to walk quicker; while moving along thus, the heel of the affected limb does not quite reach the ground, and the lumbar vertebræ undergo great motion. He cannot under any circumstances flex the thigh on the abdomen, so that when he assumes the sitting posture, he is obliged to place himself forwards on the very edge of the seat, the right thigh remaining in the same line as the axis of the trunk, the leg usually flexed and placed under the chair, or across behind the other, and he finds the utmost difficulty in putting on his stockings and shoes. He has scarcely any motion in the hip-joint. When we view the hip in front, and examine it, we see and can feel a considerable bony fulness, corresponding to the horizontal branch of the pubis: the trochanter major seems placed very high up, and is extraordinarily large as if surrounded with ossific deposits. The thigh is somewhat atrophied, being an inch and a half less in circumference than the other, but the calf of the leg is not reduced, and the muscles seem firm; the apparent shortening of the limb, when he rests on the sound one, arises from the lumbar vertebræ being much curved to the opposite side, and the pelvis being elevated on the affected side, while the real shortening ascertained by accurate measurement amounts only to half an inch.

If we place the patient horizontally and attempt to communicate to the hip-joint any movement, as of rotation, flexion, abduction, a well-marked crepitus is elicited, and the range of motion is found to be very limited indeed; a little abduction is admitted; rotation and flexion seem just to a sufficient degree to shew that no anchylosis exists. The movements give some pain to the patient, but we can press the trochanter firmly so as to direct the head of the bone deep against the fundus of the acetabulum, and we can even strike the heel and sole of the foot with violence without giving the patient the slightest sensation of pain.

The anatomical characters of this disease are very well marked. The muscles are usually of a paler colour than natural, and are found not to be so well developed as those of the opposite or sound hip. The fibrous capsule of the joint is greatly thickened, the cotyloid ligament is either ossified or absorbed, and the ligament which completes the notch, and in the natural state gives origin to the ligamentum teres, is usually converted into bone, leaving generally beneath its arch whether bony or not a space for the transmission of bloodvessels to the interior of the joint;* when the disease is fully established the ligamentum teres is altogether removed, the synovial fluid is deficient in quantity, and the cartilage is removed from the bottom of the acetabulum, and upper surface of the head of the femur. If here and there some vestige of the synovial membrane or sub-synovial tissue remain, it is in a highly vascular condition, presenting an intensely red colour. In a case of dissection which Messrs. Smith, Brabazon, and the writer witnessed lately of this disease, we observed that the shortened neck of the femur was entirely surrounded with a number of red villous-looking productions of the synovial membrane. These were of a rounded and conical form, half an inch long and two or three lines broad at their bases. They resembled much in form the long conical papillæ to be seen on the tongue and about the fauces of herbivorous quadrupeds; however, instead of being white and firm they were soft and villous, and of an intensely red colour. The line of the corona of the head was absorbed and excavated in points, and the different foveæ or depressions were completely occupied by these vascular fimbriæ. Still more recently the writer met with a similar specimen which he presented for inspection to the Pathological Society, in which these vascular fimbriæ were equally conspicuous.*

The acetabulum is generally much larger and deeper than natural, and forms a circular cup often two inches deep with a complete level brim, which is sometimes so much narrowed as to render the extraction of the head of the femur difficult. This is the most frequent abnormal appearance the acetabulum presents; but occasionally it is increased in size, and is at the same time very shallow and of an oval form.

When we examine the bottom of the acetabulum we find it widened and not any trace of Haversian gland is left; the interior presents a worn and porous appearance, the cartilage and compact stratum of bone which the cartilage normally covers, having been removed, and in some places where the friction and pressure from the head of the femur have been greatest, instead of a rough and worn porous appearance, resulting from the exposure of the cells of the bone, a dense enamel has been as it were ground into these pores, and here the surface presents the polish, smoothness, and hardness of ivory. This mechanical removal of the cartilage and exposure of the interior of the cells of the bone, and substitution for the cartilage of a dense inanimate enamel, we imagine, are processes which are not confined to the acetabulum; but their results are seen also on those parts of the head of the femur which are subjected to pressure and friction; hence we find the effects of friction, above alluded to, most

* Cruveilhier, livraison iv. p. 1. La presence d'un nerf et d'un vaisseau, ces parties fondamentales de l'organisation, semblent en quelque sorte respectées par les lesions organiques, qu'elles soient ces lesions circulent tout autour, mais ne les envahissent presque jamais, ou du moins les envahissent après tous les autres tissues lorsquelles sont parvenus à leur dernière periode.

* Dublin Journal for March 1839, No. xliii.

upon the upper surface of its head which supports the acetabulum in standing and progression. The form of the head of the bone becomes changed and flattened from above downwards; something like a bending or yielding of the neck of the bone may now be observed, and sometimes the inferior part of the circumference of the head of the femur is so much depressed that the under surface of the head has approached to the lesser trochanter.

Fig. 317.

Upon a cursory examination, it looks as if the " head of the bone were forced downwards by the action of some great pressure from above, and cases have occurred in which at last the head of the femur seemed to have sunk even below the level of the great trochanter, and to be supported by the lesser." *(B. Bell.)*

But besides these which we attribute to the effects of physical causes, there is, in the contemplation of the morbid results of this chronic disease of the hip-joint, sufficient to satisfy us that a very active *vital* process is going on in the interior of the bones, as well as in all the structures around the diseased joint. The thickening of the fibrous capsule, and hyperæmic state of the synovial structures, the exuberant growth of bone which we see around deepening the acetabulum, or surrounding its brim with bony nodules; the enlargement of the head of the femur, so as to make this head assume an oval convex surface, measuring in circumference ten inches and a half, as in the specimen from which the drawing *(fig.* 317) was taken, all these are sufficient proofs that besides the interstitial absorption going on in the interior of the cervix femoris in these cases, a very active condition of the minute arteries exists externally, giving birth to those exostotic deposits which encircle the head and intertrochanteric lines of the femur. It has been remarked, and we think with much truth, that those specimens which have been frequently produced and mistaken for united fracture of the neck of the femur, have been examples of interstitial absorption of the neck of this bone combined with external exostotic deposits; but these mistakes, however, we trust are not hereafter likely to occur.

Section III. *Accident.*—The hip-joint is, of course, like the other articulations, liable to sprains and to contusions. These do not require any special notice here; but fractures and luxations of the bones of this important articulation demand from us full consideration.

I. *Fractures.*—Fractures of the os innominatum may traverse the bottom or fundus of the acetabulum, or some portion of the brim of this articular cavity may have been broken off.

1. *Fracture of the acetabulum.* A. *Fracture of its fundus.*—When fracture of the bones of the pelvis happens to traverse the bottom of the acetabulum, the prognosis is unfavourable, as it is in all cases of fracture of the bones of the pelvis. When this fracture through the fundus of the acetabulum is the consequence of a fall on the feet, knees, or trochanter major of the femur, it sometimes happens that the head and neck of the femur unbroken are driven into the cavity of the pelvis. " Nous avons observé," says Dupuytren, " plusieurs fois, l'enfoncement de la cavité cotyloide par la pression exercée par la tête du femur, à la suite d'une chute sur le pied ou les genoux." In this case, the head of the femur is driven with force against the fundus of the acetabulum, and the latter breaks, and is crushed in, " enfoncé." The most remarkable case observed by Dupuytren was the following:—"The bottom of the cotyloid cavity had been driven in, and the head of the femur had passed entirely into the pelvis. The neck, which had not suffered any solution of continuity, was so strongly engaged in the opening, that, even when making the anatomical examination, I found it very difficult to disengage it, and to reduce this new species of luxation."* As these important remarks of Dupuytren are not accompanied by all the detail that is to be desired, where novel observations are reported, we shall here adduce the following case of fracture of the fundus of the acetabulum, with displacement of the head of the femur into the pelvis. Death occurred on the fortieth day after the injury, from diffuse inflammation. An opportunity was afforded to us of investigating anatomically the precise nature of the lesions in this case.

On the 3rd of December, 1834, a man, named William Sherlock, æt. 26, a painter by trade, was admitted into Jervis-street Hospital, under the care of the late Mr. Wallace. A few minutes before his admission, this poor man had fallen from a ladder, from a height reported to be fifty feet, on the flags of the street. On the next day, the 4th of December, when he had recovered from the insensibility and collapse which had succeeded to the fall, we found him complaining of intense pain of the right hip. He was quite unable to move the right thigh, and would not permit any examination of the hip, as the slightest movement communicated to the limb produced intense agony. The integuments covering the trochanter were discoloured, and there was much swelling around the hip-joint. The right or injured extremity was two inches shorter than the left, which circumstance he attributed to a

* Leçons Orales.

fracture of the femur, which had occurred some years previously. Besides this severe injury of the hip, it was also manifest, from some dyspnœa, cough, and bloody expectoration, that his chest was also injured, but venesection and other suitable treatment having been resorted to, the affection of the chest seemed to subside. His cough and dyspnœa for a time had disappeared, and his pulse fell to 80. On the twenty-third day from the accident, he said he felt that he had caught a most severe and violent cold, from a window having been kept open over his head. On this (23rd) morning, I found him suffering from great difficulty of breathing and violent fits of coughing, accompanied by scanty frothy expectoration. His pulse was 110, and hard, his tongue was brown and dry, his skin was hot, and I learned that these symptoms had succeeded to a rigor. They were attributed by me to pneumonia with acute pleuritis and considerable effusion, of which there were found, on examination of the chest by auscultation and percussion, very evident signs. These were actively combated by the ordinary treatment, but without success. His pulse was generally 120. He had cough, with muco-purulent expectoration, and dyspnœa. He still obstinately refused to permit any accurate examination of the limb to be made. He said his right thigh was now as powerless as at first, but the injury did not prevent him sitting up in bed, when, from the urgency of the dyspnœa, he felt the desire for this position; on one occasion he had himself taken up, and placed for a time sitting up in a chair. On the thirty-third day after his admission, I found that his right leg and thigh had swollen, that he had raved much during the night; and that he had alternate flushings and paleness of countenance, which betrayed much distress. He now complained of pain in the right shoulder. His pulse was 130, small and compressible. He had retention of urine. His temper was irritable; his tongue was red, and morbidly clean and dry. He had much thirst. His lips were pale and bloodless. He died on the 12th January, the fortieth day from the accident.

Post-mortem examination.—There was effusion of pus into the cavity of the right pleura, and the usual results of acute pleuritis; pus also in the cavity of the pericardium, and a thin reticulated layer of lymph on the surface of the heart. An incision made through the soft parts to expose the bones of the hip-joint gave exit to a large quantity of dark brown serum, mixed with pus. This collection of matter extended from the superior part of the thigh, under the peritoneum up to the kidney. The soft parts having been removed, and the bones exposed, it was found that the shaft, head, and neck of the femur were uninjured, but the head of the bone was driven through the fundus of the acetabulum, which was fractured in a stellated manner, having been divided into three portions. The spiculated edges of the cavity protruded into the pelvis to the extent of one inch. They were sharp and hard. Nature had not made the slightest attempt at reparation. The finger could be passed along the neck of the thigh-bone into the cavity of the pelvis, through the perforation in the bottom of the acetabulum. The pelvis had been broken in several places. There was a comminuted fracture of the horizontal ramus of the pubis near its crest. There was another fracture of this ramus at its junction with the ilium, and a fracture through the body of the os innominatum extended from the anterior inferior spinous process to the great sciatic notch.

B. *Fracture of the brim of the acetabulum.*—The superior and back part of the cotyloid cavity, which overhangs the head of the femur, which is called by Soëmmering the *supercilium*, is sometimes broken off, and it follows almost as a necessary consequence, that a dislocation upwards and backwards of the head of the femur shall occur. It is an accident most liable to be mistaken, and most difficult to manage. We believe, indeed, in all the cases which have occurred, that permanent lameness has been the result. In such cases, the luxation of the hip is reduced without much difficulty, but displacement again shortly recurs. In symptoms and effects the case has a strong resemblance to the congenital luxation of the femur. I was once invited by my friend, Mr. Hilles, (now of London,) to see a case of supposed dislocation upwards and backwards on the dorsum of the ilium. I met the late Dr. M'Dowel in consultation on the case. It was as follows:—

Thomas Venables, æt. 25, on the 4th of October, 1834, received a severe injury of the right hip-joint in leaping across a ditch, having alighted with force upon the right leg. He fell immediately, and was unable to rise from the ground, or to walk or stand when raised. When the patient was supported in the erect posture, he had the ordinary symptoms of dislocation of the thigh-bone upwards and backwards on the dorsum of the ilium. No crepitus was discovered. On the following morning an extending force having been applied by the pulleys, the head of the bone resumed its natural situation, and the deformity of the limb disappeared. When the patient was visited on the following morning, (the 6th,) it was found that during the night the head of the bone had started from the acetabulum, and that all the former signs of the injury had reappeared. On the 7th, the displacement was again reduced. While the bone was yielding to the force of the pulleys, the writer had the palm of his hand pressing on the great trochanter, as this last advanced slowly towards the acetabulum. He was sensible of a rough grating sensation, which was communicated to his hand, and gave him the idea as if the head of the bone were dragged along a scabrous rough surface. The case proceeded favourably until the night of the 10th, when, owing to the disturbance occasioned by the action of a purgative medicine, the dislocation recurred a third time. It was observed that, although when the patient was supported out of bed the foot was inverted, still the toes could be somewhat everted. An accurate examination being now instituted to ascertain whether a fracture existed, a distinct crepitus was discovered at the upper and back part of the acetabulum. The crepitus and frequent recurrence of the displacement rendered it sufficiently obvious that the brim of the acetabulum had been broken in the above-mentioned situation. The bone was a third time restored to its place, and a strong band placed around the pelvis. In 1836, I admitted the man into the Richmond Hospital. He was at this time unable to walk without the assistance of a crutch. The injured limb was one inch and a half shorter than the other. When standing, he rested it upon the points of the toes, the heel being drawn upwards; but a slight degree of extension was sufficient to restore it to its natural length; and when the man was lying in bed there was hardly any difference perceptible in the length of the two limbs. The breadth of the injured hip was occasionally greater than that of the sound one, and the head of the femur could be pushed upwards easily, and, of course, it always ascended, when the patient endeavoured to support his weight upon it; and in many motions of the joint, the rubbing together of the broken surfaces was distinctly audible.

After having remained in the Richmond Hospital under our observation for two months, he was discharged. Nothing could be devised to make his limb more useful to him. The fracture, therefore, of the supercilium of the acetabulum is a very serious injury, which it behoves surgeons to be well acquainted with. A successful mode of managing such cases has not yet been exemplified.*

2. *Fracture of the superior extremity of the femur.*—The head of the femur is so protected by the acetabulum, that it is seldom or never fractured, except by gunshot injuries. The neck and rest of its superior extremity are, however, we find, subjected to various accidents. The general symptoms of fractures of the neck and upper extremity of the femur are, that the affected limb is shorter than the other, the heel rises to the level of the opposite malleolus, the patella, leg, and foot seem much everted; there is a flattening of the natis, and a fulness of the groin. The patient does not attempt to stand, much less to walk. There is in the part itself, as it were, a conscious inability to support the weight of the body, and even when the patient is lying on a horizontal plane, as in bed, we find that he cannot, by the unassisted effort of the muscles of the injured limb, elevate it from the horizontal level, upon which it lies powerless. When the surgeon, standing at the foot of the bed, seizes the affected limb, and pulls it towards him, so as gradually to overcome the contractile power of the muscles, the limb is restored to its natural length, and if now we resort to the painful expedient of rotating the thigh, crepitus is rendered manifest. Whenever the surgeon relaxes the force by which the limb was restored to its natural length, the shortening, eversion, and deformity of the limb recur. Such are the general signs of fracture of the upper extremity of the thigh-bone. The portion of the bone, called the neck, may be fractured transversely with respect to the direction of its long axis, either within or without the capsular ligament. The first is denominated the *intra-capsular* fracture, the second the *extra-capsular* fracture. Oblique fractures of the neck of the bone are not impossible.

A. *Intra-capsular fracture of the neck of the femur.*—This fracture has been seldom seen in the young subject, but is one of the most common accidents to which elderly people are liable. In such persons many circumstances in their organization appear to account for their great liability to this accident. Their muscles have lost their firmness, and are more or less in a state of atrophy; the trochanter major becomes peculiarly prominent; the neck of the femur yielding somewhat, perhaps, to the weight of the body, descends and loses some of its obliquity. This atrophy of the muscles and bones is not so frequently noticed in the male as in the elderly female, in whom the breadth of the pelvis is greater and the trochanter major more projecting. These observations account sufficiently for the great liability to the intra-capsular fracture, which we notice in the elderly subject, and for the more frequent occurrence of the accident in the aged female than in the male. In the young subject the trochanter major does not project so much, the muscles surrounding the hip-joint are remarkably firm, and when falls on the side occur, the surrounding muscles and the os innominatum share, with the great trochanter, the weight of the fall. The bone in the young subject is better calculated from its form and its organization to resist the effects of falls on the trochanter, and in these fractures of the neck of the femur have been rarely witnessed. In the young subject, too, the neck of the femur is comparatively shorter than in the aged, the angle of union of the neck with the shaft of the bone is more open, and the axes of both neck and shaft are more in a line. The great proportion of animal matter existing in the bones of the young, and consequent elasticity of the bone, render it capable of resisting fracture, while, on the contrary, the comparative deficiency of animal matter, and the consequent redundancy of earthy material in the aged subject, render the neck of the femur friable. In a word, the tissue of the bones in general does not escape, in the aged, that atrophy which affects the rest of the system, and when we recollect the functions which the neck of the thigh-bone has to perform, we shall not be surprised to learn that the effects of this atrophy are more readily felt and seen in this part of the osseous system than perhaps any other. The superincumbent weight of the body and the action of muscles must have a tendency to diminish the obliquity of the neck of the thigh-bone, to render it more horizontal, and consequently less capable of bearing up against the effects of concussion.

Besides the loss of obliquity of the neck of the thigh-bone, we find two other circumstan-

* In the twelfth volume of the Dublin Medical Journal, Mr. R. Smith has made some valuable observations on this case, in relation to the diagnosis of obscure cases of injury of the hip and shoulder-joints.

ces relative to the neck of the bone itself, rendering it very liable to fracture in the aged. I mean the expansion of the cells, by which the strength of the interior of the bone is diminished; and, secondly, by the partial removal by absorption of that long bony arch of compact tissue, upon which in the adult depends, we believe, the principal strength of the neck of the bone (*fig.* 318); and even in many aged subjects, we find the partitions of the bony cells removed, and a large cavity filled with fatty medulla occupies the centre of the cervix femoris. All these alterations obviously weaken this portion of the thigh-bone, and we feel very little doubt but that when the condition of the bone above alluded to exists, even without a fall a fracture may occur. We have noticed specimens of senile degeneration of the neck of the femur in museums, in which the neck of the femur had been removed gradually by absorption, so that the head of the bone had approximated to the trochanters. Such specimens, where the history of the case was unknown, have, we doubt not, been from time to time adduced as evidences in favour of the possibility of bony consolidation of the intra-capsular fracture. These observations on the effects of senile degeneration of the neck of the thigh-bone sufficiently account for the remarkable frequency of the intra-capsular fracture of the cervix femoris in the aged subject from the most trivial causes. The fracture, under such circumstances, should, in our minds, be looked upon more as a stage of morbid alteration, from which no amendment is to be expected, than as an accidental lesion, which the efforts of nature and the aid of surgery can be deemed adequate to repair.

B. *Extra-capsular fracture of the neck, and fracture of the superior portion of the shaft the femur.*—Fracture of the neck of the femur may occur in a part of the bone immediately external to the synovial sac and capsular ligament; it may pass obliquely through the cervix femoris and trochanters, or it may occur in the cellular and spongy portion of the bone which is immediately external to these processes. In all these cases the accident is usually met with in young and vigorous individuals, and is often very severe. There is in these cases much deformity, great eversion of the limb, with considerable shortening and swelling. The fracture having traversed the bone external to the capsular ligament, there is but little to resist the full force of muscular action upon the lower fragment of the bone, while the upper is forced downwards by the weight of the body, so that, from both these causes, much shortening is produced. The muscles are in a state of spasm, and at first resist the surgeon's efforts to bring down the limb to its normal length. The muscles gradually yield to gentle and continued extension, and if now a movement of rotation be communicated to the broken femur, a crepitus can be felt by the hand pressing on the great troch nter, which on rotation of the femur is perceived to move in a small circle. Eversion of the whole limb, in cases of fracture of the upper extremity of the femur, has been noticed as one of its most prominent symptoms, and the cause of it may be fairly attributed to the preponderating influence of the rotators outwards, to which the lower fragment is abandoned when fracture has occurred: the rotators outwards are the glutæus maximus, the three adductors, the pectinalis, the psoas magnus, and iliacus internus, together with the obturators, pyriformis, and other muscles, inserted into the posterior inter-trochanteric line. These muscles are solely opposed by the rotators inwards, which are few and comparatively weak. Notwithstanding the violence of the injury in general, and the deformity, the prognosis in these cases is much more favourable than in the case of the intra-capsular fracture, because in the former a solid bony union of the fragments may be reasonably hoped for.

In considering the symptoms of fracture of the superior extremity of the shaft and of the neck of the femur, whether the seat of fracture be within or without the synovial capsule, it should be recollected that extraordinary cases may occur; thus there may be fracture combined with inversion of the limb. The cause of this inversion, in particular cases, has been sought for, and Mr. Guthrie gives ingenious anatomical reasons for this rare symptom, depending upon the line of direction the fracture may have taken; if, for example, the fracture may have taken such a course as to detach from the shaft of the femur the neck, and at the same time also the lesser trochanter, to which is attached the great rotator outwards, the psoas and iliacus, and if at the same time the attachments of the gemini, obturators, and pyriformis be destroyed, in this case Mr. Guthrie supposes that there is an anatomical reason for the rotation inwards, as the tensor vaginæ femoris and the anterior fibres of the glutæus medius remain unopposed. This explanation is ingenious, but the cause of occasional inversion of the limb in fracture, noticed by Petit, Desault, and all subsequent writers, has not yet, in our mind, been sufficiently elucidated. The phenomenon of inversion of the foot, in cases of fracture of the upper extremity of the femur, is extremely rare, but it has been noticed in the intra-capsular fracture, (Stanley, Smith,) in the extra-capsular fracture, (Guthrie,) and we have ourselves seen it in all these cases. The deviation inwards, says Dupuytren, is so rare, that we can scarcely reckon upon meeting it once in a hundred cases. The surgeon of the Hôtel Dieu attributes much of the rotation outwards in fractures of the neck of the thigh-bone to the action of the adductor muscles, but adds, "il faut dire aussi, qu'on notice presque aucune partie d'une autre cause, qui cependant peut seule rendre compte de la deviation en dedans, et apprendre à y remedier. Je veux parler de l'obliquité des fragmens dans la fracture du col du femur, si le fragment interne se porte en arrière, et l'externe en avant, il y a alors deviation en dehors. Si, au contraire, la fracture est oblique, en sens inverse, la deviation aura lieu en dedans. C'est donc par l'obliquité des fragmens, que ces variétés de deviation peuvent être appreciées."

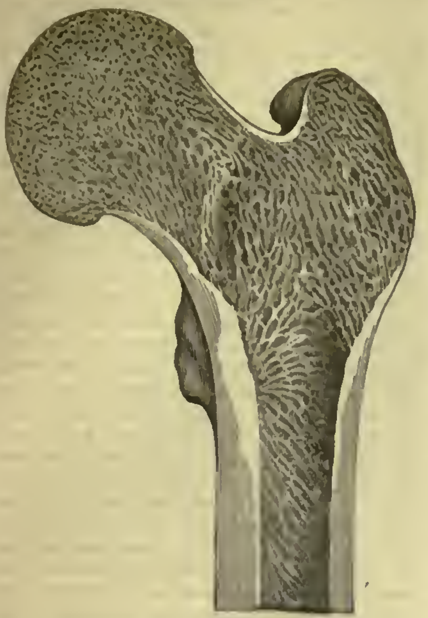
C. *Fracture of the neck of the femur, compli-*

cated with fracture through the trochanter major.—In the thirteenth volume of the Medico-Chirurgical Transactions, Mr. Stanley has remarked that among the more complicated injuries to which the hip-joint is liable, that of fracture of the trochanter major, combined with fracture of the neck of the femur, has, under certain circumstances, a strong resemblance to dislocation of this bone. Whenever the fractured portions of the trochanter can be brought into contact, a crepitus will be perceived, which will enable the surgeon to ascertain the precise nature of the injury; but when from the direction of the fracture, one portion of the trochanter major has been drawn by the muscles towards the sciatic notch, no crepitus can then be discovered. A direct source of mistake will then arise from the positive resemblance of the fractured portion of the trochanter to the head of the femur, the former occupying the place which the latter would do in dislocation, and if, with these circumstances, there should happen to be inversion of the injured limb, the difficulty of diagnosis must be considerably increased. The writer has seen such cases as those alluded to by Mr. Stanley, and when he confined his observations to the consideration of the joint only, he felt all the difficulty alluded to in forming an opinion; but in these cases the limb can in general be brought down to its natural length by forcible extension, and it is possible, too, to flex the thigh on the abdomen, which we know to be impracticable in the case of luxation. In most of the cases which the writer has witnessed of the fracture traversing obliquely the superior extremity of the shaft of the femur, detaching the trochanters, the foot and whole of the injured extremity were everted, a position it were impossible for the limb to assume, were the globular-shaped head of the bone on the dorsum of the ilium, or placed towards the ischiatic notch, and indeed, in the cases which he has seen, with inversion of the limb, the inverted position was not permanent, as when the patient was raised out of bed, and assisted to stand for a few minutes on the sound extremity, the injured limb gradually assumed an inclination forwards and outwards; the inclination, though slight, was always to a degree which it were impossible to give to the limb if the head of the bone were placed on the sciatic notch. Finally, as to the remarkable symptom of inversion of the limb, combined with fracture, we have never seen this inversion so rigid as it is in the luxation; the inversion can be overcome, and we have mostly found that in the cases in which this symptom was noticed, there existed a comminuted fracture of the superior extremity of the shaft of the femur, and the limb, if left to itself, would be found sometimes to be everted, sometimes to be inverted, and generally to possess a remarkable degree of flexibility, yielding to any movements the surgeon wishes to communicate to it. Such has been the result of the writer's individual observations on these cases.

D. *Fractures of the neck of the thigh-bone, with impaction of the superior or cotyloid fragment into the cancellated tissue of the upper extremity of the shaft of the femur.*—We have spoken of a fracture of the neck of the thigh-bone, in which the fracture runs transversely with respect to the direction of the axis of the neck of the bone, and also of oblique fractures of the cervix femoris (Dupuytren). In the former, i. e. the transverse fracture of the neck, the two opposite surfaces of the fragments are generally fairly confronted to each other, and each presents a granular broken surface; but instances have been met with in which there existed an interlocking of these surfaces. A bony spicula or dentiform process, as it were, has been seen to proceed from the broken surface of the superior or cotyloid fragment, and to sink into an alveolar-like depression on the upper surface of the lower fragment; to use the words of Cruveilhier: "L'engrènement des fragmens s'observe moins souvent, peut-être dans la fracture intra-capsulaire que dans la fracture extra-capsulaire. Cependant je l'ai observée plusieurs fois; dans un cas de fracture intra-capsulaire du col, observé sur un adulte très vigoureux, j'ai trouvé un engrènement reciproque formé ainsi qu'il suite le fragment superieur et le fragment inferieur presentaient chacun une cavité, et une avance osseuse; la cavité de l'un recevait l'avance de l'autre et reciproquement, l'engrènement était, qu'il y avait immobilité complete."

In the species of fracture which we are now about to consider, the superior or cotyloid fragment is firmly impacted into the cancellated structure of the superior part of the shaft of the femur. In this case the limb is shortened somewhat, though not much, and consequently the case may be mistaken for the intra-capsular fracture. When, however, the surgeon endeavours to bring the limb to its normal length, and to elicit crepitus, or by rotation of the femur he endeavours to ascertain whether the trochanter moves in a larger or smaller circle, he finds that he cannot elongate the shortened limb, nor elicit crepitus by rotation, nor can he learn anything satisfactory by the movement of the trochanter. In general the fracture is complete of the compact and reticular tissue of the neck of the bone, and the upper fragment is wedged into the lower, as is the fang of a tooth into its alveolus; but cases, we believe, have occurred, in which the fracture of the cervix femoris was incomplete, and had engaged merely the under stratum of the compact tissue of the neck of the bone. To comprehend well what occurs in the partial as well as in the impacted fracture, we should attend a little to the normal anatomy of the interior of the cervix femoris, and the disposition of the compact and reticular tissue, a subject the writer has elsewhere stated has been much overlooked, see Dublin Journal, vol. vi. p. 222, from which we quote the following words: "Let us make a vertical section through the neck of a healthy femur, in the direction of its long axis, and continue it down through the shaft of the dry bone, the section leaving one-half of the femur in front, and the other behind with the lesser trochanter, as has been done in the specimen of the healthy femur of a well-formed adult man, from which *fig.* 318 has been taken. This simple view shews us, that the principal strength of the neck resides in an arch of compact tissue, which begins small

Fig. 318.



where the globular head joins the under part of the neck, but which gradually enlarges downwards towards the lesser trochanter, and even so low as the middle of the femur, where it will be found nearly twice the breadth of the opposite wall of the shaft of the bone; the compact stratum which, scarcely thicker than a wafer, invests the entire of the head, upper part of the neck, and trochanter, seems to have little reference to any design of imparting strength or resistance to this portion of the bone, and the same may be said of the whole of the reticular tissue of these processes, while, on the contrary, the compact tissue of the under surface of the neck seems artfully arranged, if we can so say, so as to give support to the weight of the body in the erect position; hence do we find this compact stratum thrown into an arch, upon which the weight of the body falls, as that of a carriage does on the C spring which sustains it.

When we fall or leap from a height on the feet or knees, the thin upper stratum of the neck, and the whole of the reticular tissue of the bone will first receive, and probably yield somewhat to, the weight, by which some of the force of the shock may be decomposed, but to the bony arch of compact tissue, to which we have alluded, must ultimately be referred any violence which the neck of the femur can receive from any impulse transmitted from above.

We seldom hear of a fracture of the neck of the femur occurring to a healthy adult when he falls with violence on his feet or knees, for the weight of the superincumbent body is thrown in the most favourable manner on the bony arch of compact tissue before alluded to, which from its density and form, and strength derivable from both, it is almost always able to resist; and even a fracture of the acetabulum or rupture of the capsular ligament and dislocation are accidents more likely to happen under these circumstances.

But, on the other hand, let us suppose a person to fall on the trochanter major, which is resisted by the ground, while the weight of the pelvis, &c. acting obliquely on the under surface of the neck, will have a tendency to bring the neck of the femur into a straight line with the shaft of the bone, or in other words, to efface its obliquity; here the compact tissue, so often alluded to, receives the force from below in a most unfavourable manner, and this tissue cracks across, and if no more happens for the present, we shall have the simplest form of partial fracture of the neck of the femur.

While circumstances are in this state, we can conceive the possibility of a patient being able to stand after such an accident, and even walk for some distance; and when examined by the surgeon, we can understand how the latter, as it has often happened, might be deceived into the opinion that there was really no fracture. Again, we can easily imagine how under such circumstances an awkward movement or a fall may render the fracture complete, or how, from a severe secondary injury, or even the continued action of the first impulse, somewhat varied in its direction, the upper fragment of the broken neck of the femur could be wedged into the cancelli of the shaft.

Anatomical characters of fracture of the neck of the thigh-bone.—In those cases in which opportunities have occurred of making recent anatomical examinations of those who have died shortly after having suffered fracture of the neck of the thigh-bone, blood has been found extensively extravasated beneath the skin, among the interstices of the muscles, and we find the line of the fractures through the trochanters and upper portion of the shaft of the femur itself marked out by blood in a coagulated state, which had insinuated itself into and among the interstices of the broken bones. When we examine a case of intra-capsular fracture which had taken place a long time previously to the death of the patient, very remarkable changes in the structures around the joint are noticed. The muscles, when compared with those of the opposite side, are more or less atrophied. This observation, however, only applies to the greater number of the muscles around the hip-joint, as some of the smaller ones (in cases of ununited fractures of the neck of the thigh-bone of long standing) are usually found to have undergone a considerable change in their appearance and structure; of all these, the obturator externus seems to be the most changed and thickened. This is easily accounted for, when we recollect that when the neck of the femur is fractured, there is a strong tendency in the muscles around the joint to drag up the femur, and cause its shortening; indeed, the capsular ligament and the obturator externus alone resist the ascent of the head of the bone on the pelvis. The tonic force of the muscles has constantly this tendency to elevate the femur on the dorsum of the ilium, and when the patient begins to walk, and to throw his weight on the fractured limb, then it is more particularly that the power of the obturator externus is called into action to restrain the ascent of the trochanter major, which is kept downwards by the obturator and by the strength of the capsular ligament, which undergoes a corresponding change of structure. The capsular ligament has been found semi-cartilaginous, and occasionally even spiculæ of bone have been found in it; we have also known it to be much elongated, so as to allow the lower fragment to ascend much on the dorsum of the ilium. We have found the capsular ligament usually entire in old cases, but occasionally the bursa, which exists in front of or under the psoas muscle, seems to have freely communicated with the interior of the joint. In some cases the natural thickness of the capsule is not much increased; in others it is very considerably so. In one of the cases alluded to by Mr. Colles, the capsular ligament was a quarter of an inch thick, in some places half an inch, and it had, at the same time, a firmness of texture which might be termed semicartilaginous. Two or three particles of bone were found in it. The synovial membrane, where it meets the neck of the femur, has been frequently found lacerated in recent cases; in older, inflamed, and in older still, adhesions of the synovial structures to each other have been observed. Thus the head of the fractured femur has been found adherent to the acetabulum, and we have frequently found filamentous adhesions between the synovial membrane of the neck of the bone and the interior of the synovial lining of the fibrous capsule. The synovial membrane, in the normal state, where it invests the narrowest part of the neck of the bone, is thrown into longitudinal plicæ or folds; some of the lowest and most distinct of these are denominated by Weitbrecht "retinacula." We do not believe that this accurate anatomist gave this name to these fibro-synovial folds with any practical knowledge of the functions which they occasionally perform in cases of fracture; but we know very well by experience that, in recent cases of the simple intra-capsular fracture of the neck of the femur, it very frequently, if not generally, happens that, although the neck of the femur is broken transversely with respect to its longitudinal axis, the cylinder of fibro-synovial membrane, which is reflected over the neck of the bone, is sometimes left unbroken, or is only partially lacerated. The fibrous periosteum, which is here added to the synovial investment of the neck of the femur, strengthens much this part of the membrane, and both together, in cases of intra-capsular fractures, serve the purpose of keeping nearly in apposition the broken fragments; and in cases in which the greater part of this cylindrical investment of the neck of the bone remains entire, or nearly so, the unbroken membrane and the vessels which pass along it must be the medium of vascular communication between the fragments.

The phenomena which extra-capsular fractures present are not unlike those which are the result of fractures elsewhere of the femur. We may remark, however, that one of the results of this lesion of the neck of the femur (as it is, indeed, of almost all other injuries or alterations of structure of this part of the bone) is, that the posterior part of the neck of the femur is diminished one-half in its normal length; the posterior inter-trochanteric ridge of bone approaches to within half an inch of the circular line which marks the junction of the head and neck of the bone. A large quantity of callus is usually thrown out in the line of the extra-capsular fracture, and the trochanter major becomes much deformed by it, and the neck so much shortened, that there is danger of the motions of the hip-joint being interfered with.

In recent cases in which intra-capsular fracture had occurred, little or no change has been observed worth noticing; but in old cases several phenomena of importance present themselves. 1st, In some cases we find a false articulation to have been formed; 2dly, there is union of the broken surfaces of the upper and lower fragment by means of ligamentous bands; 3dly, it is reported that complete bony union is effected, but the controversy upon this subject can scarcely be said to be yet terminated.

Very soon after intra-capsular fracture has occurred, the surfaces of the broken fragments undergo changes; they are smoothed off by the power of the absorbents, or are mechanically rubbed down by the friction of the broken surfaces, or by both these processes combined. In general the neck of the femur disappears altogether, and the basis of the head of the bone corresponds to the level of the circular brim of the acetabulum. The surfaces are generally brought into contact by the muscles, and frequently adhesions are formed between the neck of the bone and the internal surface of the capsular ligament, which, as has already been remarked, is greatly thickened; an oily fluid, resembling natural synovia, is shed over the broken surfaces, and here are all the elements of a false articulation present. The trochanters are, in consequence of the removal of the neck of the bone, brought near to the edge of the acetabulum, and bony growths generally shoot out from these processes and from the inter-trochanteric line posteriorly. These bony projections or vegetations sometimes rise as high as the edge of the acetabulum, and when the patient stands or walks, these bony growths rising up from the trochanter are supposed to afford a prop to the pelvis, and thus to assist somewhat the structures which perform the functions of the false articulation. It has been noticed that, in general, the removal of bone from the upper fragment extends as far as the basis of the head and the level of the circular brim of the acetabulum; but in some cases this fragment has been hollowed out. Again, in obedience to influences which we cannot explain, it has happened that the lower surface of the upper fragment formed an uniform convex surface, looking downwards, and corresponded to a large excavation formed in the substance of the great trochanter. This, we find, occurred in one of Mr. Colles's cases: the lower surface of the upper fragment was convex, and covered with spots resembling ivory, while the upper surface of the lower fragment was widely expanded into a cup. We have, in our museum, a very remarkable specimen of this abnormal condition of the hip-joint. The upper or cotyloid fragment seems united to the acetabulum by an imperfect anchylosis, while the lower surface of this fragment represents perfectly the half of a sphere looking downwards; the neck of the femur has been entirely removed, and a cup is hollowed out in the great trochanter to receive the convex surface of the upper fragment above alluded to. This surface, as well as the cavity formed in the trochanter, have the polish and hardness of ivory. The history of the case, as to how the functions of the joint had been performed, is unknown. The patient died in the Richmond Hospital, under the care of Dr. Hutton, of a disease unconnected with the chronic affection of the hip-joint. In the examination of old cases of intra-capsular fracture, we have found the capsular ligament short and strong, as already mentioned, and that it retained the trochanters close to the brim of the acetabulum, the cervix femoris having been altogether removed. In a case which Mr. Brabazon and the writer examined lately, of an old woman who had fractured the neck of her femur several years before her death, and in whom there was shortening of the extremity for two inches and a half, the neck of the femur had altogether disappeared to its base The surface on the internal part of the shaft of the femur, from which the neck of the bone nominally springs, was plane and smooth, and no vestige even of the lesser trochanter existed. The under surface of the globular-shaped head of the femur was removed to the exact level of the brim of the acetabulum, in which the remainder of the head was still retained by an inter-articular ligament, which seemed to have been reduced to the structure of loose cellular membrane. The acetabulum of this side, too, was evidently smaller than that of the opposite side, and the cartilage covering it, and that also investing the remnant of the head of the bone, were partially removed. From want of use, it would appear that all these parts were in a state of atrophy. In this respect there was a correspondence between the internal and external structures of the broken limb, for the whole extremity was deformed, shortened, and, as is usual, much reduced in size when compared with the opposite limb. Union by means of a ligamento-cartilaginous substance is by no means uncommon. In this case, as in almost all others, the neck of the thigh-bone altogether disappears, and the trochanters are brought up to the level of the acetabulum, which still retains the remnant of the head of the bone. The broken surfaces are united closely enough to each other by a fibrous substance, and this union is sufficiently analogous to that which we frequently see in cases of fractured olecranon or patella.

We have spoken of a species of fracture which is called the *impacted* fracture. In this case the femur is broken generally at the basis of the neck, not far from the inter-trochanteric lines: sometimes it is only the under part of the neck which is broken, and then the fracture is only partial; but generally the compact tissue all round this portion of the neck is, by an accident, cracked across, and the superior fragment, that is, the whole of the cervix femoris, is impacted into the cellular structure of the superior extremity of the shaft of the femur (*figs.* 319, 320). The limb is shortened half an inch, and in general everted. In the Dublin Hospital Reports, vol. ii. Mr. Colles has given a good delineation of this species of fracture. In Sir A. Cooper's work, also, similar specimens may be seen of this impaction of the upper fragment. " La realité de ce fait interessant" seemed new to the editors of Dupuytren's " Leçons Orales," in 1832, in which we find it stated that the superior fragment of the broken neck of the thigh-bone is sometimes driven into the thickness of the spongy texture of the superior extremity of the inferior fragment, and the consolidation is effected readily enough. To conclude in the words of the Leçons Orales: " plusieurs pièces d'anatomie pathologique, tirées du Museum de l'Hôtel Dieu, et représentant les fragmens ainsi consolidés, ont été montrées à l'amphithéâtre, et ont convaincu chacun de la realité de ce fait interessant. Il est utile de noter cette cause de deviation; elle peut rendre compte, suivant les cas, de quelques faits exceptionnels de deviation du pied en dedans dans la fracture du col du femur, faits exceptionnels, qui ont été observés par plusieurs auteurs."* In the museum of the Richmond Hospital we have some specimens of this fracture. *Fig.* 319 represents a section of the supe-

Fig. 319.

rior extremity of the femur of a woman who met with this species of fracture. The history of her case, as recorded in the catalogue, is as follows:—" Mary M'Manus, æt. 52. Fracture of the neck of the femur external to the capsule. The upper fragment has been driven down, and has become firmly impacted in the cancelli of the shaft of the bone. The trochan-

* Leçons Orales, tom. ii. p. 100.

ter minor is split, the fissure passing at right angles with the body of the femur. The descending ramus of the pubis was broken obliquely, the fracture passing downwards and inwards from the thyroid foramen. There was a large effusion of blood into the crushed cancelli of the bone. The patient, from whom the preparation was taken, was thrown down by a cart loaded with hay. The horse and cart passed over her. The injured limb was shortened three quarters of an inch, the foot was everted, and the slightest motion was painful. She died on the fourth day after the occurrence of the accident, having never recovered from the shock." Another specimen (*fig.* 320) shews

Fig. 320.

this species of fracture in the case of a woman who survived the accident. "Alicia Sherlock, æt. 64. Section of the head and neck of the femur, shewing fracture of the cervix external to the capsule. The neck of the bone has sunk nearly to a right angle with the shaft. The compact structure which lines the concavity of the cervix has been broken, while the very thin stratum which invests the upper surface has yielded to the force without breaking, but the cervix has sunk into the cancellated texture of the shaft at a right angle, and is now supported upon the lesser trochanter. There is no motion whatever between the broken surfaces, nor the slightest trace of fracture at the central part of the neck of the bone. The injury was produced by a fall on the trochanter. There was but little alteration in the position of the foot, but the tendency was to eversion. The shortening amounted to half an inch, and crepitus was not distinguishable. The patient lived three months and a half after the receipt of the injury." In both these cases we have a confirmation of our opinion, that the reduction of the compact arch of bone which occupies the under surface of the neck of the femur to a thin lamina, predisposes to fracture of this portion of the neck of the thigh-bone. In the case in which the examination was made four days after the accident (*fig.* 319) we find, of course, that there was no osseous deposition around the inter-trochanteric lines, but that, on the contrary, in the case, A. Sherlock, (*fig.* 320), which survived the accident for more than three months, exuberant growths of bone surrounded the seat of fracture, and contributed to form a kind of socket, which received the superior fragment, by means of which the patient was enabled to throw her weight on the injured limb, and even to walk. The lesser trochanter, in most of the cases which we have examined, was greatly increased by bony depositions, and became a prop to support the head, and it is probable that, in these cases, the acetabulum is propped up by the growths of bone from the shaft of the femur. "This is a mode of union," says Mr. Colles, (alluding to the impaction,) "very little inferior to callus in point of firmness, but very different in its nature," and which, he conceives, is peculiar to fracture of the neck of the thigh-bone. In these cases Mr. Colles has found a thin cartilaginous plate every where interposed between the neck and shaft. The new osseous production could have very little assisted in keeping the fractured pieces in apposition, for it was principally thrown out about the trochanters, a small portion only being formed below the neck, yet the motion allowed between the fragments was so very inconsiderable, that it required a close inspection to discern it, so that, in this instance, the new osseous matter contributed very little to the consolidation of the broken bone, the firmness of which (inferior only to bony anchylosis) must therefore be ascribed entirely to the interposed thin plate of cartilage. In one of Mr. Colles's cases, No. XI. a vertical section shewed that the neck had been fractured near to the trochanters, and lay across the top of the shaft; its broken extremity being in contact with the outer plate of the shaft. The external solid walls of the neck were very thin.* In a specimen of fracture of the cervix femoris, which we possess in our museum, the neck of the bone has been broken at its basis, near the inter-trochanteric lines, and was impacted nearly transversely into the cancellated structure of the shaft of the femur, and the force of the fall was so considerable that the upper fragment has absolutely penetrated the outer wall of the trochanter, and would have been in naked contact with the tendon of the glutæus maximus, had it not been for the existence of the bursa there situated.

From the specimens that we have examined, and have in our possession, we entertain no doubt but that solid bony union may take place between the impacted cervix femoris and the superior extremity of the shaft of the femur. In all cases of the impacted fracture, when the patient had survived the accident for a month or more, whether the union was complete or incomplete, exuberant growth of bone had sprung from the inter-trochanteric lines.

Does bony consolidation of the intra-capsular fracture of the cervix femoris ever occur?— This question has for the last twenty years been

* Dublin Hospital Reports, vol. ii. p. 351.

much agitated; Desault, Platna, and John Bell long ago expressed their opinion that a fracture within the capsular ligament would not admit of union by callus. Sir A. Cooper in his Treatise on Dislocations and Fractures (p. 127) says, "In all the examinations which I have made of transverse fractures of the cervix femoris entirely within the capsular ligament, I have never met one in which a bony union had taken place, or which did not admit of motion of one bone upon the other. To deny its possibility and to maintain that no exception to the general rule can take place would be presumptuous, especially when we consider the varieties of direction in which a fracture may occur, and the degree of violence by which it may have been produced; as, for example, when the fracture is through the head of the bone and there is no separation of the fractured ends, or when the bone is broken without its periosteum, and the reflected ligament which covers its neck torn, or when it is broken obliquely, partly within and partly externally to the capsular ligament; but all I wish to be understood to say is, that if it ever does happen, it is an extremely rare occurrence, and that I have not met a single example of it."

Sir A. Cooper's opinions, when they were published, particularly in Paris, excited astonishment, and many observations were made in the clinical lectures and works of the day upon the supposed error of the doctrine, that the intra-capsular fracture of the neck of the thigh-bone was not susceptible of bony consolidation. Messrs. Roux, Dupuytren, and others contended that they had treated many cases of the intra-capsular fracture of the neck of the thigh-bone successfully, and that bony consolidation had been effected, and besides shewed to their classes what they considered as decided examples of such union of this fracture. They did not content themselves by referring to living cases, because these were likely to be questioned, but they produced various specimens obtained by post-mortem examinations of persons who had recovered from the effects of the fracture, but had died of other disease. Some of these specimens were examined by Mr. Crosse, and some were sent to London to Sir A. Cooper, but they failed to convince either Mr. Crosse or Sir Astley that they were true instances of the intra-capsular fracture consolidated by bone. We may say the same of some preparations in the museum of the Royal College of Surgeons, London, which were supposed to be proofs of a bony union of the neck of the thigh-bone subsequent to a fracture within the capsular ligament, but says Mr. Wilson, "I have attentively examined these two preparations, and cannot perceive one decisive proof in either of the bone having been actually fractured." One of these cases was published in the Edinburgh Medical and Surgical Journal as an example of united fracture. The writer has known many specimens adduced as proofs of bony consolidation of the intra-capsular fracture of the neck of the thigh-bone, which, upon examination, were found to have been the result of disease. The neck of the thigh-bone, we know, is greatly shortened when the hip-joint is the seat of that abnormal change which we have stated to be the result of chronic rheumatic arthritis, but in this case the previous symptoms, the history of the case, and when these cannot be collected, the state of the acetabulum and other appearances, sufficiently point out the difference. Again, the effect of senile degeneration of the cervix femoris is very liable to be mistaken for an united intra-capsular fracture. In this, however, the history of the case, the co-existence of the same condition on both sides, the penetration of the interior of the attenuated cellular structure by an oily medulla, and other characters of the senile degeneration, will serve to prevent false conclusions. Lastly, we have also frequently known specimens of the impacted fracture, where the whole cervix has been firmly driven into the substance of the great trochanter, mistaken for examples of bony union of the intra-capsular fracture. The quantity of callus that is in these cases added to the great and lesser trochanters, which encloses the impacted neck of the bone, is calculated on a superficial examination to induce erroneous conclusions, but a section of the bone, as represented in *fig.* 320, will explain the true nature of the case.

Various cases have been laid before the public and read before different learned societies, which have been considered as very decided evidences of bony consolidation of the intra-capsular fracture of the neck of the femur.

Case 1.—In the year 1827 Mr. Langstaff presented to the Medico-Chirurgical Society of London a specimen of what he considered to have been an intra-capsular fracture united by bone. The case was that of a woman who was 50 years of age when the fracture occurred. She was confined for nearly twelve months to bed after the injury, and during the remainder of her life, that is, for ten years, she walked on crutches. On dissection it was found that the principal part of the neck of the femur was absorbed, and the head and remaining portion of the neck were united principally by bone, and partly by a cartilaginous substance. The capsular ligament was immensely thickened and embraced the joint very closely, the cartilaginous covering of the head of the bone and acetabulum had suffered partial absorption, the internal surface of the capsular ligament was coated with lymph. On making a section of the bone, it was evident that there had been a fracture of the neck within the capsular ligament, and that union had taken place by osseous and cartilaginous media. With a view of ascertaining whether there was real osseous union the bone was boiled many hours, which discoloured it, but by destroying all the animal matter it satisfactorily proved the extent and firmness of the osseous connexion, and the vacant spaces occupied with cartilaginous matter. These appearances are represented by a drawing made shortly after boiling.*

Case 2.—Dr Brulalour, surgeon to the hospital at Bourdeaux, sent to London the parti-

* Vol. xiii. of the Society's Transactions.

culars of a case of fracture of the neck of the femur, which were read before the Medico-Chirurgical Society on the 5th of June, 1827. The following is an abstract of it. Dr. James, an English physician, æt. 47, in good health, was thrown from his horse on the 20th of March, 1826. He fell directly on the great trochanter, but got up and walked a step or two, which occasioned such acute pain in the hip-joint that he instantly fell again. On examination immediately after the accident, Dr. Brulalour observed the principal signs of fracture of the neck of the femur. Extension of the limb was kept up for two months so as to preserve it of its natural length. He recovered the full use of the limb so as to be able to walk without any assistance, even that of a cane. Dr. James, on the 20th of December, about nine months after the accident, was attacked with hæmatemesis, which in two days terminated fatally. The post-mortem examination of the right coxo-femoral articulation shewed—1st, the capsule a little thickened; 2d, the cotyloid cavity sound; 3d, the inter-articular ligament in a natural state; 4th, the neck of the femur shortened, from the bottom of the head to the top of the great trochanter was only four lines, and from the same point to the top of the small trochanter six lines; 5th, an unequal line surrounded the neck, denoting the direction of the fracture; 6th, at the bottom of the head of the femur and at the external and posterior part considerable bony deposit had taken place. A section of the bone was made in a line drawn from the centre of the head of the femur to the bottom of the great trochanter so as perfectly to expose the callus. The line of union indicated by the callus was smooth and polished as ivory. The line of callus denoted also that the bottom of the head of the femur had been broken at its superior and posterior part.

Case 3.—Mr. Stanley, surgeon to St. Bartholomew's Hospital, in May 1833 read before the Medico-Chirurgical Society of London a case of bony union of a fracture of the neck of the thigh-bone within the capsule, occurring in a young subject æt. 18. In the examination of the body of this young man, who died of what was considered to be small-pox about three months after the accident of the hip-joint, no other morbid appearances were discovered besides those of the injured hip-joint. The capsule of the joint was entire but a little thickened, the ligamentum teres was uninjured, a line of fracture extended obliquely through the neck of the femur, and entirely within the capsule, the neck of the bone was shortened, and its head, in consequence, approximated to the trochanter major. The fractured surfaces were in the closest apposition and firmly united, nearly in their whole extent, by bone. There was an irregular deposition of bone upon the neck of the femur, beneath its synovial and periosteal covering along the line of the fracture. Mr. Stanley adds, "the foregoing case is remarkable from the occurrence of a fracture of the neck of the femur within the capsule at an early age, and it is, I believe, the only example of it on record."

Sir A. Cooper has published a letter in the Medical Gazette, April 1834, vol. xiv., which is intended to explain his sentiments upon this subject, and to set the profession in general and the French surgeons in particular right as to the conceptions formed of the doctrine he held as to the susceptibility of the bony consolidation of the intra-capsular fracture. In it we find the following case.

Case 4.—Mrs. Powell, aged above 80 years, fell down in the afternoon of the 14th of November, 1824. Sir Astley Cooper saw her soon after, and found her complaining very much of pain in the left hip. The limb could be moved in every direction, but this motion produced excessive pain. She lay on her back with the limb extended, and nothing whatever was done, except to apply fomentations, in the first few days. He believed there was a fracture of the neck of the thigh-bone although the limb remained quite as long as the other, and he could perceive neither a crepitus nor any altered appearance in its position, except a slight inclination of the toes outwards. She had more constitutional irritation than Sir Astley ever observed from a similar accident. She suffered much pain in the hip, and was in consequence obliged to take an opiate, but she got very little rest. She generally had much thirst. There was the utmost difficulty in keeping her bowels open, and she had great pain and difficulty in making water. She had no appetite for common food, and for three weeks appeared so weak that she was under the necessity of taking wine and brandy. For some time all her urine and stools were passed in bed, but not involuntarily, and only because she could not be persuaded to use proper means; in consequence her back became very sore. Latterly she complained of pain in the abdomen, which was very tender on pressure, and even the weight of the bed-clothes was inconvenient. Her tongue became very dry and brown, and the last twenty-four hours she was insensible. She died on the morning of the 19th December about five.

Examination.—This took place at seven in the evening. There was some ecchymosis amongst the muscles about the injured part and in the cellular membrane about the sciatic and anterior crural nerves. The greatest part of the fracture of the neck of the thigh-bone, which was entirely within the capsular ligament, was firmly united. A section was made through the fractured part, and a faint white line was perceived in one portion of the union, but the rest appeared to be entirely bone. This case, says Mr. Swan, beautifully shews the principle which Sir A. Cooper has advocated, viz. that when the reflected ligament remains whole, and the bones are not drawn asunder, the nourishment to the head of the bone continues, and union will be produced even in the short space of five weeks, by only placing the knee over a pillow, and in other respects leaving the case to nature.

We find Mr. Samuel Cooper is of opinion that a bony consolidation of the intra-capsular fracture is proved. He says,* "Sir A. Cooper

* Surgical Dict. p. 575, last ed.

has satisfied himself that osseous union sometimes takes place, and he has in his own collection a most unequivocal specimen of it, which he was kind enough to show me two years ago. The possibility of bony union is now universally acknowledged, but the cure in this way is far less frequent than that by means of a ligamentary connexion."*

It does not appear to us that this question is yet so entirely settled as the last writer's observations would lead us to imagine; although in this city (Dublin) the subject has been carefully investigated for many years, we do not find our museums yet contain a single specimen of the intra-capsular fracture united by bone. In Paris we find Cruveilhier, one of the most eminent pathologists in France, expressing himself in the most unreserved manner, that a bony consolidation of the intra-capsular fracture was impossible. Not unaware, as must be supposed, of the eight cases referred to by his pupil, M. Chassaignac,† (amongst which are those of Langstaff, Stanley, and Sir A. Cooper,) Cruveilhier, to whom Chassaignac's memoir is dedicated, thus expresses himself:—"Je suis porté à considerer comme des cas de deformation de la tête et du col, la plupart, si non la totalité des faits, que l'on invoque généralement pour établir la reunion de fractures intra-capsulaires du col du femur, à l'aide d'un cal osseux, le cal est impossible, parceque les fragmens libres, au milieu de la synovie, ne sont point entourés des tissues chargés de la reparation de la solution de continuité." Thus not content with asserting that bony union is impossible, he further adds that he is convinced from numerous pathological observations, and from experiments on animals, that the ideas of bony union by means of a first, a provisional callus, and then by means of a final callus, are erroneous; he is certain that there is but one and the same callus, which passes through different stages of development, until the ossification is complete; he is of opinion that the ends of the broken bone, no matter how confronted or held together, never are directly united. This union, he thinks, can only take place through the intervention of callus, which is always thrown round the bones where fractured, like a clasp or bony ferule; therefore, he reasons, the cause of the difference between the intra-capsular and extra-capsular fracture, with reference to their susceptibility of bony consolidation, is, that in the first the fragments are as it were abandoned to themselves to effect an union; here there is no bony ferule or clasp possible, while in the second the fragments are in the same condition as in all other fractures; that is to say, they are surrounded by soft parts, by the ossification of which the bony clasp is formed. Thus does he not only deny the possibility of bony consolidation in the case of the intra-capsular fracture, but endeavours to explain why the union is impracticable.

We cannot agree with this eminent pathologist in the observations that the ends of the bones themselves take no part in effecting a bony union, for in cases of impacted fracture alluded to by us in a preceding article, particularly in the case of Sherlock, from which *fig.* 320 has been taken, bony consolidation had taken place in almost the whole line of the fracture, and could only have been effected by the union of the two bony surfaces which were confronted to each other. No doubt the union here was further fortified by the external effusion of new callus, which surrounded the bone at the seat of the fracture. When we reflect on the cases adduced in proof of the bony consolidation of the intra-capsular fracture, we must either disbelieve the facts, or admit that the union is not impossible.

It would have been satisfactory if the test by boiling the specimens of the united fractures had been resorted to in all these cases, as it had been in Mr. Langstaff's; this observation particularly applies to the case reported by Dr. Brulalour, of Bourdeaux. We find in Chassaignac's report of this same case, taken from the memoir sent to the Academy of Medicine of Paris, (Seance du 16 Avril, 1827) in alluding to the specimen in question he says:—"Scié, dans toute sa longueur le cal se présentait sous la forme d'une ligne oblique, raboteuse, d'une couleur moins blanche et d'un consistence un peu moins ferme que le reste de l'os."

We had thus far entered into this much agitated question, when an interesting opportunity occurred to us of making the post-mortem examination of a case of united intra-capsular fracture. The history of the case was this:—

Owen Curran, æt. 70, was for the last five years an inmate of the pauper department of the House of Industry; he was very infirm on his limbs, and his mind was in a state of dotage; on the 1st of August, 1837, while walking across his ward, he fell on his right side; he was unable to rise, and complained of pain in his right hip; he was carried to bed, and was immediately visited by the late Mr. William Johnstone, who was then acting for me as clinical pupil, who found the limb everted, and only half an inch shorter than the other. Mr. Johnstone considered the case a fracture of the cervix femoris, which required no other surgical treatment than that of placing and preserving the limb in a semiflexed position over pillows. The old man suffered but little pain in the injured part, at all events he did not complain of it. In about five weeks after the accident he was raised out of his bed, and when placed standing, he was able to put the heel of the injured limb to the ground. On the 30th of September, that is, about eight weeks after the accident, my friend Mr. Smith entered in his note-book the following memorandum of this case:—"As the patient lies in bed he can elevate the injured limb by the unassisted efforts of its own muscles. The eversion is slight, and the degree of shortening amounts to one inch; no force can bring the limb down to the length of the other. From the history and symptoms, this seems to have been a case of impacted fracture." This man survived the accident one year and nearly

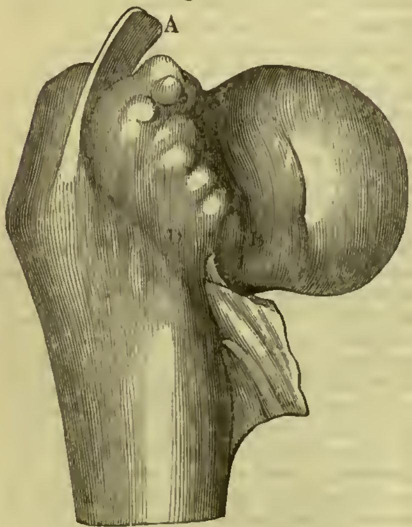
* Loc. cit.

† De la Fracture du col du femur. Par E. Chassaignac, M.D., Paris, 1835.

ten months, during which time he was contented to remain most of the time in his bed, but when placed on his feet, could stand very well, and was able but unwilling to walk. On Tuesday the 20th of May he got an attack of bronchitis, which, the following Friday, terminated fatally. At twelve o'clock, on Saturday, the 25th May, assisted by Mr. Brabazon and some of the pupils of the hospital, I made an examination of the body. The right leg and thigh were much everted. The trochanter major was elevated, and projected much outwards; the degree of shortening just amounted to one inch; the muscles presented a healthy appearance, the capsular ligament was of a yellowish colour, and somewhat thickened. The femur was removed from the acetabulum; this latter cavity presented a healthy appearance, except towards the margin of it; here the cartilage was softened. The round ligament was sound.

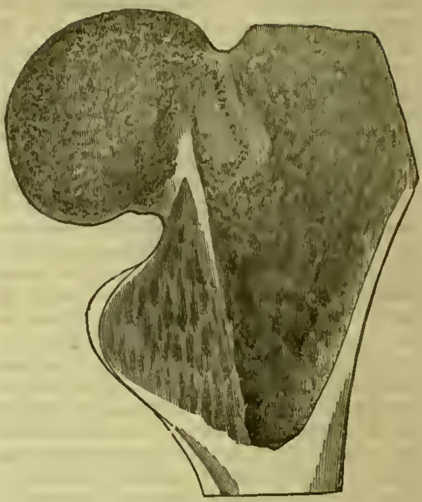
The head and neck of the bone had lost their normal obliquity, and were directed nearly horizontally inwards (*fig.* 321); the cervix presented, both anteriorly and posteriorly, evidence of a transverse intra-capsular fracture having occurred; the globular-shaped head was closely approximated behind and below to the posterior intertrochanteric line, and to the lesser trochanter, so that the neck seemed altogether lost except anteriorly, where a very well-marked ridge of bone shewed the seat of the displacement and of the union of the fragments.

Fig. 321.



This ridge is evidently the upper extremity of the lower fragment of the cervix. The fracture of the neck posteriorly was found to have been closer to the corona of the head than anteriorly, and the fibro-synovial fold in the former situation remained unbroken. A section has been made of the bone through the head, neck, and trochanter; one portion has been subjected to maceration and to boiling; and the bony union has been unaffected by these tests. Scarcely any portion of the neck can be said to have been left.

Fig. 322.



The section, *fig.* 322, shews the compact line which denotes the union of the fragments; the head and shaft seem to be mutually impacted into each other, and almost the whole of the cervix has been absorbed; the line of union is serrated, solid, and immoveable; and the cells of the head and substance of the shaft seem to communicate freely in all places, except where the thin line of compact tissue here and there points out the seat of the welding together of the remaining portions of the head and neck of the femur.

The bone was in its recent state, on the 25th of May, laid before a meeting of the Pathological Society. It seemed to be the universal opinion of the members present that it was a decided specimen of the intra-capsular fracture of the cervix femoris, which had been solidly united by bony callus. This case may be adduced in formal contradiction to the observation and theories of that very eminent pathologist, Cruveilhier. It cannot be said to invalidate the more guarded opinions of Sir A. Cooper, who, in his observations upon this subject, distinctly stated that "he would not be understood to deny the possibility of union, when the bone was broken, without its periosteum and reflected ligament being torn, or when there was no separation of its fractured ends."

Cases such as the foregoing are certainly rare, but they appear to the writer to belong to the class of impacted fractures; they differ from those alluded to in the foregoing article merely in this, that in the former the fracture of the cervix takes place at its basis near the trochanters, and that, in the latter, the fracture occurs near to the head of the bone, and is thus entirely intra-capsular, or rather may be considered as fractures of the intra-capsular portion of the cervix femoris. The question then, viz. does bony consolidation of the intra-capsular fracture of the cervix femoris ever occur? seems to us replied to in the affirmative.

When an impaction of one, or a mutual

impaction of both of the fragments has taken place, then under such peculiar circumstances a firm bony consolidation of the fragments may be expected.

Finally, although this is not the place to speak of the surgical treatment of such cases, we may remark that the most valuable practical information, in our mind, derivable from the discovery of facts like the foregoing, is that the lenient method of treatment, viz. by position alone, and without splints, may be eminently successful, so far as the accomplishment of a firm reunion of the fragments is concerned.

II. *Luxations.*—Luxations of the head of the femur from the acetabulum are by no means so frequent as fractures of the bones which enter into the composition of the hip-joint.

This comparative immunity from this form of accident arises from these circumstances,—that the acetabulum which lodges the head of the femur has great depth, and that the fibrous membranes which secure this bone in the cotyloid cavity have great strength, and restrain within certain limits its movements. Independently, however, of congenital luxations, and of those which are the result of disease, there are six distinct forms of dislocation of the hip-joint to be described as the result of accident alone.

The dislocations of the head of the femur from accident may be classed as follows:—*a.* dislocation upwards and backwards on the dorsum ilii; *b.* directly backwards towards the ischiatic notch; *c.* downwards and inwards into the foramen ovale; *d.* upwards, forwards, and inwards on the horizontal ramus of the pubes. Besides these, of late years two more unusual luxations have been described and verified by post-mortem examinations, viz. dislocation downwards towards the tuberosity of the ischium, and dislocation upwards between the anterior inferior spine of the ilium and the ilio-pubal eminence.

a. Dislocation of the head of the femur upwards and backwards on the dorsum of the ilium.—When the head of the thigh-bone is thrown on the dorsum ilii, the limb on the luxated side is from one to two inches shorter than the other; the thigh is slightly flexed, or a little advanced upon the other, and carried into a state of abduction, and of marked rotation inwards. The patella and inner side of the dislocated limb look directly inwards, and the great toe corresponds to the tarsus of the opposite foot. The great trochanter, carried forwards and upwards, approaches the crest of the ilium and its anterior and superior spine, and forms there a very well marked tumour; the nates raised up by the head of the femur is very salient towards its superior and posterior part. If we make attempts to bring the limb backwards into a state of extension or abduction or of rotation outwards, we find we give much pain to the patient, and that we cannot move the bone in any of these directions. We can, without causing suffering to the patient, augment a *little* the flexion towards the abdomen, and adduct the dislocated thigh, and we can also increase the rotation inwards already existing, or, to use the words of Sir A. Cooper, "when the leg is attempted to be separated from the other it cannot be accomplished, as the limb is firmly fixed in its new situation, so far as regards its motion outwards. The thigh can be slightly bent across the other and towards the abdomen, but extension of the thigh and rotation outwards are impossible." Rotation inwards, on the contrary, is to a great extent permitted, so much so indeed that we have seen the back part of the heel turned forwards, while the toes pointed backwards. During these extreme motions of rotation inwards, if the hand be pressed on the dorsum of the ilium deeply, the head of the femur will be perceived to roll on the ilium, and its trochanter major also can at this time be felt to be nearer than natural to the anterior superior spinous process of the ilium; the trochanter is less prominent than that on the opposite side, for the neck of the bone and the trochanter are resting in the line of the surface of the dorsum ilii. Upon a comparison of the two hips, the roundness of the dislocated side will be found to have disappeared. A surgeon, then, called to a severe and recent injury of the hip-joint, looks for a difference in length, change of position inwards, diminution of motion, and decreased projection of the trochanter.

The explanation of the manner in which the dislocation of the head of the femur upwards and backwards on the dorsum ilii takes place has been the subject of some difference of sentiment. The late Mr. Todd has, in our opinion, given some judicious observations on this subject;* he says, "the elementary work on luxations most generally read and referred to in this country, is Dr. Farrell's translation of Boyer's Lectures, arranged by Richerand. The following is the description therein given of the manner in which the luxation of the femur, at present under consideration, is produced.

"When by a fall from a place, more or less elevated, on the soles of the feet, or on the knees, the thigh is pushed forwards and inwards, the head of the femur, forced towards the superior and external part of the acetabulum, breaks the internal and orbicular ligaments, escapes through the laceration in the latter, and ascends on the external face of the os ilium; but as the part of the os ilium immediately above and at the external side of the cavity is very convex, the head of the femur soon abandons its first position, and slides backwards and upwards into the external fossa of the os ilium, following the inclination of the plane towards the fossa, and obeying the action of the glutæi muscles, which draw it in this direction. The head of the femur, in ascending thus on the external face of the os ilium, pushes upwards the glutæus minimus, which forms a sort of cap for it, and the glutæus maximus and medius are relaxed by the approximation of the points into which they are inserted. The pyriformis is nearly in its natural state; the gemini, obturatores, and quadratus femoris are a little

* Dublin Hospital Reports, vol. iii. p. 397.

elongated. The psoas magnus and iliacus internus are relaxed, as are also the other muscles inserted into the trochanter minor."*

From the foregoing opinions Mr. Todd dissents in the following words:—"To admit of the head of the femur being 'forced towards the superior and external part of the acetabulum,' and of its ascending 'on the external face of the os ilium,' it will be obvious to those who carefully examine the mechanism of the articulation, that the thigh must be extended on the trunk, and the dislocating force applied externally and inferiorly, so as to produce what may be termed an excess of adduction. To the limb assuming such positions, which appear to me to be quite essential towards the production of this dislocation in the manner described by Bayer, some considerable obstacles exist. In the first place, I believe it seldom happens that a person who falls from a height will reach the ground with the thigh extended on the trunk; in the descent the superior power of the flexor muscles will predominate, and at the moment of the application of force to the limb it will be more or less in a bent position. It is scarcely necessary to observe that this circumstance must materially influence the direction in which the head of the bone will be protruded from the articulating cavity.

"Secondly, should the thigh and leg be completely extended at the time that the force is applied, it is probable that the other limb will be extended also, and will thus prevent a movement of the stricken limb inwards beyond a certain point; or, in other words, the opposite limb will prevent that extent of adduction inferiorly which is necessary to remove the head of the femur from the acetabulum, and to admit of its being forced upon the anterior convex surface of the dorsum ilii. But whether the opposite limb be extended or not, it must oppose a certain limit to adduction, if that term can be applied with propriety to a lateral movement of the lower extremity, by which it is carried beyond the middle line of the body.

"Sir Astley Cooper attributes this direction of the limb to the circumstance of the injury being inflicted when the knee and foot are actually turned inwards; however, it appears to me that muscular action is also in favour of the limb assuming this position.

"If it be admitted that the thigh is generally in a state of demiflexion when the force causing this dislocation is applied, it must also be admitted that in this state the pyriformis, obturatores, and gemini have but little effect as rotators, the power of these muscles as such being greater or less, according as the junction of their fibres with the femur approaches or deviates from a right angle; and that the power of the anterior portion of the glutæus medius and of the tensor fasciæ latæ, as rotators inwards, is increased in this position, the angle which their fibres form with the thigh-bone being augmented; thus the last-mentioned muscles will appear to possess much influence in determining the inverted position of the limb, as they must draw forwards the trochanter major and external side of the thigh, at the moment in which the head of the bone escapes from the acetabulum.

"The inclination of the thigh forwards and inwards which constitutes so remarkable a feature of this dislocation, may be attributed partly to the tension of the psoas magnus, the iliacus internus, and the pectinalis, and also to the peculiar form of the surface of the pelvis, to which the upper part of the femur is applied; but certainly not as Mr. Samuel Cooper has asserted, to the tense state of the triceps and gracilis, for these muscles are relaxed."

Anatomical characters of the luxation of the head of the thigh-bone on the dorsum ilii.—The appearances which have been noticed in the anatomical examination of the hip-joints of individuals who, having had a luxation of this articulation, have died very soon afterwards of other severe injuries received at the same time, may be collected from the study of some facts of this nature already published. Of these none gives us a better idea of the recent effects of a dislocation upwards and backwards on the dorsum ilii than the case related by the late Mr. Todd, in the third volume of the Dublin Hospital Reports, which is as follows:—

Case.—In the summer of 1818, a robust man, in attempting to escape from his bedroom window in the second floor of a lofty house, fell into a flagged area, by which accident his cranium was fractured, and his left thigh dislocated upwards and backwards.

The dislocation was reduced without difficulty; however, an extensive extravasation of blood having taken place on the brain, the patient lingered in a comatose state for about twenty-four hours, and then died. On the day after dissection was performed, and the following appearances were observed in the injured joint and the parts contiguous to it.

On raising the glutæus maximus, a large cavity filled with coagulated blood was found between that muscle and the posterior part of the glutæus medius. This was the situation which had been occupied by the dislocated extremity of the femur. The glutæus medius and minimus were uninjured. The pyriformis, gemini, obturatores, and quadratus were completely torn across. Some fibres of the pectinalis were also torn. The iliacus, psoas, and adductors were uninjured. The orbicular ligament was entire at the superior and anterior part only, and it was irregularly lacerated throughout the remainder of its extent. The inter-articular ligament was torn out of the depression on the head of the femur, its attachment to the acetabulum remaining perfect. The bones had not sustained any injury.

Cruveilhier, in the 28th and 29th livraisons of his valuable work on Pathological Anatomy, has given two cases of what he considers to be old luxations of the head of the femur upwards and outwards on the dorsum ilii, which had been left unreduced; the history of these

* Lectures of Boyer, p. 156.

cases was unknown. When we carefully examine the author's account of them, and refer to the eight accompanying drawings he has given of them, doubts may well arise in the mind as to whether these are to be considered congenital luxations, or the result of accidents which had occurred after birth. The author does not himself seem free from suspicion on this matter, for, in commencing his observations on the pathological anatomy of cases of luxation of the femur on the dorsum ilii, upwards and outwards, he says, "elles sont tantôt congeniales, tantôt posterieurs à la naissance. Existe-t-il des différences notables entre les unes et les autres sous le point de l'anatomie pathologique? Il m'est permis d'en douter jusqu'à ce que des faits positifs aient établi le contraire." We have in some of the preceding pages adduced what we have considered positive proofs that the anatomical characters of the congenital luxation of the hip-joint are altogether peculiar, and the appearances either in the living or the dead are in our opinion by no means to be confounded with those which are the result of luxations which have occurred after birth, and have been left unreduced.

When opportunities have occurred of examining the hip-joints of those who have for many years survived a dislocation of the head of the femur upwards and backwards on the dorsum ilii, and which had been left unreduced, remarkable changes have been noticed to have taken place in the bones and surrounding structures.

Muscles.—The muscles of the dislocated hip have been found for the most part in a state of comparative atrophy, and the direction of their fibres has of course been altered by the ascent of the superior extremity of the femur. Among the muscles of the hip-joint the condition of the glutæus minimus has been most dwelt on by authors.

It is stated on the respectable authority of Boyer, that when the head of the femur is dislocated upwards and backwards on the dorsum ilii, it passes between the external iliac fossa, and the little glutæus; that it carries this muscle up, and is as it were capped by it ("pour ainsi dire coiffée"). This muscle, he elsewhere adds, envelopes immediately the head of the femur; it undergoes very remarkable changes; it becomes pale; its fibres disappear almost entirely, and are changed into a fibrous substance which is firm and solid, and which has been sometimes seen converted into bone. Cruveilhier seems to have adopted Boyer's idea as to the change this muscle undergoes in these cases. But if it be true, as we believe it is, that at the moment the luxation we are now considering occurs, the limb is in a state of semiflexion, we shall find it difficult to conceive how the head of the bone in passing can encounter any of the fibres of the glutæus medius or minimus, except it be the most posterior and inferior of them.

Mr. Wallace has, in the Transactions of the College of Physicians in Ireland,* given a very minute and valuable account of a case of dislocation of the head of the femur on the dorsum ilii. The history of the case was unknown; but the state of the parts engaged left no doubt on his mind that it must have been many years since the bone had been dislocated, and from the appearance of the body he concluded that the subject was not less than fifty. The glutæi muscles were in a state approaching to that of atrophy: the posterior edge of the glutæus medius ran exactly over the head of the femur; the texture of the glutæus minimus resembled adeps more than healthy muscular fibre.

The pyriformis did not extend to the trochanter major, but terminated at the distance of some inches from this process, in the new capsule which covered the head of the femur. There was not a trace of the obturator internus, its place having been occupied by a quantity of fat of a peculiarly gristly texture; the quadratus and gemelli were pale and small, and were bisected by an irregular tendinous line. The direction of these muscles between their points of attachment was more oblique than natural; the psoas and iliacus were diminished in size, and their line of direction from the brim of the pelvis to their connexion with the lesser trochanter was altered, as was also the direction of the triceps, pectinales, and obturator externus, all which were carried upwards above the level of their usual course by the elevation of the upper extremity of the femur on the dorsum ilii.

The femoral vessels and nerves having passed under Poupart's ligament, were sunk into a deep fossa, and extended backwards and outwards until they approached the lesser trochanter; they ran more in a serpentine or tortuous course than the corresponding vessels of the opposite limb; the sciatic nerve was flattened, its direction curved, and its vessels were varicose. Its entire structure appeared as if it had been the seat of chronic inflammation.

Ligaments.—In this case a very strong ligamentous fasciculus extended below the anterior and lower part of the ilio-pubic eminence and the lesser trochanter; this must have performed the function of a check ligament to the motion of eversion, for any attempt at turning the limb outwards rendered this ligament very tense. A thick capsule surrounded the new articulating surface of the ilium, and also the head and neck of the femur; although the inner surface of this was smeared with synovia, it had not the smooth aspect of an original synovial membrane. There was imbedded in the capsule a piece of bone of a rounded figure, half an inch in diameter.† There were no remains of round ligament.

Bones.—The great trochanter was thrown forwards with respect to the head of the bone: the anterior internal and inferior portion of the head of the femur was applied to the dorsum ilii, and there was an articulating surface worn

* Vol. V. p. 252.

† Mr. W. imagined this to be a portion of the acetabulum.

on the head of the femur, which marked its point of contact with the os innominatum: the articulating surface thus formed on the head of the femur was very slightly convex, about one inch and a half in diameter, smooth, whitish, hard, and polished, though not uniformly so; for in some parts the bone appeared red and porous; the remaining portion of the head of the femur was not opposed to bone, but applied to the capsule which surrounded the joint; the head had lost its natural rounded form, was very irregular, and deprived of its cartilage, but some parts of it were covered by a substance of the nature of ligament. There were several small pits on the head of the femur, but none of them appeared to have been the depression for the attachment of the round ligament. There was an irregular ossific deposit round the lesser trochanter.

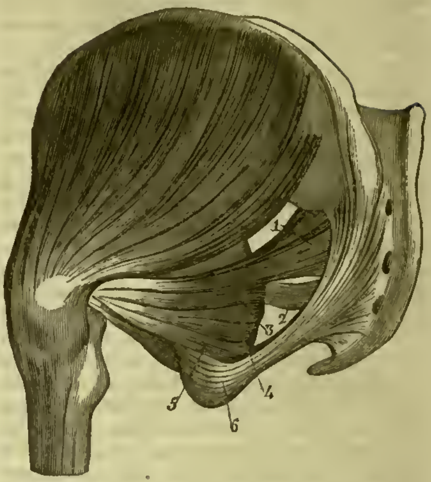
The surface of the ilium, to which the head of the bone was applied, was elevated half an inch above the level of the surrounding bone, so that this cavity appeared to have been formed upon a plate of bone which had been planted, as it were, on the ilium. The superior and posterior portion of the new acetabulum, or about two-thirds of its whole extent, was smooth and polished, and presented a suitable corresponding surface to receive the head of the femur; the aspect of the articulating surface on the ilium was backwards, outwards, and upwards. There was scarcely a vestige of the old acetabulum in its site; there was a superficial fossa, of a triangular form, filled with a fibrous substance, continuous with a surrounding cellular tissue. There was no articular cartilage on any portion of the bones which formed the new joint. There was a deep groove, one inch in depth, formed on the outer side of the ilio-pubic symphysis, for the lodgement of the conjoined tendons of the psoas and iliacus muscles in their passage over the brim of the pelvis to the lesser trochanter.

The pelvis, in this case, was much elevated on the side corresponding to the luxation.

b. Luxation backwards or towards the ischiatic notch.—The space which is called the ischiatic notch is bounded above and anteriorly by the ilium, posteriorly by the sacrum, and inferiorly by the sacro-sciatic ligament (*fig.* 323). It is formed for giving passage to the pyriformis muscle and to the sciatic nerve, as well as to the great arteries, the glutæal, ischiatic, and internal pudendal. Its situation, with respect to the acetabulum in the natural position of the pelvis, is a little above its level, and it is also placed behind it; when the head of the bone is thrown into this space, it is placed backwards and upwards with respect to the acetabulum. Therefore though called the dislocation backwards, it is to be remembered that it is a dislocation backwards and a little upwards.

In this dislocation the head of the thigh-bone is placed on the pyriformis muscle, between the edge of the bone which forms the upper part of the ischiatic notch and the sacro-sciatic ligaments, behind the acetabulum, and a little above the level of the middle of that cavity.

Fig. 323.



1, *Pyriformis*; 2, *lesser sacro-sciatic ligament*; 3, *gemellus superior*; 4, *obturator internus*; 5, *gemellus inferior*; 6, *tuber ischii*.

It is the dislocation most difficult both to detect and to reduce; to detect, because the length of the limb differs but little, and its position is not much changed as regards the knee and foot, as in the dislocation upwards; to reduce, because the head of the bone is placed deep behind the acetabulum, and it therefore requires to be lifted over its edge, as well as to be drawn towards its socket.

The signs of this dislocation are, that the limb is about half an inch shorter than the other, but generally not more than half an inch; that the trochanter major is behind its usual place, but still remains nearly at right angles with the ilium, with a slight inclination towards the acetabulum; the head of the bone is so buried in the ischiatic notch that it cannot be distinctly felt, except in thin persons, and then only by rolling the thigh-bone forwards, as far as the comparatively fixed state of the limb will allow. The knee and the foot are turned inwards, but not so much as in the dislocation upwards, and the toe rests against the ball of the great toe of the other foot. When the patient is standing, the toe touches the ground, but the heel does not quite reach it; the knee is not so much advanced as in the dislocation on the dorsum ilii, but is still brought a little more forwards than the other, and is slightly bent. The limb is fixed, so that flexion and rotation are in a great degree prevented.

The following case of dislocation backwards towards the ischiatic notch affords us a good example of this accident. John Magee, æt. 54, a strong muscular labourer, was admitted into Jervis-street Infirmary, 10th of November, 1831, under my care, in consequence of his having been severely injured in his left hip. He stated that while carrying on his back a sack of potatoes, (about 3 cwt.) he unfortunately placed his foot upon a round stone, which rolled from under him, and he came down with considerable violence on his left knee and side; when raised, he was incapable of walking, and was immediately carried to hospital. The following morning, on examination, we made the following observations: while standing, the body was bent forwards, inclining towards the left or affected side; the left knee and foot were turned inwards; the knee somewhat more advanced and higher than the other, half flexed, and the toes were resting on the ball of the great toe of the opposite foot; posteriorly, the natis was prominent, and its lower fold was obliterated; the distance between the anterior superior spinous process of the ilium and trochanter major was less by one inch than between the same points on the unaffected side; the head of the bone could not be distinctly felt; the limb could be drawn inwards across the opposite thigh, but any attempt to move it in the contrary direction was productive of considerable pain; he complained of much uneasiness in the groin (which was attributed to the tense state of the muscles inserted into the trochanter minor); the patient complained greatly of numbness extending along the posterior and outer part of the thigh and leg to the foot. The bone was, in this case, easily reduced, not, however, without the assistance of the pulleys.

This dislocation is improperly denominated by some, luxation downwards and backwards. Some surgeons, on the other hand, describe cases of this accident, and yet name them dislocation upwards and backwards on the dorsum ilii. Of this class, is an interesting example published by the late Dr. Scott, of the Armagh Infirmary, in the third volume of the Dublin Hospital Reports. The man, the subject of the accident, died thirty-six hours after the injury.

Dr. Scott says:—"When the patient was lifted out of bed and placed erect, the limb retained the posture before described; it was nearly two inches shorter than the other; the knee rested above its fellow; the toes were turned inwards, and lay above the opposite instep. On viewing the hip, the trochanter was manifestly higher on the maimed side than the other. The hollow naturally formed behind that process had disappeared—the buttock was shorter and rounder, but flaccid; the head of the bone could not be felt through the glutæi muscles. No effort of the patient could extend the limb, but he had the power of bending it a little towards the abdomen, by making the opposite leg a fulcrum for the inverted toes to creep upwards upon. The dislocation was reduced, and he died in thirty-six hours afterwards, in consequence of the injury some of the organs in the abdomen received, at the same time that the hip-joint was dislocated." It is stated, that "on dissecting down to the hip-joint, an extensive extravasation of blood presented itself in the cutaneous cellular membrane, covering the trochanter major, and also beneath the fascia lata of the thigh, extending several inches above and below the trochanter. The glutæus magnus being raised from its origin, a considerable extravasation was found in the loose cellular tissue under the glutæus medius. A cavity capable of containing a pullet's egg was also brought into view. This cavity was situated directly where the great sciatic nerve passes under the pyriform muscle; it contained fluid blood; its boundaries were the pyriformis above, the sciatic nerve before (supposing the body upright), the trochanter major, and insertion of the glutæus medius external and posterior; the glutæus maximus directly posterior. Here the displaced head of the femur had been lodged. The fleshy substance of the gemelli and quadratus muscles was found torn across. The pyriformis and obturator internus were perfect; the extravasated blood followed the course of the sciatic nerve deep into the thigh; there was also extravasation between the glutæus medius and minimus muscles. The internal and upper part of the capsular ligament of the joint was ruptured; the external portion remained unbroken. On turning the head of the bone out of its socket, the ligamentum teres was found to have been torn from its insertion into the dimple of the head of the thigh-bone; the brim of the acetabulum, at its upper part, was fractured to the extent of about one inch; the fractured portion lay loose and nearly unconnected; a fracture traversed the acetabulum." In this case it is manifest, from the dissection, that the head of the bone lay beneath even the level of the lower edge of the pyriform muscle, as Dr. Scott states that the boundaries of the cavity (capable of containing a pullet's egg, and filled with coagulated blood,) which no doubt was the new situation that the head of the dislocated femur for a time rested in,—that the boundaries of this cavity were "the pyriformis above," &c. The dissection we consider a valuable one, adding something to our knowledge of the anatomical characters of the luxation into the ischiatic notch; differing, however, in some few particulars, from that of Sir A. Cooper, Dr. Scott's, it is to be recollected, was the dissection of a case in which the bone had been only a few hours misplaced. When we analyse the previous symptoms of Dr. Scott's case, we do not, it must be confessed, read the characteristic features detailed of the dislocation backwards; still the pain the patient suffered along the course of the sciatic nerve rather pointed the attention to a dislocation on the sciatic notch, than to the ordinary one of dislocation upwards on the dorsum ilii, in which the nerve is not, at least directly, interfered with; and the observation added, that "the head of the bone could not be felt through the glutæi muscles," also would lead us to infer that among many of the symptoms this patient laboured under, some were such as would lead us to suspect that the luxation was that backwards towards the sciatic notch, a suspicion that, in the writer's mind, the dissection given by Dr. Scott would fully justify.

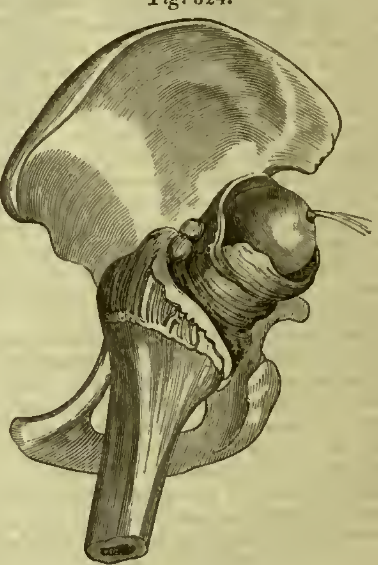
We suspect, also, that one of the cases

published by Mr. Bransby Cooper* as one of dislocation on the dorsum ilii, was rather the dislocation we are now considering, namely, the luxation towards the ischiatic notch. Among some of this patient's symptoms, it is mentioned that the trochanter major was plainly felt behind and a little above the natural situation with respect to the ilium; the head of the bone could be felt neither in the sitting, standing, nor lying posture. Indeed, Mr. B. Cooper himself remarks that, "upon taking into consideration all these diagnostic marks, I was induced to consider the accident a luxation on the dorsum of the ilium; although the head of the bone was not drawn up so high as usual, as indicated by the slight shortening of the limb; and the trochanter major was also drawn further backwards than is usual, in the dislocation on the dorsum, so that, perhaps, this might by some surgeons have been described as a dislocation to the ischiatic notch." Mr. Cooper further adds:—"I doubt, however, if this appellation as applied to a certain variety of dislocation of the hip, does not rather mystify than facilitate our diagnosis, for it leads to the supposition that the head of the bone sinks into the osseous hiatus,—a circumstance which could not occur even in the skeleton itself, from the size of the head of the bone, and much less could it happen in the living subject, when this notch is filled up with ligaments, muscles, vessels, and nerves." This respectable surgeon proposes, therefore, to expunge from the classification of dislocations the luxation into the notch, but to consider it only as a variety of the dislocation on the dorsum ilii, distinguishing the one as a luxation upwards, the other backwards, on the dorsum. To this proposition we cannot by any means assent, for we consider that a dislocation backwards behind the ischium, and to the ischiatic notch which is below the level of the ilium, never can be properly designated a variety of the dislocation on the dorsum ilii, although we might assent to the proposition to consider it a variety of the dislocation backwards. The case as described by Sir A. Cooper, of dislocation on the sciatic notch, we are satisfied is to be seen occasionally, though rarely, in the living; and the dissection made by Sir Astley himself, in which he found the head of the bone resting behind the acetabulum on the pyriform muscle, the preparation of which is to be found in the museum of St. Thomas's Hospital, should, we imagine, place the matter beyond dispute.

Anatomical characters.—We have, says Sir Astley Cooper, a good specimen in the collection of St. Thomas's Hospital, which I met accidentally in a subject brought for dissection. The original acetabulum is entirely filled with a ligamentous substance, so that the head of the bone could not have been returned into it. The capsular ligament is torn from its connection with the acetabulum at its anterior and posterior junction, but not at its superior and inferior. The ligamentum teres is broken, and an inch of it still adheres to the head of the bone. The head of the bone rests behind the acetabulum, on the pyriformis muscle, at the edge of the notch above the sacro-sciatic ligaments. The muscle on which it rests is diminished, but there has been no attempt made to form a new bony socket for the head of the os femoris. *Fig.* 324.

Around the head of the thigh-bone a new capsular ligament is formed; it does not adhere to the articular cartilage of the ball of the bone which it surrounds, but could, when opened, be turned back to the neck of the thigh-bone, so as to leave its head completely exposed.

Fig. 324.



*Luxation in the sciatic notch.**

Within the new capsular ligament, which is formed of the surrounding cellular membrane, the broken ligamentum teres is found. The trochanter major is rather behind the acetabulum, but inclined towards it relatively to the head of the bone. This dislocation, he adds, must have existed, from the appearances of the parts, many years. The adhesions were too strong to have admitted of any reduction, and if reduced, the bone could not have remained in its original socket.

c. Luxation upwards and inwards on the pubes.—This luxation is more easy of detection than any other of the thigh. It happens from a person while walking putting his foot into some unexpected hollow in the ground, and his body at the moment being bent backwards, the head of the bone is thrown forward upon the os pubis.

The limb in this species of dislocation is an inch shorter than the unaffected one; the knee and the foot are turned outward, and

* Guy's Hosp. Reports, Jan. 1836.

* From Sir A. Cooper, pl. iv. on Fractures and Dislocations.

cannot be rotated inwards, nor flexed without causing acute suffering. The inguinal region is the seat of the principal pains, which however from this point extend along the thigh, and are the consequence of the stretching which the anterior crural nerve necessarily suffers as it is raised up at the neck of the bone.

The striking criterion of this dislocation is, that the head of the thigh-bone may be distinctly felt upon the pubes, above the level of Poupart's ligament, and it feels as a hard ball, which is readily perceived to move by bending the thigh-bone. The femoral artery has been usually felt pulsating along the inner side of the head of the bone, but Mr. Smith presented lately to the Pathological Society the cast of a case of this luxation, in which he had noticed that the femoral artery ran in a tortuous manner directly across the head of the dislocated bone.

The great trochanter is drawn upwards and forwards, so as to be situated in the trajet of a line which would pass from the anterior inferior spine of the ilium, downwards and forwards. In a case of a dislocation of this species which was left a long time unreduced, the motion of the knee backwards and forwards was fully twelve inches. The following case was admitted into Jervis Street Hospital, under the care of Mr. O'Reilly, during the time I was one of the surgeons to that institution, and as it seemed to me the best marked case of the kind I had ever witnessed, I beg here to lay it before the reader from my case-book.

Case.—P. Bryan, a powerful man, aged 37, was admitted into Jervis Street Infirmary, Dec. 4, 1828. He was intoxicated when the accident which produced the luxation occurred, and consequently was unable to give any idea as to how the injury was produced.

As the patient lay on his back in bed the affected limb appeared to lie parallel to its fellow, but then there was an eversion of the whole limb, and the foot of course turned outwards. One circumstance particularly caught our observation, viz. the preternaturally arched appearance which the upper third of the shaft of the femur presented; the adductor muscles were full and prominent; there was an unusual prominence underneath Poupart's ligament; the anterior superior spinous process appeared retired.

On making more minute examination it was found that the eversion of the foot was permanent, and we were surprised to find that there was but little difference between the length of both limbs; certainly the injured one was little more than half-an-inch shorter than the sound one. A considerable depression existed where formerly the trochanter major lay; this process of bone was very evident, and could be readily felt about two inches below and somewhat anterior to the anterior superior spinous process of the ilium, and about the same distance internal to it a well-marked prominence in the inguinal region shewed the new situation which the head of the femur occupied; along its inner side were seen and felt the pulsations of the femoral artery. On communicating a motion of rotation outwards, the head of the bone could be easily felt under the soft parts; the nates was flattened; the femur was but little moveable with respect to the pelvis, and any attempt to draw the thigh backwards caused great pain to the patient: to flex it was impossible. A motion of rotation outwards could be communicated to the dislocated femur, but no rotation inwards was permitted. Adduction of the limb was admissible, even to permit the knees to touch. When the patient stood up, he naturally threw his weight on the sound limb, and the affected one was flexed slightly at the knee, and the heel touched the inside of the opposite foot, as in the "first position" of dancers. The reduction of the dislocation was effected in the ordinary method; indeed the rules laid down by Sir. A. Cooper were fully adopted, and in due time succeeded.

Anatomical characters of this luxation.—Sir. A. Cooper gives us an account of the dissection he made of one of these luxations of the femur on the pubes, which had been a long time unreduced; he found the original acetabulum partially filled by bone, and in part occupied by the trochanter major, and both are much altered in form; the capsular ligament is extensively lacerated, and the ligamentum teres broken. The head of the thigh-bone had torn up Poupart's ligament, so as to be admitted between it and the pubes (*fig.* 325). The head

Fig. 325.

*Luxation on the pubes.**

and neck of the bone were thrown into a position under the iliacus internus and psoas muscles, the tendons of which, in passing to their insertion over the neck of the bone, were elevated by it and put on the stretch. The crural nerve passed on the fore-part of the neck of the bone,

* From Sir A. Cooper, loc. cit. plate v.

upon the iliacus internus and psoas muscles. The head and neck of the thigh-bone are flattened, and much changed in their form. Upon the pubes a new acetabulum is formed for the neck of the thigh-bone, for the head of the bone is above the level of the pubes. The new acetabulum extended upon each side of the neck of the bone, so as to lock it in a certain direction upon the pubes. Poupart's ligament confines it on the fore-part; on the inner side of the neck of the bone passed the artery and vein, so that the head of the bone was seated between the crural sheath, and the anterior and inferior spinous process of the ilium.

d. Luxation downwards and inwards into the foramen ovale.—When the femur is in a forced state of abduction, if violence be in any manner applied so as still further to exaggerate this movement, the head of the femur having previously glided from above downwards in the acetabulum to its utmost, applies itself to the interior of the capsular ligament, which it stretches; if the force be continued the capsule soon gives way, and the head of the femur, bursting through the rent, is dislocated and lodged in front of the obturator foramen.

Fig. 326.

Luxation into the foramen ovale.

The symptoms by which we recognize this accident are very well marked, as the limb in this dislocation is two inches longer than the other. The body is bent forwards owing to the psoas and iliacus internus muscles being put upon the stretch (*fig.* 326). The knee is considerably advanced; if the body be erect it is widely separated from the other, and cannot be brought without great difficulty towards the middle line or made to touch the other knee, owing to the extension of the glutæi and pyriform muscles. The foot, though widely separated from the other, is generally neither turned outwards nor inwards, although it varies a little in this respect in different instances, but the position of the foot does not in this case mark the accident. The adductor muscles are elongated and form a round prominent line which extends from the pubes to the middle of the thigh. The foot and the knee are turned outwards because the adductor and the other muscles which execute the movement of rotation outwards are on the stretch and elongated. The thigh cannot be adducted, and when we wish to communicate this movement to the limb the patient feels severe pains because of the tension which the glutæi and rotators outwards suffer. The reason of the flexion of the leg is two-fold; first to relax the hamstring muscles which are put upon the stretch by the dislocation, and to establish an approach to an equality in the length of the limb.

When we examine closely the injured hip, we notice a considerable hollow at the upper and outer part of the thigh where the great trochanter is normally seen projecting, and a depression is noticed below the centre of Poupart's ligament. The head of the dislocated bone can be felt occasionally at the inner and outer parts of the thigh towards the perineum. The position of the head of the bone is below the acetabulum and a little anterior to it. The bent position of the body, the separated knees, and the increased length of the limb constitute the striking and characteristic features of this rare accident.

That excellent practical surgeon, Mr. Hey of Leeds, had not during a period of public and private practice for thirty-eight years seen a case of this accident of luxation downwards and inwards into the foramen ovale, until in the year 1797 three patients were brought into the infirmary of Leeds. In one of the best marked examples of this accident the dislocated thigh appeared much thicker at the superior part than the other; the adductor muscles, it appears, were upon the stretch, and the inguinal hollow we can collect was effaced (perhaps by the tension of the skin and effusion). Mr. Hey says, the head of the bone could not be distinctly felt through the muscles; yet, from the appearance and the touch, it was sufficiently evident that the head of the bone lay upon the great foramen of the os innominatum. It seemed probable that it had passed so far from the acetabulum as to be in contact with the descending part of the os pubis.

There was in this case a considerable hollow at the upper and outer part of the thigh where the great trochanter is usually felt projecting.

The following case of dislocation of the femur into the foramen ovale I saw in Steevens's Hospital, and my friend Dr. Osbrey has obliged me with his notes of the case, which were as follows:—

Michael Murphy, æt. 21, a labourer, admitted June 4th, 1834, under Mr. Colles with dislocation of the head of the femur into the foramen ovale.

He stands with his entire weight upon the sound side, the left thigh flexed on the pelvis, his knee bent, and toes turned out and resting on the ground, from which the heel is raised; the thigh is abducted so that he cannot bring his knees nearer than within five inches of each other, when standing up not within nine, and at this time his toes are thirteen inches asunder; the thigh is wasted, and he cannot support any weight on the limb. When asked to walk without support he places his hand firmly on the knee, and bears his weight on the arm and leg without throwing any of it on the thigh. His pelvis is lower on the injured side, and there is a slight curvature of the spine, the convexity to the same side, in consequence of which there is great apparent lengthening of the limb. The real difference when measured from the symphysis pubis to the point of the inner ankle is two inches and a half, but there is little or no difference when measured from the spine of the ilium; and when the measurement is taken from the tuber ischii the dislocated limb is two inches longer than its fellow. There is considerable deformity about the joint; a deep hollow exists immediately below the anterior spine of the ilium, through which the sartorius runs obliquely, joining a prominent ridge when the muscle is in action. The prominence of the trochanter is altogether lost, and that process can be with difficulty felt. The fold of the buttock is completely obliterated, and there is a fullness towards the upper and back part of the thigh, caused by the head of the bone, which can be felt through the adductor muscles, and seems to be situated further inwards than is usually described in this accident. He states that he received the injury five weeks ago; he was thrown down on his right side obliquely against a wall, by a horse running away with a cart, and the wheel of the cart passed over his left hip above the trochanter; he felt great pain at the time which was chiefly referred to the inside of the knee. He was carried home and nothing was done for him for a fortnight, when he went to a hospital, where several attempts were made at reduction; all, however, failed, and after remaining there a fortnight longer he came up to Dublin in the state above described.

On the 12th of June two attempts to reduce the bone failed altogether, and the man returned to the country.

Anatomical characters.—It seems probable that the head of the dislocated femur passes so much forwards and inwards from the acetabulum as to be in contact with the inner margin of the thyroid foramen, where this foramen is completed by the rami of the ischium and pubes. The convexity of the great trochanter has the acetabulum behind it, and the lesser trochanter is placed immediately external and anterior to the tuberosity of the ischium. The ligamentum teres and lower part of the capsular ligament have been torn through, and the head of the bone "become situated in the interior and inner part of the thigh upon the obturator externus muscle."

We have, says Sir Astley Cooper, an excellent specimen of this accident in the collection of St. Thomas's Hospital, which I dissected many years ago. The head of the thigh-bone was found resting on the foramen ovale, but the obturator externus muscle was completely absorbed, as well as the ligament naturally occupying the foramen now entirely filled by bone. Around the foramen ovale bony matter was deposited so as to form a deep cup, in which the head of the thigh-bone was inclosed, but in such a manner as to allow considerable motion; and the cup thus formed surrounded the neck of the thigh-bone without touching it, and so enclosed its head that it could not be removed from its new socket without breaking its edges. The inner side of this new cup was extremely smooth, not having the least ossified projection at any part to impede the motion of the head of the bone, which was only restrained by the muscles from extensive movements.

The original acetabulum was half filled by bone, so that it could not have received the ball of the thigh-bone if it had been put back into its natural situation (*fig.* 327). The head of the thigh-bone was very little altered, its articular

Fig. 327.

*Luxation into the foramen ovale.**

* From Sir A. Cooper, pl. ii.

cartilage still remained, the ligamentum teres was entirely broken, and the capsular ligament partially torn through. The pectinalis muscle and adductor brevis had been lacerated, but were united by tendon. The psoas muscle and iliacus internus, the glutæi and pyriformis, were all upon the stretch.

c. Cases of unusual dislocations.— In Guy's Hospital Reports we find the account of two cases of dislocation of the head of the femur upwards and outwards towards the anterior superior spinous process of the ilium.

In the first of these cases, detailed by Mr. Morgan, the affected leg (the left) was shortened to the extent of at least two inches, the foot was excessively everted, so much so as almost to give the toes a direction backwards. The injured limb had a tendency to cross that of the opposite side, so that the heel was thrown over the instep of the opposite foot; nevertheless when the feet were placed side by side, they remained in that position. The limb was susceptible of all the natural motions to some extent, with the exception of rotation, but the man complained of great pain when under examination. The projection of the trochanter major was entirely lost, whilst the luxated head of the bone might be felt under Poupart's ligament, just below and to the inner side of the anterior superior spinous process of the ilium, and it apparently lay between the anterior and inferior spinous process of the ilium, and the junction of this last bone with the pubes; it thus rested upon the brim of the pelvis, and projected upwards towards the abdomen; the femoral artery was not displaced in this dislocation, but could be traced taking its usual course, and consequently situated to the inner side of the displaced bone.

In this case a speedy reduction of the dislocated bone was effected, but in the second case I have alluded to, the bone was left unreduced for years. We are indebted for the publication of the whole case, accompanied with the dissection, to Mr. Bransby Cooper, who tells us that the preparation which illustrates the accident the patient suffered from, was presented to Sir Astley Cooper, by his friend Mr. Oldknow of Nottingham, and the bones are preserved in the museum of Guy's Hospital. The subject of the accident was a lunatic, aged 28, and as far as we can learn from the detail of the case given, his symptoms were very much those which Mr. Morgan's patient presented before the dislocation was reduced.*

Upon dissection it was found that the old acetabulum was deprived of articular cartilage, and was in part filled up by bony deposit, so as to be rendered wholly unfit for the reception of the head of the femur. The new acetabulum was nearly directly above the original cavity, and was bounded on the outside by the two anterior spinous processes, and on the inside by the line of junction of the ilium and the horizontal branch of the pubes, that is to say, by the ileo-pubal eminence. The form of the new cavity for the reception of the head of the femur was very like the natural acetabulum, but not quite of equal dimensions; it is protected above by a growth of bone which overlapped the head of the femur, and must have formed the principal point of support of that bone. The inferior part of the new acetabulum was the most deficient. The trochanter major sunk partly into the old acetabulum, and polished points on both the old and new acetabulum indicated where the head of the femur and trochanter major played in the various motions this imperfect joint enjoyed.

We are not informed how the muscles were altered from their normal state, but may infer that most of them were more or less atrophied; it is probable, however, that both the obturator externus and internus were put much upon the stretch, and retained the bone more or less downwards. It would have been interesting to have learned the precise situation of the rectus femoris, tensor vaginæ, and sartorius, psoas, and iliacus, but we can easily imagine that the latter were much shortened, and that they were raised up from the pubes by the dislocated bone, the tendon of the rectus must have been thrown outwards over the rest of the femur and trochanter major. The head of the femur was altered from its original figure, so as to be adapted to the new acetabulum, portions of it being diminished where it did not come in contact with the new cavity, so that its spheroidal figure was lost. The periosteum of the femur, as well as of the new acetabulum, assisted in forming the new capsular ligament. The articular cartilage of the head of the femur has been absorbed, and the same porcelain-like concretion, as is seen in the acetabulum, is provided at corresponding points. From the form of the articulating surfaces, and the fixed position of the femur, both at the head and the trochanter major, it will be observed that no other motion than flexion could be permitted, and even that motion, from the closeness of the attachment at the trochanter, but to a limited extent.

Luxation of the head of the femur downwards and backwards. — This luxation may be considered as a very rare accident. When the last edition of Sir A. Cooper's work on Fractures and Luxations was published, the baronet had not seen such an accident, as he remarked, "it is to be remembered that there is no such accident as a dislocation of the hip downwards and backwards."

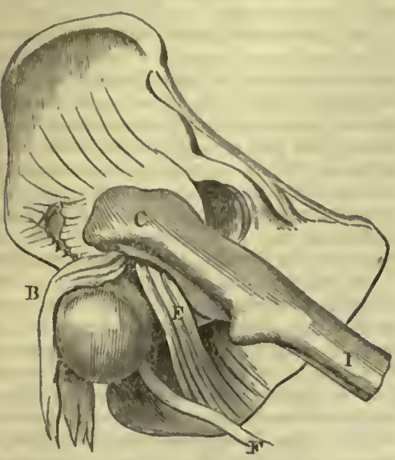
Dupuytren says, "I have only twice or thrice seen this luxation downwards and backwards. The limb was then twisted inwards, a little elongated, and it was impossible to adjust it to its ordinary place and position, without reducing the luxation, which once accomplished, the displacement did not a second time recur."

My friend Mr. Wormald, assistant-surgeon to St. Bartholomew's Hospital, has published an account of an accident of this kind in the Medical Gazette, June 28, 1837, and the preparation, which shews the relative position of the head of the dislocated bone, &c. and the acetabulum,

* Guy's Hospital Reports, January, 1836, p. 99.

is preserved in the museum of the hospital. *Fig.* 328.

Fig. 328.



Dislocation downwards and backwards.

B, *obturator internus*; C, *trochanter major*; D, *the acetabulum*; E, *obturator externus*; F, *sciatic nerve*; I, *shaft of the femur.*

" A maniac who eluded the vigilance of his keepers, leaped from a third story window. Besides dislocating his thigh, he received other injuries, of which he died in about an hour.

" On examining the dislocated limb, it was found considerably shortened and inverted, forming about half a right angle with the body, the shaft of the femur crossing the symphysis pubis was fixed immoveably in this situation; as the patient was sinking, no attempt was made at reduction.

" Twelve hours after the death of the patient I commenced the dissection, by reflecting the glutæus maximus, when I found some of the fibres of the glutæus medius and minimus ruptured at their posterior edge. The pyriformis and gemelli were also partially torn, but those portions of the tendon of the obturator internus which pass through the lesser ischiatic notch were drawn out, and separated from their connexion with the muscular fibres; the head of the femur presented itself through a rent of the capsule, opposite to the upper part of the tuber ischii above the quadratus, so that the great sciatic nerve was somewhat displaced and pressed against the tuber ischii.

" In this case there was no difficulty in detecting the nature of the injury, as, besides the symptoms already described, the head of the femur could be felt resting on the tuber ischii, covered by the outer edge of the glutæus maximus.

" If this patient had been in a condition to attempt reduction of the dislocation by fixing the pelvis, and employing extension in the direction of the shaft of the bone, at the same time everting the limb, the head of the femur would have been brought opposite the rent in the capsule, and would have been in all probability replaced in the acetabulum without greater difficulty than is usually experienced."

(*Robert Adams.*)

HYPERÆMIA AND ANÆMIA, (ὑπὲρ, *super*; α, negative; and αἷμα, *sanguis*) (in morbid anatomy). These are terms employed to denote opposite conditions of the various membranous or parenchymatous textures of the body as regards the quantity of blood contained in their bloodvessels; the former, as its derivation denotes, indicating a superabundant supply of blood, the latter a deficiency of that fluid. They are useful terms to the anatomist, inasmuch as they express simply the state of a texture, without any theory being involved respecting the cause or origin of that state. It ought always to be the first business of the anatomist to observe carefully the actual condition of the parts submitted to his examination; this having been done, he should search diligently for some cause, mechanical, chemical, or vital, which will satisfactorily account for the phenomena.

All vascular textures, it is obvious, are liable to these conditions; and it is equally evident that the relative frequency of their occurrence in different textures will coincide with the natural facility of the flow of blood to or from them, as well as the quantity of blood contained in them in the normal state. Thus the lung or the spleen is favourable for the formation of hyperæmia, as well from the large supply of blood in each as from the free communication between their respective arterial and venous systems, and between the ramifications of vessels of the same kind.

A bleached state of the same organs may be taken as a good example of the opposite condition, or anæmia; but the most complete anæmia is, of course, to be found in organs or tissues which, in the natural state, contain but a small quantity of blood.

It is important to notice that hyperæmia may occur independently of disease and altogether as a cadaveric phenomenon, and there is no mistake more frequently committed by the incautious observer than that of attributing to the influence of a morbid process during life appearances which simply result from the ordinary physical laws which death has allowed to exert full sway over the tissues. Indeed, it is only since anatomists have ceased to regard every instance of an unduly injected tissue as a diseased one, that valuable practical conclusions have been drawn from post-mortem observations.

We may pronounce hyperæmia not to be morbid, when it is found to occupy only the most dependent parts of organs, the blood having deserted the vessels of the more elevated parts. At every post-mortem examination we have abundant examples of hyperæmia of this kind; if the body have been laid on the back, as is usually the case, the whole of the skin of that region is largely injected with blood; the subcutaneous cellular tissue is in a similar condition, and the adjacent muscles more or less so likewise. The blood in these cases is chiefly contained in capillaries and veins, the ramifications of which will be found fully injected. The dependent parts of all the vascular tissues and organs of a body thus placed, exhibit similar appearances. The scalp on the occiput, the posterior lobes of the brain, and the cerebellum are much more injected than the anterior parts of the same textures. The posterior parts of the lungs, of the stomach and intestines, of the spleen, liver, and kidneys exhibit the same state of vascular congestion. That this results altogether from position and the blood in the vessels obeying the universal law of gravitation, may be clearly proved by reversing the position of the body, when after a little time the blood will desert the former dependent but now elevated parts, and those portions of the texture which before were almost devoid of blood from their elevated position, now have their vessels filled with it.

When hyperæmia results from a mechanical obstacle to the circulation, it is not accumulated at one part of an organ or viscus, but all parts appear equally gorged with the blood. In certain diseased states of the heart and liver, the intestinal canal presents an example of this general hyperæmia, owing to the mechanical obstacle to the free circulation of the blood in the right heart. The circumference of the intestine is every where reddened by the blood accumulated in its capillaries.

Andral, by whom of late years the term hyperæmia itself was brought into use in morbid anatomy, gives the following varieties of it. 1. Active or sthenic hyperæmia, denoting the state indicated by the ordinary expression *acute inflammation*. 2. Passive or asthenic, resulting from diminished tone in the capillary vessels. 3. Mechanical, from an obstacle to the venous circulation. 4. Cadaveric or post-mortem, being the result of those physical and chemical laws to which all inorganic matter is subject, and to which all organized bodies are also subjected when the vital spark has ceased to animate them.* This last variety, moreover, he subdivides into two genera. *First genus*, hyperæmia produced at the moment of death.—Cause; the contractility of tissue which resides in the small arteries, continuing to act after the heart has ceased to beat. *Second genus*, hyperæmia produced at a certain period after death. This genus comprehends the following species:—1. Hyperæmia by hypostasis or dependent position. 2. Hyperæmia by transudation of the blood or of some of its component parts through the parietes of its vessels. 3. Hyperæmia by chemical affinities.

Anæmia, a term long in use to express a general exsangueous and cachectic condition of the body, is also applied to a local state of exsangueousness. Any cause which would impede or cut off the wonted supply of blood to a part will occasion this condition in it; the diminution in the calibre of the principal artery of an organ, from mechanical pressure or disease in the vessel, or a depressed state of the nervous influence. Hyperæmia of one organ may give rise to anæmia of another, the former as it were attracting the blood away from the latter.

The general condition of anæmia is not unfrequently brought under the physician's notice either as the result of some excessive and long-continued hemorrhage or of some deranged state of general nutrition, giving rise to a deterioration in the quality of the blood, or a general deficiency in the powers of the nervous influence. The surface of the body is pale, the mucous membranes, as far as they can be seen, partake of the same exsangueous state, the secretions are defective and vitiated, the tone of the muscular and vascular systems is considerably diminished, and this state may go on without any specific morbid change in any organ, beyond its participation in the general scanty supply of the blood, or it may co-exist with an organic disease, which, although it may have been at first the result of the primary exciting cause of the anæmia, now serves to increase it, or offers the greatest impediment to its removal.

(R. B. Todd.)

* Path. Anat. by Townsend, vol. i. p. 15.

HYPERTROPHY AND ATROPHY, (ὑπερ, *super*, α, *priv.*, and τρεφω, *nutrio*), (in morbid anatomy). When any organ or tissue has acquired a certain increase of developement, without any manifest alteration of its natural structure, it is said to be in the state of *hypertrophy*—the increase being due to a greater activity of the nutritive process in the part affected. A familiar example of hypertrophy, although not morbid, is afforded by the augmentation which muscular fibre acquires in consequence of increased action. If the biceps muscle of one arm be actively exercised, while that of the other does not undergo any considerable degree of action, the former acquires a great increase of size, it becomes denser and firmer, and manifests the physical and vital phenomena of the muscular tissue with more than ordinary energy.

There is no texture in the body which does not occasionally exhibit evidence of the hypertrophous condition. The circumstances which favour its production are an abundant and a free afflux of blood to the part, an energetic nervous influence and an increased demand upon the organ, or increased exercise if it be muscular; and indeed these are the almost invariable conditions under which hypertrophy is manifested. The heart becomes hypertrophous under an exalted nervous influence, or from a necessarily increased exercise from the effort to overcome some obstacle to the free circulation of the blood through its cavities; one kidney acquires a great increase of size if the other one be incapable of performing its function. It may be said that the liver is in a state of hypertrophy in the fœtus in utero, for it has a larger supply of blood than in extra-uterine life, and the lungs have not as yet begun to share with it in the office of decarbonizing the venous blood. The bladder also, like the heart, acquires an enormous developement of its muscular coat, when any obstacle obstructs the free flow of the urine from it. The physical condition, then, of a hypertrophous organ differs but in degree from that of the part in its normal state. There are, in general, increase of size, of weight, and of consistence, with more or less alteration of shape consequent upon the former; an increased supply of blood, and a consequent heightening of colour. To judge therefore how far an organ has experienced hypertrophy, the anatomist must carefully compare its present condition, as regards size, weight, colour, consistence, and supply of blood, with the average state of the parts in health.

Atrophy is not only opposite in its nature to hypertrophy, but it results from causes of an entirely opposite kind. A defective state in the nutritive process is its immediate cause:—the affected part shows manifest signs of wasting; it diminishes in size and in consistence; it loses its colour from the deficient supply of blood; its physical and vital properties are manifestly altered, and are fully developed. When the wasting has gone to its greatest extent, the natural texture disappears, or is so altered as to present but few of the characters of its normal condition. As frequent exercise and use favour the production of hypertrophy, so on the other hand disuse and inactivity give rise to atrophy. Neither the vascular nor the nervous systems of such parts afford their wonted supplies; and those physical characters which are present in hypertrophy in an exalted condition, are in atrophy either absent altogether, or but feebly developed. The muscles of paralytic limbs, the hearts of old persons which have been overloaded with fat, the diminution in size and almost total disappearance of the thymus gland in the adult, the diminution of the left lobe of the liver in extra-uterine life, the obliteration and conversion into a fibrous cord of certain disused venous and arterial canals, and the wasting of the optic nerve where the eye is destroyed, are examples of atrophy of every day's occurrence. (See the articles on the morbid anatomy of the different textures and organs.)

(R. B. Todd.)

ILIAC ARTERIES* (so called from their situation in the iliac regions) are three upon each side of the body, viz. the primitive iliac, the internal and the external iliacs; they are the main arteries of the pelvis and the lower extremity.

Primitive iliac arteries *(common iliacs, arteriæ iliacæ primitivæ, s. communes, s. pelvi-crurales;* Fr. *Artères iliaques primitives;* Germ. *Gemeinschaftliche Hüft-pulsadern,)* are two, one on each side: they are vessels of great size, from three-eighths to four-eighths of an inch in diameter, but short, their length varying from one and a half to two and a half or three-quarters of an inch, the arteries being longer or shorter, according to the height at which the aorta divides. They arise from the termination of the aorta, their origin corresponding, as a mean point, to the interval between the bodies of the fourth and fifth lumbar vertebræ, and somewhat to the left of the middle line of the vertebral column; the exact height of their origin, however, varies considerably, ranging in ordinary between the bodies of the third and fifth vertebræ; but they have been found to arise very near to the diaphragm.* From their origin they descend, and at the same time incline outward and backward, forming with each other an acute angle, but more so in the male than in the female subject, because of the greater width of the pelvis in the latter, until they reach a point ranging between the body of the fifth lumbar vertebra and the sacro-iliac articulation,† where they terminate by dividing into the internal and external iliacs. The point of reference usually assigned for this division is the sacro-iliac articulation; but this appears not to be strictly correct, the exact point varying as well on the opposite sides of the same as in different subjects; for the most part the division takes place between the two points, which have been mentioned; at times nearer to one, at times to the other, and according to Velpeau, it usually occurs nearer to the spine upon the right than upon the left side; hence, according to the same authority, the right external iliac artery is longer than the left, and were it possible to ascertain these diversities of origin during life, advantage would result therefrom, inasmuch as the prospect of success in high ligature of the external iliac must be influenced by the height of its origin, and the difficulty of reaching the primitive or the internal iliacs must be increased in the same proportion. These views appear well-founded; the division of the primitive iliac rarely takes place so far outward as the sacro-iliac articulation, and for the most part it is nearer to the body of the vertebra, or higher upon the right than the left side, and therefore the external iliac of that side is usually the longer, but this disposition is not constant; the division of the right primitive artery is not always higher than that of the left, nor consequently the right external longer, and therefore while probability is in favour of the conclusion which the facts stated indicate, it cannot be absolutely relied upon.

The primitive iliac arteries are of the same size, and nearly the same length; the right, however, is considered for the most part somewhat the longer, because of the situation of the

* But little dissection is necessary to display the iliac arteries; the abdominal wall having been divided and thrown back, the peritoneum may be detached from without inward, along with the contained viscus, from the iliac fossa, which having been done to a sufficient extent, care being at the same time taken to leave uninjured the spermatic vessels the vas deferens and the ureter, the iliac arteries will be exposed still covered by their immediate investment.

* Velpeau, who cites Petscho on the authority of J. F. Meckel.

† Bogros.

aorta upon the left side of the spine; Velpeau, however, seems to question the existence of any difference in the length of the two vessels, inasmuch as the right divides generally nearer to the spine than the left, the inclination of their origin to the left being thus compensated, but to whatever extent this view may hold good, it is by no means strictly correct; in fact the length of the arteries, whether comparative or absolute, is far from regular; nor is the preponderance, when present, always upon the same side; the opinion generally entertained is probably correct, the right artery being in the majority of instances somewhat longer than the left; but the writer has found the left the longer of the two, and the same disposition has been observed by J. F. Meckel; this is, however, an unusual disposition.

The relations of the arteries are simple. During their descent they are situate in front of the bodies of the lumbar vertebræ, with the intervening fibro-cartilages, of one, two, or more of these bones, according to the height at which the arteries arise, and also of the lateral part of the base of the sacrum; they are both covered upon three sides by the peritoneum, viz. in front and laterally, the membrane descending upon them from the root of the mesentery; the mesentery itself also and the small intestines are placed before them, and the latter overlap them upon either side. Farther, they are in front of the superior branches of the middle sacral artery and of the sympathetic nerve. That of the right side at its outset is placed before the left primitive iliac vein, which it crosses at its junction with the cava, and partially before the commencement of the cava itself; during its course it is in front of the right primitive vein, at first only partially, but, as it proceeds, covering it to a greater extent, until at its termination it is directly before it.

External to both, but on a plane posterior to them, are the psoæ muscles, the left artery however being nearer to the muscle than the right, between which and the psoas the right primitive vein and the cava intervene, being at the same time posterior to it.

Internal to both at their origin is the middle sacral artery; on the left side the left primitive vein lies along the inside of the artery, but on a plane behind it.

Anteriorly the arteries are crossed at their termination by the corresponding ureter, that duct being interposed between the peritoneum and the vessel, but more adherent to the former. The relation of the ureter to the iliac arteries is not uniform, either on opposite sides or in different subjects; the bifurcation of the primitive iliac may be assumed as the mean point of reference for its transit, the duct descending into the pelvis between the external and internal iliacs, and before the internal; but its precise relation will depend upon the height at which the bifurcation takes place and the side of the body to which it belongs, and hence it very frequently, if not usually, crosses the external iliac upon the right and the termination of the internal on the left.

The artery and vein, the relations of which differ remarkably upon the two sides, the vein being external upon the right and internal upon the left, and upon both posterior, are enclosed within a condensed cellular investment, prolonged upward upon the aorta and downward upon the secondary iliacs; upon the primitive vessels it is so thin that it may at times seem absent; but, as it descends, it increases in thickness, and acquires upon the external iliacs considerable strength.

The primitive iliac arteries ordinarily give only minute branches to the adjoining parts, viz. the ureter, the peritoneum, the vein, lymphatic glands and cellular structure; but occasionally they have been found to give off the ilio-lumbar artery, and more rarely a renal or spermatic artery.*

Although, according to the view usually taken, the primitive iliac terminates by dividing into internal and external, yet in many instances it will be found that the primitive and external iliacs appear as one vessel giving off the internal from its posterior side, and nearly at right angles, while in the fœtus the reverse seems the case, the primitive and internal being continuous and rather giving off the external.

Internal iliac artery.† (*Arteria iliaca interna*, s. *hypogastrica*, s. *umbilicalis*; Fr. *artere iliaque interne, ou hypogastrique*; Germ. *Becken-pulsader* oder *innere Huft-pulsader.*) This artery from the time of birth supplies the viscera and parietes of the pelvis, both externally and internally; prior to that epoch it is the channel through which the blood is transmitted from the body of the fœtus to the placenta, whence it may then be termed with propriety the "placental artery," since such is its chief office, the other distribution being of inconsiderable extent, and the divisions of the artery intended for it small in proportion; hence the vessel presents a remarkable contrast at the two periods of life, in the fœtus being a large and long vessel extending from the termination of the aorta, for, as has been before stated, it seems at that time the continuation of the primitive iliac artery, to the placenta giving off in its course small branches to the viscera and parietes of the pelvis, while in after life the placental artery has disappeared, and in its stead is found a short trunk of considerable size,—the commencement of the placental artery as it had been—from which arise numerous vessels for the pelvis and its viscera.

The internal iliac arises from the posterior side of the primitive iliac artery,‡ between the body of the last lumbar vertebra or the sacro-vertebral angle, and the sacro-iliac articulation, but generally higher upon the right side than the left; it descends into the pelvis in front of

* J. F. Meckel.

† The internal iliac and its branches should be examined first with the pelvis complete, the peritoneum and viscera being detached from its lateral wall, and the latter alternately empty and distended; afterward a section of the pelvis may be made through the symphysis pubis and the middle of the sacrum, preserving the viscera with their attachments to one side; but this should not be done until after the dissection of the perineum.

‡ See primitive iliac for point and mode of division.

the sacro-iliac articulation or of the lateral part of the sacrum, as it may be, inclining backward and outward, and describing a curve concave forward, until it reaches the superior part of the great sciatic notch, where it usually divides; this however is by no means uniform, the point of its division ranging between the brim of the pelvis and the notch. The internal iliac is an artery of great size, but in the adult smaller than the external; its course is somewhat tortuous and short, from one and a half to two and a half inches.

During its descent the artery is placed before the lumbo-sacral nerve, on the left side before the primitive iliac vein, and on both before the sacro-iliac articulation or the lateral part of the sacrum. Before it are in the male the bladder or its lateral connections, in the female the uterus and its broad fold of peritoneum; externally the artery corresponds to the internal iliac and the commencement of the primitive iliac veins, to the inside of the psoas magnus muscle, to the brim of the pelvis, to the obturator nerve, which it crosses nearly at right angles, to the lumbo-sacral and first of the anterior branches of the sacral nerves, and to the superior attachment of the pyriformis muscle: the ilio-lumbar artery is also external to the internal iliac, between it and the wall of the pelvis. Internal to it are the peritoneum, the rectum with its mesentery, and the superior hemorrhoidal vessels, (these parts being nearer to the artery upon the left than the right,) and the small intestine when in the pelvis.

The external iliac vessels are above, before, and external to the internal.* In the fœtus the condition of the internal iliac differs remarkably from that which it presents in after life; in it both in size and direction this artery appears the continuation of the primitive trunk, exceeding the external as much as afterward it is exceeded by it. It is the channel which conveys the blood to the placenta, and it is generally entitled the "hypogastric or umbilical artery;" "placental" would certainly be preferable. It passes from the primitive iliac or rather from the aorta, for there the primitive iliac appears only the commencement of the placental artery, downward and at first outward as far as the sacro-iliac articulation, where it gives off the external iliac artery, then forward to the side of the bladder, descending but little into the pelvis and at the same time giving off pelvic branches; it next changes its direction and ascends inclining inward toward the umbilicus, at first by the side of the bladder and then in the anterior abdominal wall, between the peritoneum and the rectus muscle or its sheath, and on either side of the urachus; thus forming a curve convex downward through the concavity of which pass the vas deferens or round ligament before, the ureter posteriorly and the rectum, the extremity of the ilium and the appendages of the uterus in the mean space. Having reached the umbilicus the artery escapes through it from the body of the fœtus and is conducted by the umbilical cord to the placenta; during their transit to the placenta the arteries at the very early periods of utero-gestation, are straight, but afterwards, in proportion as the developement advances, they become tortuous, and are twined round the umbilical placental vein, whence the length of the arteries exceeds that of the cord which varies from one to two feet. At the placenta the two arteries are connected by a considerable anastomosis, and divide into numerous branches, which subdivide minutely in the lobes of that structure, the ramifications of the several lobes being distinct from each other; ordinarily the two vessels are distinct until they approach the placenta, but they have been found to unite into a single one before escaping from the abdomen of the fœtus.* The placental arteries give off within the body of the fœtus branches similar in number and destination with those of the primitive iliac of the adult, but in a rudimental condition; between the summit of the bladder and the umbilicus however they do not furnish branches, and hence, the circulation through them between these points ceasing at birth, they become obliterated to the same extent and connected into impervious cords, known by the name of umbilical ligaments; these hold the same course and relation with the original vessels, and are less distinct in proportion to the age of the subject; they are covered upon their abdominal aspect by the peritoneum, which is reflected upon them to a greater or less extent according to the subject, and thereby forms triangular falciform folds, the base of which is below in the iliac fossa, and the apex above toward the umbilicus, and in the free edge of which the ligament is contained. At a point intermediate to the brim of the pelvis and the upper part of the sacro-sciatic notch the internal iliac artery divides into branches; these are numerous, amounting altogether in the male to nine, and in the female to eleven; but in their mode of origin they vary very much, arising sometimes separately, sometimes by common trunks, but for the most part from two, into which the iliac divides; these are an anterior one giving off the hemorrhoidal, the umbilical, the vesical, the uterine, the vaginal, the sciatic and internal pudic, and a posterior, from which arise the ilio-lumbar, the lateral sacral, the obturator and the gluteal. Another diversity in the mode of their origin is that of the obturator from the epigastric or external iliac.

The branches of the internal iliac are arranged either into four sets, viz. posterior, anterior, internal, and inferior,† or into two, internal and external,‡ the former distributed within, the latter without the pelvis; the latter seems the more simple division, and is the one which will be adopted in this article.

The *internal* branches are in the male five, in the female seven; they are as follow—

1. The *iliolumbar artery* varies in size and origin; for the most part it arises from the posterior

* This is to be understood to refer to the recumbent posture; in the erect posture the external are not superior to the internal vessels.

* Cloquet.
† Cloquet.
‡ Harrison.

division of the internal iliac, at times from the iliac itself; at times from the gluteal, occasionally from the primitive iliac, and frequently by a trunk common to it and the lateral sacral; from its origin, which is somewhat below the base of the sacrum, it runs upward, outward, and backward toward the iliac fossa, passes in front of the sacro-iliac articulation and the lumbo-sacral nerve and external to the obturator nerve; having surmounted the outlet of the pelvis it passes behind the psoas muscle, the external iliac vessels and the anterior crural nerve, and emerges from behind them at the superior and internal part of the fossa, where it divides. As the artery emerges from the pelvis it gives off a branch which descends along the brim, gives small branches to the inside of the psoas, and finally anastomoses with a branch from the epigastric artery; while concealed by the psoas it gives branches to it and the iliacus internus. Finally it divides into two sets of branches, superior or ascending, and external or transverse; the former ascend beneath the psoas, supply it, the iliacus and the quadratus lumborum, send a branch into the vertebral canal through one of the inferior intervertebral foramina, and finally communicate with the inferior lumbar arteries. The external set pass outward into the iliac fossa, and are distinguished into two, a superficial and deep; the former run across the iliacus muscle, superficial to it and beneath the iliac fascia, supply the muscle and anastomose freely with corresponding branches from the circumflex branch of the external iliac artery: the superior of the superficial branches runs round the crest of the ilium within its inner edge, as it proceeds it gives branches downward to the iliacus and upward to the quadratus lumborum, the transversalis and oblique muscles, some of which turn over the crest and communicate with branches of the gluteal artery; finally it ends in a direct and free anastomosis with the ultimate branch of the circumflex artery, the fossa having thus an artificial circle formed around it internally, between these branches and the original iliacs. The branches of the deep set pass into the substance of the iliacus muscle, and between it and the bone, and are distributed to the muscle, the periosteum, and the bone, one of them entering the ilium through the canal to be observed at the bottom of the fossa; their deep branches also communicate with the circumflex iliac, the gluteal and the external circumflex femoral arteries. Sometimes there are two ilio-lumbar arteries.

2. The *lateral sacral artery* may be either single or double, and arises either from the posterior division of the iliac, from the iliac itself on its inner side, from the gluteal, or the sciatic, and frequently in common with the ilio-lumbar: it runs downward, and inward in front of the lateral part of the sacrum, the sacral nerves at their exit from the anterior sacral foramina, and the pyriform muscle external to the middle sacral artery and the sympathetic nerve; it descends to the extremity of the sacrum and then anastomoses with the middle sacral and the artery of the other side; at times instead of terminating thus it enters the sacral canal through the third or fourth foramen and is distributed internally. Its branches are distinguished into two sets, an anterior or internal and a posterior or external. The former are distributed to the sacral nerves within the pelvis, to the pyriform muscle, to the pelvic cellular tissue and glands, to the levator ani muscle and to the sacrum. The posterior are the larger, they are usually four, but at times more numerous, two branches sometimes taking the same course; they pass backward along the sacral nerves, through the sacral foramina, into the canal, and then divide into two, of which one is distributed within the canal to the nerves and their ganglia, to the membranes and the sacrum; the other escapes backward through the posterior sacral foramen, and is distributed upon the back of the sacrum in the sacro-vertebral channel, anastomosing with the adjoining vessels.

3. The *middle hemorrhoidal artery* is sometimes wanting, its place being supplied by branches from the other divisions of the iliac; it is of about the same size as the previous arteries, and varies very much in its source, arising from the anterior division of the iliac, from that vessel itself or from the pudic, the sciatic or lateral sacral arteries, it runs downward, forward, and inward along the side and front of the rectum, at first between the intestine and the levator ani, and then between it and the fundus of the bladder in man and the vagina in the female, and divides into branches, of which the greater part are distributed to the rectum, anastomosing with the branches of the superior hemorrhoidal from above and with those of the inferior hemorrhoidal from below; others are distributed to the fundus of the bladder, the prostate and vesiculæ in man, and to the vagina in the female.

4. The *vesical arteries* are subject to great variety; they are numerous and smaller than the last described: they are distinguished by Harrison into three sets, inferior, middle, and superior; the inferior set consists of those branches given to the fundus of the bladder by the middle hemorrhoidal, pudic, and sciatic arteries; the superior, furnished by the umbilical, are two or more in number, and are distributed to the superior region of the bladder, but the middle is a single vessel larger than the others, and given off by the iliac artery, though frequently arising from some of its branches, particularly the umbilical: it is entitled by Chaussier " vesico-prostatique:" it passes downward and inward to the fundus of the bladder, and then divides into branches distributed to the bladder, and in the male also to the prostate, the vesiculæ and neck of the bladder.

5. The *umbilical artery*. In the adult subject a small arterial canal usually from an inch and a half to two inches and a half long extends from the termination of the internal iliac, or from one of its branches to the superior lateral part of the bladder; there it is continued with, or seems to have attached to it superiorly the umbilical ligament, the artery appearing

rather to be continuous with the last branch arising from it. A variable number of branches arise from it; these are generally the superior vesical, at times the vaginal or the uterine; and according to their number and size its size varies; it is not destined to any part, but only gives rise to these branches, being in reality not a branch of the iliac but so much of the vessel, originally the umbilical or placental, as intervenes between the origin of the great branches and the point at which it becomes impervious, which remains open because of the origin of the vesical arteries, &c. from it, but is thus reduced in size because of their minuteness.

6. *The uterine artery* arises either from the anterior division of the iliac, or from the pudic, or at times from the umbilical; it runs forward, inward, and somewhat downward, until it reaches the superior lateral part of the vagina, and entering the broad peritoneal fold of the uterus it ascends in it along the lateral region of the uterus in a very tortuous manner, its tortuosity increasing as it proceeds. As it ascends, it gives off a considerable number of transverse branches, which attach themselves to both surfaces of the organ, penetrate its substance, and supply it with blood, anastomosing, at the same time, freely with those from the other side. When it has reached the attachment of the ligament of the ovary, the artery anastomoses with the spermatic artery. Before the artery attaches itself to the uterus, it gives a considerable branch to the vagina, which descends along it to a greater or less extent and is distributed to both its aspects. Branches also go from it to the Fallopian tube, the round ligament, and the ligament of the ovary, and likewise communicate with branches of the spermatic.

The uterine artery in the unimpregnated condition of the uterus is a small vessel, little, if at all, larger than the hemorrhoidal or vesical arteries, but during impregnation, and the more so in proportion as that state advances, it undergoes a remarkable change, becoming greatly enlarged, so much so as to equal or exceed in size any of the other branches of the internal iliac; and at the same time assuming a most tortuous arrangement as well in its branches as in its trunk.

7. *The vaginal artery* arises also, when present, from the anterior division of the iliac, or from the pudic, the uterine, the umbilical, or hemorrhoidal; it is therefore very irregular and often absent, its place being supplied by branches from others. It runs forward and downward along the side of the vagina, distributing branches to it, and also to the bladder and rectum. At the extremity of the vagina it terminates in the external genital organs, and communicates with the branches of the pudic artery.

The *external* branches of the internal iliac artery are four, viz.

1. The *obturator* or *thyroid artery*, (*artere sous-pubio-femorale*, Chauss.) is a vessel of considerable size, inferior only to the gluteal, pudic, and sciatic branches, and about equal to the epigastric artery, but irregular in that as well as in other respects. It arises most frequently from the posterior division of the internal iliac or from the iliac itself immediately before its division; it runs forward and somewhat downward along the lateral wall of the pelvis toward the superior posterior part of the subpubic or thyroid foramen, through which it escapes from the pelvis into the superior internal part of the thigh. The course of the vessel may be divided into three parts:—1st, that within the pelvis; 2d, that in the subpubic canal; 3d, that in the thigh. Within the pelvis the artery is nearly parallel to the brim of the pelvis, or ilio-pectineal line, and from one-half to three-fourths of an inch beneath it, it holds a similar relation to the external iliac vessels, which are above the line and from which it is distant from three-fourths of an inch to one and one-fourth. It is accompanied by the obturator vein and nerve, and is placed between them, the nerve being above and the vein beneath it. It is situate within the pelvic fascia; externally it rests against this fascia above the origin of the levator ani muscle, and separated by it from the internal obturator muscle; internally it corresponds in front to the side of the bladder to an extent proportioned to the degree to which that viscus may be distended, and is connected to it by cellular substance; posteriorly it corresponds to the peritoneum of the pelvis, the ureter, and at times to the anterior division of the iliac artery or some of its other branches. In this part of its course it gives off a branch which ascends to the iliacus and psoas, branches to the obturator internus, to the lymphatic glands of the pelvis and the bladder; lastly, as it approaches the subpubic foramen it gives an important branch, which ascends posterior to the pubis, distributes small branches as it proceeds, and ends in an anastomosis with a branch, which descends from the epigastric artery. Harrison has occasionally found a considerable branch given off in this situation, which passed to the side of the prostate and the perineum, supplying the place of deficient branches of the pudic artery.

In escaping from the pelvis the artery is contained in an oblique canal leading inward and forward. This canal, the subpubic, is bounded superiorly and externally by the pubis, which presents on the under surface of its horizontal ramus an oblique channel, by which the roof of the canal is formed; inferiorly and internally it is bounded by the margins of the obturator muscles and ligament; toward the pelvis it presents a defined aperture circumscribed above by the pubis and below by the pelvic fascia, the attachment of which to the bone is interrupted at the part at which the artery passes out, and which describing a curve beneath the vessels, between its points of attachment at either side contributes thus to form a rounded aperture through which they escape without perforating the fascia; a thin prolongation of the fascia is detached from it beneath the vessels into the canal. Hernia occasionally protrudes through this canal, and the artery has been found by Cooper behind the neck of the sac and rather to its inner side. While within the canal the artery gives outward a considerable branch—its posterior or external, or it might be with propriety called its thyroid branch—which runs downward and backward along the external margin of the *thyroid* foramen, between the two obturator muscles, giving them branches, and at times altogether consumed in them. Having reached the tuberosity of the ischium, it gives branches to the quadratus and adductor magnus muscles, to the upper attachments of the flexors of the leg, and to the ilio-femoral articulation, into which it sometimes sends through the cotyloid notch a branch more frequently supplied by the internal circumflex (femoral) artery; it also sends another round the thyroid foramen, which meets a similar branch from the obturator. It anastomoses with the internal circumflex and the sciatic arteries. At its entrance into the thigh, the obturator artery is situate above and before the obturator externus muscle, and behind the pectinalis, which with some of the fibres of the adductor longus must be divided in order to expose the vessel. It descends between the pectinalis, the long and short adductors, and is distributed to them, the adductor magnus, the gracilis, and the integuments upon the upper and inner part of the thigh. It gives also a branch, which runs round the margin of the thyroid foramen, and meets the branch already described from its thyroid branch. The artery anastomoses freely with the internal circumflex artery.

The obturator artery presents many varieties as to its source, of which some are deserving of particular attention. According to J. F. Meckel its ordinary source is the posterior division of the internal iliac, either immediately or by a trunk common to it and the ilio-lumbar, but at least once in ten times it arises from another source. The next most frequent is the internal iliac itself above and before its division; then the anterior division of the iliac; occasionally the external iliac, and sometimes the femoral, even so low as two inches from Poupart's ligament. The most frequent variety, and which according to the same authority is as common as the origin from the internal iliac itself, is that the artery arises from the epigastric, or from a trunk common to both. Sometimes it has a double origin, being formed by the union of two branches of equal size, one from the epigastric, and the other from the internal iliac, and at times it has a different source upon opposite sides. In every case the destination of the artery is the same; it runs to the inner aperture of the subpubic canal, in order to escape to the thigh, and in so doing it holds a very intimate relation to the internal femoral ring in those instances in which it proceeds either from the epigastric or from the femoral. When it arises from the epigastric, it runs obliquely downward, backward, and inward, above the crural arch, toward the superior aperture of the pelvis, then entering the pelvis posterior to the pubis it turns downward beneath it, and gains the subpubic foramen. During its descent into the pelvis the artery superiorly is covered by the peritoneum, and inferiorly corresponds to Poupart's ligament and the internal femoral ring, but the side of the ring, at which it may be placed, varies in different instances. When the common trunk from which the epigastric and obturator arise is short, the obturator lies close to the inside of the external iliac vein and then is situate on the outer side of the ring, while when the common trunk is long the artery is more remote from the vein, coasts along the base of Gimbernat's ligament, and thus runs obliquely across the front and inner side of the aperture. According to the case, therefore, will be the relation of the artery to the neck of femoral hernia; in the former it will be situate external and posterior to it, in the latter anterior and internal.

When hernia descends not only into the lymphatic compartment of the sheath, but, as has been observed by Burns, also into that belonging to the vein, thus forming a double protrusion, the artery may, if the common trunk be short, be situate external to the neck of the former and internal to that of the latter.

The comparative frequency of this mode of origin of the obturator artery has been differently estimated. According to Monro it occurs in one of twenty cases; Velpeau coincides in this opinion; Lawrence states it to be once in ten; J. F. Meckel considers it to be as frequent as that from the internal iliac; and according to the observations of Cloquet the proportion of instances in 250 subjects in which the artery was found to arise from the epigastric, whether on one or both sides, was one in three, and that of all the origins from the epigastric to all those from other sources was still greater, about 1.2½. A more important question is the proportion borne by those instances in which the obturator arising from the epigastric is situate on the inside of the neck of the hernia, to the total number of such cases, or to that of cases of femoral hernia requiring operation, for it is obviously with it that the operator is concerned. Cooper has not met the artery on the inside of the hernia, though in six of twenty-one cases he found the origin from the epigastric; and Lawrence states that the proportion of the former cases does not exceed one in eight or ten, and therefore that the obturator artery would be endangered only once in eighty or one hundred operations.

When the obturator arises from the femoral artery, which Cloquet found in six of 250 subjects, it ascends into the abdomen beneath the crural arch, along the pectinalis muscle and internal to the femoral vein, and in femoral hernia is found behind the sac.

We are indebted to J. F. Meckel for solving the apparent irregularity of these origins of the obturator, and reducing them to a mere variation of the normal condition; the obturator, as has been stated, is normally connected with the epigastric by an anastomotic branch, and hence may be considered as having two origins, an anterior and a posterior, a disposition the reality of which is more manifest at the earlier periods of life, and according as the one or the other may be deficient or more developed, the obturator will be derived principally or altogether from the internal iliac or from the epigastric; when both are equally so it will present the double origin.

2. *The glutæal artery*, denominated also *posterior iliac*, is the largest branch of the internal iliac, and arises from, or is the continuation of the posterior division of that vessel; it runs downward, backward, and outward, until it reaches the superior part of the great sciatic notch; it then changes the direction of its course, and making a turn passes directly outward between the lumbo-sacral and the anterior branch of the first sacral nerves, and escapes from the pelvis through the upper part of the notch above the pyriformis muscle, and accompanied by the superior gluteal nerve. As soon as the artery has escaped from within the pelvis and gained its external aspect, it divides into branches. The trunk of this artery, as it is the largest, so is it the shortest of the branches of the iliac; within the pelvis it corresponds externally to the lumbo-sacral nerve, internally to the rectum, and inferiorly to the first sacral nerve and the pyriformis; it gives small branches to the rectum, the pyriformis, and the surrounding cellular structure; at times it also gives off the ilio-lumbar, the lateral sacral, or the obturator.

At its exit posteriorly from the pelvis it is situate between the adjoining margins of the pyriformis and the gluteus minimus, and it is covered by the gluteus maximus.

The branches into which it divides after its escape are two, a superficial and deep one. The first passes outward and upward between the glutei maximus and medius, and divides into numerous branches, which are distributed to these muscles, particularly to the maximus; many of them descend in its substance toward its insertion, and there meet branches of the circumflex (femoral) and sciatic arteries; others pass through the muscle, become superficial, and supply the integument and subcutaneous fat; others again pass onward, traverse the attachment of the gluteus maximus to the sacrum, and are distributed to the muscles and integuments of the posterior sacral region.

The second, the deep branch, passes outward, upward, and forward, between the glutei medius and minimus muscles toward the superior anterior spinous process of the ilium in an arched course around the attachment of the gluteus minimus. As it proceeds it gives off numerous branches upward from its convexity and downward from its concavity; the former are distributed to the gluteus medius; the latter are chiefly two, of which one runs forward and downward toward the anterior part of the great trochanter between the two muscles, gives branches to both, and finally throws itself into the gluteus medius near the trochanter, and is consumed in it: it communicates freely with the external circumflex artery. The other runs downward and forward toward the back of the trochanter, lies for some way upon the gluteus minimus, or over the interval between it and the pyriformis, gives branches to both muscles, and then gains the surface of the os innominatum by traversing the gluteus or by passing between it and the pyriformis, pursues its course upon the bone, to which it gives an artery, above the ilio-femoral articulation, to the capsule of which it also gives branches, and approaching the anterior inferior spinous process of the ilium it terminates in supplying the gluteus minimus, and anastomosing with the external circumflex artery.

The deep division of the gluteal artery having run round the line of attachment of the gluteus minimus, and reached the superior anterior spinous process, terminates in an anastomosis with the circumflex iliac, the ilio-lumbar, and the external circumflex arteries; branches also turn over the crest of the ilium, and so communicate with the iliolumbar. The deep division, also, furnishes a nutritious artery to the ilium, the canal for which is to be seen on the dorsum of the bone. The branches of the gluteal artery are numerous and large; in order to expose them the gluteus maximus having been dissected clean may be detached from the femur and raised toward the sacrum, when the branches may be displayed running in every direction as from an axis.

The situation of the gluteal artery external to the pelvis permits the trunk of the vessel to be secured; the gluteus maximus being the only muscle by which it is covered, it may be exposed by the division of that muscle; the situation of the artery may be first determined "by drawing a line from the posterior spinous process of the ilium to the midspace between the tuberosity of the ischium and the great trochanter; if we divide this line into three, we shall find the gluteal artery emerging from the pelvis at the juncture of its upper and middle thirds."* The ligature of this artery in case of aneurism has been very much superseded in favour of that of the internal or even of the primitive iliac, the latter of which has been tied by Guthrie for aneurism of the gluteal artery; the propriety of this proceeding, however, may be questioned; the ligature of either the internal or the primitive iliac must be regarded a more serious operation than that of the gluteal, and the latter has proved so efficacious in the many instances in which it has been had recourse to, that, while it is practicable, the other can be hardly justifiable.

3. *The ischiatic artery* arises from the anterior division of the internal iliac, which, after having given off its internal branches, divides into two, of which the posterior and larger is the ischiatic; it is the second in size of the branches of the iliac, being smaller than the gluteal; but in the adult it appears, for the most part, in direction the continuation of the original vessel; its course within the pelvis is long; it descends, at the same time inclining forward, and forming a curve convex backward, toward the inferior part of the great sciatic notch, and escapes through it from the pelvis, superior to the sacro-sciatic ligaments and inferior to the pyriformis muscle; it then descends

* Harrison.

behind the ischium between its tuberosity and the great trochanter of the femur, and gives off as it descends numerous branches distributed in the superior posterior region of the thigh. Within the pelvis the artery is situate internal to the sacral nerves and the pyriformis muscle, external to the rectum and the peritoneum, in front of the sacrum, the nerves and the attachments of the pyriformis, and posterior and external to the pudic artery; in escaping from the cavity it passes between the pyriformis and ischio-coccygeus muscles, and is accompanied by the pudic artery, to which it holds the same relation as before, but is closer to it, and by the sciatic nerve; within the pelvis it is internal and anterior to the sacral plexus, but as it goes out it passes between its branches, and thus becomes posterior to the nerve.

Without the pelvis the ischiatic artery corresponds in front to the spinous process of the ischium, the gemelli, with the obturator internus muscles, and the quadratus; posteriorly, it is covered by the gluteus maximus and the integuments; it is situate at first behind the sciatic nerve, but as it descends it becomes internal to the nerve, the distance between them increasing at the same time. While behind the spinous process of the ischium the ischiatic artery is external to the pudic artery, and more superficial, i.e. still posterior; but as the pudic passes to the inside of the tuberosity of the bone, while the ischiatic runs on its outside, the two vessels immediately separate and cease to be related.

Within the pelvis the ischiatic artery gives some irregular and small branches to the rectum, the bladder, the uterus, the vagina, the cellular tissue, the pyriformis and levator muscles; at times it is considered as giving off also the pudic, the hemorrhoidal, or obturator arteries. The branches which it furnishes external to the pelvis are numerous; among them are distinguished the following:—1. The *coccygean* branch, of considerable size, runs downward and inward toward the coccyx, across the pudic artery and posterior to it, passes through the great sacro-sciatic ligament, and divides into branches, which are distributed to the ligament, to the gluteus, the coccygeus, and levator ani muscles, to the posterior aspect of the sacrum and coccyx, and to the fat and integument; its branches communicate with those of the pudic. 2. A considerable branch or set of branches, which run outward and downward toward the back of the great trochanter upon the internal obturator, gemelli, and quadratus muscles, supply them with branches, and anastomose with the circumflex (femoral) arteries. 3. A branch or branches to the inferior part of the gluteus maximus, prolonged through it to its insertion, and then meeting the circumflex and perforating arteries. 4. A branch or branches, which attach themselves to the sciatic nerve, naturally of small size, but regular, and remarkable for the extraordinary change they undergo after the interruption of the main artery of the thigh; they arise about the tuberosity of the ischium, and descend along the nerve giving it branches, and communicating with branches from the perforating arteries, which also attach themselves to the nerve, whereby a chain of anastomoses is established along it, which, when the main channel has been interrupted, becomes amazingly enlarged and forms, as it were, one remarkably tortuous vessel along the entire length of the nerve. 5. A very considerable branch, the termination of the artery, distributed to the upper extremity of the flexors of the leg, the biceps, &c. and of the adductor muscles; the ramifications of which communicate with the perforating and internal circumflex arteries.

The ischiatic artery is circumstanced external to the pelvis so similarly to the gluteal, that, if necessary, it might be exposed during life by a similar operation; for a method of determining its situation prior to operation, the reader is referred to the description of the pudic artery.

4. The *internal pudic artery* arises from the anterior division of the internal iliac, which for the most part, after having given off its other branches, divides into the ischiatic and the pudic; the height at which the division takes place is uncertain; at times it does not occur until the trunk has descended to the sciatic notch, or even escaped from the pelvis. The pudic artery is smaller than the sciatic; it passes downward, forward, and inward, until it reaches the inferior part of the great sciatic notch, through which it escapes from within the pelvis in company with the ischiatic artery, the pudic, and sciatic nerves; having escaped from the pelvis it crosses the extremity of the spinous process of the ischium and the attachment of the anterior sacro-sciatic ligament, and returns into the cavity through the anterior notch, accompanied by the pudic nerve; having re-entered the pelvis, it then runs forward, inward, and downward internal to the tuberosity of the ischium, until it reaches its anterior extremity, whence it continues its course upward along the inside of the rami of the ischium and pubis toward the arch of the pubis, and beneath the latter finally divides; the course of the artery, therefore, forms a considerable curve convex downward and backward, during which the vessel is contained within the pelvis at its commencement and its termination, and is without the cavity during the intermediate part. Its course is thence divided into three stages, during two of which it is within, and in the third without the cavity.

The first stage of the artery's course, throughout which it is contained in the pelvis, extends from its origin to the lower part of the posterior sacro-sciatic notch, through which it escapes from the cavity; it is of variable length, in consequence of the variable height at which the vessel arises. The relations of the artery during this stage are posteriorly and externally the sacral nerves, the pyriform muscle, and the sacrum; internally the peritoneum and the rectum; it is posterior and external to the fundus of the bladder and the vesiculæ seminales, and anterior and internal to the ischiatic artery; previous to its exit it sometimes passes between the sacral nerves before forming the plexus. It goes out from the pelvis below the pyriformis and above the spinous process of the ischium and the anterior sacro-sciatic ligament, passing between the pyriformis and the ischio-coccygeus muscles, and having the ischiatic artery and sciatic nerve both external and posterior to it. Its second stage is situate without the pelvis; it is usually its shortest one, lasting only while the artery is crossing the extremity of the spinous process of the ischium, and not exceeding an inch in length; it is here situate behind and above the spinous process and the anterior or lesser sciatic ligament; it is covered posteriorly by the superior edge of the posterior ligament and by the gluteus maximus muscle; it is internal to both the ischiatic artery and sciatic nerve, and it is crossed posteriorly by the coccygean branch of the former.

The third stage of the artery is its longest and most important one; during it the vessel is situate within the skeleton of the pelvis, though not within the pelvis, in the ordinary sense of the phrase, i. e. within its visceral cavity, being excluded therefrom by the structures which form its floor; it lies along the inside of the tuberosity of the ischium and the rami of the ischium and pubis, and its course and relations being different at the posterior and anterior parts of the stage, they may with advantage be considered separately. In the posterior part, or as far forward as the anterior extremity of the tuberosity or the base of the triangular ligament of the perinæum, the artery descends; in the anterior it ascends; in the posterior it is situate in the outer wall of the space which intervenes between the inside of the tuberosity of the ischium and the rectum—the ischio-rectal space. This space is cuneiform, its base below, toward the surface; its apex above, toward the pelvis; its inner wall is formed by the levator ani and the dense thin expansion by which the muscle is covered externally or inferiorly, its outer by the obturator fascia attached inferiorly to the edge of the great sacro-sciatic ligament and of its falciform process, and by the obturator muscle: the space is occupied by a mass of adipose cellular structure, traversed by some branches of the pudic vessels and nerves. In a canal in the obturator fascia the artery is contained through the posterior part of the third stage; by some it is maintained to be between the fascia and the muscle, in a sort of canal formed internally by the fascia, externally by the muscle and tuberosity, and inferiorly by the great sciatic ligament; but this is not correct; the vessel being in the fascia, and not external to it; the line of its course is convex downward, about an inch and a half from the under surface of the tuberosity of the ischium at its most depending part, and from two to two and a half inches from the surface, this distance varying of course according to the condition of the subject; the line approaches the margin of the ramus or the spinous process, thence forward or backward. In the anterior part of the stage the vessel is enclosed in the triangular ligament along its attachment to the bone; consequently, it is separated from the surface by the superficial stratum of this structure first, in the second place by the crus penis, covered by the ischio-cavernous muscle, and behind it by the transversus perinei muscle; and lastly, by the superficial structures of the perineum. As the artery proceeds it becomes more superficial, and finally emerges from the triangular ligament, beneath the subpubic ligament, as the dorsal artery of the penis.

It is in its third stage that the pudic artery is exposed to danger in the lateral operation of lithotomy; it may be wounded in either of the two steps of dividing the urethra and prostate or the subsequent division of the superficial structures: in the former case, the danger of the accident will be greatest when the section is effected with the scalpel or gorget, and in proportion to the width of the blade, and the degree to which the cutting edge may be directed outward, will the danger be enhanced; in the second, the risk will be alike with all cutting instruments, and will be determined by the width of the blade, the attention paid to a proper degree of lateralization, the manner in which the instrument is made to effect a division of the parts, and the extent of the section. The branches of the pudic artery are numerous, and may be conveniently arranged according to the stage of its course, in which they are given off. In its first, before its exit from the pelvis, it gives branches to the bladder, the rectum, the vesiculæ, prostate, vagina, and uterus; it also frequently furnishes the middle hemorrhoidal.

In its second stage, while external to the pelvis, it gives branches to the gluteus, the pyriformis, the obturator and gemelli muscles, the sacro-sciatic ligament, the ischium, and sacrum; they anastomose with the ischiatic, the gluteal, and internal circumflex arteries.

Those which arise in its third stage are the most important. 1. The artery gives, while on the inside of the tuberosity of the ischium, branches which are distinguished into external and internal; the former are small, and go to the adipose structure beneath the tuberosity, to the attachment of the biceps, to the obturator internus, and the integuments: the internal are larger; they come through the obturator fascia, run inward toward the anus, and are distributed to the adipose cellular structure of the ischio-rectal space, to the levator and sphincter ani, to the extremity of the rectum, and the margin of the anus; they anastomose with branches of the middle hemorrhoidal artery and with those of the other side: they are variable in number, being one, two, or three, and are denominated "external hemorrhoidal;" they are liable to be divided in operations in the vicinity of the anus, e. g. in the superficial incision in the lateral operation or in operation for fistula; they are, however, so small that they seldom give trouble, either ceasing to bleed spontaneously, or being commanded by brief compression.

2. *The perineal artery.*—At a short distance from the base of the triangular ligament the pudic gives off a branch of considerable size and length, by many regarded as one of its ultimate branches; the pudic, according to them, terminating by dividing into two branches, an inferior, "the perineal," and a superior.

The perineal artery comes through the obturator fascia, and descends to the perineum, posterior to the transverse muscle, though at times before it; when it has got below the muscle it changes its direction, and runs forward, upward, and inward, superficial to the triangular ligament, toward the root of the scrotum; at this part of its course it is situate along the outer side of the interval which separates the crus penis and the corpus spongiosum urethræ, internal and parallel to the crus, and covered by a superficial lamina of the fascia of the perineum, a deeper layer of which intervenes between it and the muscles of the crus and bulb and the triangular ligament; as it proceeds it gives the following branches: 1. outward, one to the integument and subcutaneous structure beneath the anterior part of the tuberosity of the ischium; 2. inward, one which runs to the interval between the front of the rectum and the bulb of the corpus spongiosum, superficial and parallel to the transverse muscle; it supplies the integument and subcutaneous structure of the perineum, and the common insertion of the superficial sphincter, the transverse muscle, the bulbo-cavernous and the levator ani in front of the rectum. This branch is at times furnished by the pudic itself; it is denominated by some "the proper perineal," by others "the transverse perineal." 3. A branch to the bulbo-cavernous; 4. one to the ischio-cavernous muscles.

The perineal artery having reached the back of the scrotum sends long branches into the subcutaneous structure and integument of that part, and entering the septum scroti, terminates in it as the "artery of the septum." In the female, the ultimate branches of the artery are distributed to the labia majora.

The perineal artery, from its superficial situation, is exposed to be divided on many occasions; in lateral lithotomy it may be cut, but for the most part it escapes, its course being external to the line of incision; some of its branches, however, cannot escape, the transverse perineal particularly must, as a matter of course, be divided. Having given off the perineal artery, the pudic pursues its course, enclosed in the triangular ligament, along the rami of the ischium and pubis, toward the arch of the pubis; arrived under cover of the crus penis, it gives off a considerable branch, destined principally for the urethra and the corpus spongiosum, and denominated hence by Chaussier "urethro-bulbaire," by Harrison "arteria corporis bulbosi vel spongiosi urethræ," but by Boyer and Cloquet "artère transverse;" it is short, runs transversely inward, enclosed in the triangular ligament about a quarter of an inch from its base, but nearer to it externally than internally; at the bulb it divides into two parts, of which one, the smaller, is distributed to the ante-prostatic gland; the other enters the bulb and ramifies through its vascular structure, being prolonged through it as far as the glans, supplying at the same time the membrane of the urethra and its lacunæ; a branch from it passes into the corpus cavernosum, and anastomoses with the artery of that structure. In the female, the branch corresponding to this is distributed to the vascular plexus which surrounds the orifice of the vagina.

The artery of the bulb is one of much practical importance; it is liable to be wounded in lithotomy in the act of opening the urethra; this accident is incurred when the canal is opened too high, i. e. too near to the arch of the pubis, or too much from the side rather than from beneath, and in either case is pretty certain to occur; the proceeding by which to avoid both the artery and the bulb itself, is to cut into the urethra as far back, i. e. from the surface, and as far from the arch as the guidance of the staff will assure the operator to be safe, the point of the knife being directed as much from below as the interference of the bulb and the lateral line of incision will permit; further, it is the design of the operator to open the canal in the membranous portion and behind the bulb; and in order to effect this, the incision should be made as near as may be to the base of the triangular ligament, or, if possible, behind it. If divided, the artery of the bulb may be tied, though not without some difficulty; it is prevented from retracting by being enclosed in the triangular ligament, but it is situate deep; its distance from the anterior surface of the ramus of the pubis being about three-fourths of an inch; its shortness as well as its being concealed by the crus penis and by the bulb with their muscles, and being in the superior angle of the wound, must also increase the difficulty of securing it.

The pudic artery having reached the base of the subpubic ligament divides into its two final branches, the artery of the corpus cavernosum and the dorsal artery of the penis.

3. *The artery of the corpus cavernosum* arises from the pudic between the crus penis and the ramus of the pubis and immediately enters the crus obliquely; it is prolonged through the vascular tissue of the corpus cavernosum to its extremity, distributing branches to either side, and communicating with that of the other. For the peculiar distribution of the arteries of the corpus cavernosum and spongiosum, according to Müller, see the article Erectile Tissue.

4. *The dorsal artery of the penis*, which appears in direction the continuation of the original vessel, comes through the triangular ligament and ascends in front of the subpubic ligament through the angle formed by the crura penis at their junction; having surmounted the crus it attaches itself to the dorsal aspect of the penis and runs forward upon it on either side of the suspensory ligament parallel to the artery of the other side, and contained together with it, the dorsal vein, and nerves, in the groove formed by the apposition of the crura, internal to the nerve and external to the vein; it is prolonged to the anterior extremity of the corpus cavernosum, where it breaks up into branches, which uniting with those of the other form an arterial zone behind the corona glandis, and sinking into the glans are distributed to its tissue.

During their course along the dorsum of the penis the arteries are tortuous, communicate frequently, are covered not only by the skin and subcutaneous cellular structure, but also by a dense filamentary expansion, or fascia, which invests the penis beneath them, and they give branches to those structures as also to the fibrous membrane of the corpus cavernosum, and finally to the prepuce. The dorsal artery is at times furnished by the obturator, or the external pudic artery.

Beside the varieties of origin which have been mentioned, the pudic presents some important varieties in its course. It has been found by Burns in four instances, "instead of passing out of the pelvis between the sacro-sciatic ligaments to attach itself to the lateral and inferior part of the bladder, and to traverse the upper segment of the prostate gland in its course to the ramus of the ischium." Another variety is described by Harrison, in which the proper trunk of the pudic is found unusually small, and the dorsal artery of the penis arises originally and separately from the internal iliac, runs along the side of the bladder and prostate gland, and escapes from the pelvis along with the dorsal vein of the penis beneath the arch of the pubis. The latter disposition, *mutatis mutandis*, has been found by Tiedemann in the female as well as in the male, and is figured in his thirtieth plate. It is described by Winslow as the normal arrangement, only that according to him the vessel, which takes this unusual course, arises sometimes from the common pudic, at others from the iliac. Haller questions the occurrence of this disposition, but describes another, in which the inferior vesical artery arising from the middle hemorrhoidal is continued on the dorsum of the prostate into the dorsal artery of the penis, given, as in ordinary, from the pudic.

Among the varieties of the arterial system few possess greater interest than these, inasmuch as no foresight or skill can guard against the untoward accidents which attend their presence in lithotomy; their possibility forbids a section of the prostate upward; but fortunately they are rare.

The situation of the pudic artery upon the exterior of the pelvis admits the possibility of tying the vessel in the living subject; the plan of operation necessary for the purpose is similar to that to be adopted with the gluteal artery, only it must be performed lower down; it is the same with that for the ischiatic artery; for determining the situation of which or the pudic the following directions are given by Harrison:*—"Place the individual on his face with the lower extremity extended and the toes turned inwards: feel for the summit of the great trochanter, and for the base or articulated end of the coccyx; these two points are on a level; then draw a line from one to the other, and we may be certain that the pudic artery and the spine of the ischium are opposite the junction of the middle and internal thirds of this line." The ischiatic artery may be reached as easily, or even more so, than the gluteal; but the difficulty which must attend the seeking for the pudic must be extreme.

* Vol. ii. p. 103.

THE EXTERNAL ILIAC ARTERY, (*arteria iliaca externa*, Lat.; *artère iliaque externe*, Fr.; *portion iliaque de la crurale*, Chauss.; *Aussere Hüft-pulsader*, Ger.) is the vessel destined for the supply of the lower extremity, of which the portion contained within the abdomen, in the iliac region, is denominated the "external" iliac, in contradistinction to the artery of the pelvis, the "internal."

It commences at the division of the primitive iliac artery, at a point intermediate to the body of the last lumbar vertebra, or the sacro-vertebral prominence, and the sacro-iliac articulation, and it terminates at the crural arch, at a point midway between the superior anterior spinous process of the ilium and the spinous process of the pubis,* or at the outer side of the ilio-pectineal eminence of the os innominatum. The point at which the vessel commences is not uniform either in all subjects or on the two sides of the same; depending upon the point at which the primitive iliac divides, which is variable, it will be higher or lower, nearer to the vertebra or to the articulation, according to the situation of the bifurcation of that vessel: on the right side of the body the artery commences for the most part nearer to the body of the vertebra than on the left, on which it is of course nearer to the articulation; hence the artery arising higher upon the former is longer upon that side than upon the latter, the difference in length varying from a quarter to half an inch. The external iliac terminates in the femoral or crural artery, strictly so called; but the distinction between the two is one only of convenience, inasmuch as they are but different stages of the same vessel; there appears therefore much propriety in the

* The situation of the artery at its termination is differently stated by different writers; Boyer states it to be midway between the spinous process of the ilium and the symphysis pubis; Cloquet, midway between the spine of the ilium and the spinous process of the pubis; Harrison, about half an inch to the pubic side of the centre of the crural arch. The relation of the vessel to the points between which it is placed, is probably not the same in all cases; but that assigned to it by Cloquet seems most generally applicable. According to Cooper, with whom Cloquet concurs, there are, in the male, 3¼ inches from the symphysis pubis to the middle of the artery, and in the female 3¾, while the distance to the superior anterior spinous process of the ilium is in the former 5¾, and in the latter six inches; the artery must therefore be external to the mid-point, being for the most part concave forward and inward above, and convex forward below; but in this particular it is not uniform, being sometimes nearly straight; the degree of its tortuosity also appears to depend upon the age of the subject and the plenitude of the vessel. The direction of the artery is oblique, and as the primitive iliac and it are continuous in the adult, the course of both the vessels may be defined, during life, by a line extending from the umbilicus, or from half an inch below it, at its left side, to a point midway between the superior anterior spinous process of the ilium and the spinous process of the pubis, the upper extremity of the line varying according to the situation at which the aorta divides.

designation adopted by Chaussier, which, while it recognises the identity of the vessel throughout its course, sufficiently marks the grounds of distinction between its two portions. The external is somewhat smaller than the primitive iliac, but in the adult considerably larger than the internal; its direction is downward, outward, and forward, and hence it forms with the primitive iliac a curve convex backward, and seems the continuation of that vessel; its length is from three to four inches, and during its course it forms one or more curvatures.

Such is the disposition of the vessel in the adult; but in the younger subject it is different in some respects; in the fœtus the external iliac is considerably smaller than the internal, and does not seem the continuation of the primitive iliac, which at that epoch is continued into the internal; the external appearing rather as a branch or a smaller division from a trunk common to the other two: after birth the relative disposition of the iliacs gradually changes, until they acquire that of the adult.

The relations of the external iliac artery are as follows: posteriorly, it corresponds through the upper half of its course to the lateral part of the superior aperture of the pelvis; inclining outwards as it descends, it corresponds in its lower half to the os innominatum, and the more perfectly, the nearer it approaches the crural arch, at which part it is placed in front of the bone, crossing it nearly at right angles, and separated from it by an interval occupied by the psoo-iliac aponeurosis and the psoas muscle.

At its outset the external iliac vein is directly behind the artery, and on its right side, also the commencement of the primitive iliac vein, the artery crossing the junction of the two vessels, on that side, obliquely in its descent; during the remainder of its course, the vein, though posterior to it, is also internal; throughout the lower half of its course it lies upon the psoo-iliac aponeurosis, supported by the os innominatum, and at first separated from the bone only by the aponeurosis; but as it proceeds separated from it also by the tendon of the psoas parvus when present, and by the inner margin of the psoas magnus, it is very near to the os innominatum, external to the ilio-pectineal eminence, and being here supported by bone, and made steady by its connections it may with certainty be compressed and its circulation perfectly commanded. Internally, the artery corresponds above to the aperture of the pelvis, to its viscera more or less intimately, according to their state of distension or contraction, and also to the small intestines which descend into it; in the lower half of its course, the external iliac vein, which at its outset is behind or beneath the artery, is internal, though still somewhat posterior to it; at the crural arch the artery and vein are nearly upon the same level, being supported by the os innominatum; the artery however somewhat anterior to the vein, but as the vein recedes from the arch it inclines less inward than the artery, and at the same time retreats more from the surface; and hence it gradually gets more completely behind the artery until at its junction with the primitive vein it is concealed by it anteriorly.

The artery is covered by peritoneum, upon its inner side through a considerable part of its course; above the membrane covers it completely; but as it descends the extent becomes less in consequence of the ascent of the vein; which thus gradually intervenes between the artery and the membrane, and removes the latter from it altogether in the lower part of its course. When the primitive iliac divides at a high point, the ureter descends into the pelvis internal to the external iliac immediately after its origin; this occurs more frequently upon the right side than the left. Beneath the peritoneum the artery is covered by an investment, of which presently again, attaching it superiorly to the peritoneum and inferiorly to the vein.

Externally the artery corresponds through its entire course to the psoas magnus muscle, but it is separated from it by the psoo-iliac fascia, to which it is connected by its immediate investment; the relation of the artery and the muscle are, however, somewhat different at the upper and lower parts of the vessel's course; above, the artery does not lie upon the muscle, but rests against its inner side along its anterior part, while inferiorly it lies upon the inner margin of the muscle at the same time that it rests against it externally.

The genito-crural nerve is situate along the outer side of the artery; this nerve, long and slender, a branch of the lumbar plexus, descends upon the psoas, extenal to the artery, and at first at a little distance from it; as it proceeds, it approaches the vessel, and lies close to it enveloped in the fascia propria; at the lower part of its course its genital branch frequently passes in front of the artery. The anterior crural vein is also external to the artery; but it is considerably posterior to it, separated from it by the outer margin of the psoas, between which and the iliacus it lies, and also by the fascia iliaca, which covers it; the nerve is about half an inch from the artery at the crural arch; as it recedes from the arch the distance increases.

In front, the artery is covered immediately by a cellular investment, formed by the sub-peritoneal cellular structure—the fascia propria—upon the posterior wall of the iliac fossa; this encloses both the artery and the vein and at the same time connects them; it varies in its condition according to the subject, in some it appears a dense, but still cellular expansion, in others from the deposition of fat it forms an adipose stratum, which however still presents a more condensed character in immediate contact with the vessels; it adheres closely to the surface of the fascia iliaca upon either side of the vessels and thus attaches them to it; it is prolonged upward upon the primitive iliac vessels, and below, it ascends between the peritoneum and the fascia transversalis upon the anterior abdominal wall; upon the primitive iliac it is very thin and proportionally weak; but as it descends it increases in thickness and strength until at the lower part of the external iliac. It forms a stratum of some thickness and considerable resistance, deserving of much attention in a practical point of view; there are imbedded in it immediately above the crural arch, and superficial to the artery, one or more lymphatic glands; the genito-crural nerve also descends enclosed in this structure, at the outside of the artery. Beneath the investment, and immediately above the crural arch, an expansion of limited extent, presenting frequently a true fibrous or aponeurotic character, arises from the front of the vessels, and passing forward becomes identified with the fascia transversalis upon its internal surface; thus connecting the vessels to the anterior part of the superior aperture of the femoral sheath, and closing the interval between these parts, which otherwise would be unguarded.

In the second place the artery is covered anteriorly through about four-fifths of its course by the peritoneum of the iliac fossa; in the inferior fifth, i. e., for from half to three-fourths of an inch immediately above the crural arch, the membrane passing from the front of the artery to the anterior wall of the abdomen leaves the iliac artery uncovered; and hence the practical inference that the external iliac artery may be tied without disturbing the peritoneum.

Beneath the peritoneum the artery is crossed at the inferior part of its course by the spermatic vessels, and at the superior, upon the right side very frequently by the ureter.

Thirdly, the viscera of the iliac fossa on the one hand, or of the pelvis on the other, according to circumstances, cross or overlap it; on the right, the cœcum and the termination of the ileum; on the left, the sigmoid flexure and the commencement of the rectum, and on both sides the small intestines are placed in front of it. And when the viscera of the pelvis become distended and rise from the cavity they overlap it from that side.

The third relation of the artery in front is the anterior wall of the iliac region; the details of this it is not proposed to examine at length, but only so far as they may be concerned in the relations of the artery; the structures composing the wall being numerous, they may be conveniently arranged into three sets, viz., the superficial, the intermediate, and the deep or lining structures.

The superficial structures are three, the skin, the subcutaneous cellular tissue, and the fascia. Of these the first does not require to be dwelt upon; the second is subject to much variety in its condition; it forms a stratum of considerable thickness in every case; when, however, the superficial cellular structure of the body is charged with much adeps, it then forms an uniform and thick stratum of fat without any distinction into laminæ; this is best exemplified at the early periods of life, particularly in children cut off by an acute disease; when, on the contrary, the body is emaciated, it forms a condensed cellular expansion much thinner than in the former case, and divisible frequently into laminæ. This structure is continued from the iliac over the other regions of the abdomen, downward upon the thigh, and in the middle line upon the spermatic process of the male and the organs of generation. Numerous superficial vessels are contained in and ramify through it; these are derived from several sources, but that which is proper to the iliac region is the superficial epigastric artery which ascends from the femoral superficial to the aponeurosis of the external oblique muscle and intermediate to the inguinal rings.

Beneath the subcutaneous stratum is the third superficial structure, the fascia; this is a thin dense expansion by which the external oblique muscle and its aponeurosis are covered; it is not confined to the abdomen, but is continued into a similar expansion upon the adjoining regions whether upward or downward; it adheres closely to the muscular portion of the oblique, particularly at the junction of the muscular fibres with the aponeurosis along the linea semilunaris, but its connection to the aponeurosis itself is more free, an extensible and delicate cellular tissue being interposed. Hence it is easily detached from the latter; it is most dense, fibrous, and strong upon the iliac region; as it ascends thence it becomes less dense and fibrous, and assumes more of a simply condensed cellular character; it is not equally distinct in every subject, in all it can be recognized at the crural arch, and for some distance above it, but as it recedes from the arch it frequently seems to be gradually resolved and to cease. Below, it is attached posteriorly to the outer edge of the crest of the ilium, and along this line it meets the insertion of the fascia lata of the back of the thigh; in front between the superior anterior spinous process of the ilium and the spinous process of the pubis it descends over the crural arch, having only a cellular connection to it, and being separable with ease from it, as well as from the aponeurosis of the oblique; immediately below the arch it is united to the superficial surface of the fascia of the thigh, both externally and internally, on the latter side passing back to the pectineal line of the pubis, into which it is inserted along with the pubic portion of the fascia lata; in the interval between the spinous processes of the pubis it is prolonged downward upon the spermatic processes, and is continued upon them in the form of a sheath into the scrotum, where it invests the testicle; it is very thin and transparent upon the spermatic process. The existence of this structure, to which attention appears to have been first directed by Camper, can always be demonstrated however fat or young the subject may be, though, as has been stated, it is not always equally manifest; it seems distinct from the subcutaneous cellular structure, which frequently forms a uniform and thick stratum of fat between it and the skin. Different views have been taken of its nature; by Scarpa it is regarded as a prolongation of the fascia lata of the thigh, while others and the majority consider it as a continuation of the superficial fascia, so called, of the same part, and formed by the deep stratum of the abdominal subcutaneous cellular structure converted by condensation or removal of its adeps into an expansion; to me it appears that the view taken of its nature by Scarpa is correct, not in the sense that it is a prolongation of the fascia lata, but that it is of the same nature, and that it is to the abdomen the same structure which the fascia lata is to the thigh; it is a question entitled to consideration only for accuracy's sake, but I have frequently verified the inferior connections of this expansion such as they have been detailed, and further it appears to me that it is not properly continuous with the superficial fascia of the thigh, for if it be detached from the aponeurosis of the oblique muscle and the crural arch without injury to its connection with the fascia lata, and be then held perpendicular to the latter, the superficial fascia of the thigh may be removed from the angle which it will thus form with the fascia lata, and its connection still remain perfect: a favourable subject and a careful dissection will certainly be required for the purpose, but this circumstance will not invalidate the conclusion; it is also to be recollected in making the dissection, that the fascia detaches processes over the inguinal lymphatic glands.

The structures of the second order of parts concerned with our subject, are the aponeurosis of the external oblique muscle, the internal oblique and the transversalis muscles; of these the first, which is immediately beneath the fascia, extends over the entire anterior wall of the fossa reaching from the linea semilunaris above to the crural arch below; internally it is united with that of the other side in the linea alba, and inferiorly it forms the crural arch by its border, which is attached externally to the superior anterior spinous process of the ilium, internally to the spinous process of the pubis, and in the interior to the iliac fascia and the fascia lata. The direction of this band is to be borne in mind, for it does not run directly from one of these points of bone to the other; but it descends toward the thigh, and recedes from the surface at the same time that it passes inward, hence it is concave both forward toward the surface and upward toward the abdomen; the cause of this direction is its connection inferiorly and posteriorly with the fascia lata and the fascia iliaca. The aponeurosis consists primarily of tendinous fibres which run in the same direction as the fibres of the muscle, i. e., downward and inward, parallel to each other, and also to the crural arch, though rather converging toward it internally, and thereby form a tendinous expansion; the longitudinal fibres of the aponeurosis are crossed by others which run downward and outward; these are very irregular in number and do not interlace with the former, to which they are superficial; hence the aponeurosis does not possess great strength in the transverse direction, and its longitudinal fibres are liable to be separated, and deficiencies to be thereby formed in the aponeurosis, which are not unfrequently to be observed. The superficial inguinal ring is seated in the aponeurosis; this aperture, for the particulars of which see the articles ABDOMEN and HERNIA, is of variable form and size; in some cases it is elliptical, in others triangular; in the male it is larger than in the female; its position is oblique, the longer diameter inclining from the pubis upward and outward toward the superior anterior spinous process of the ilium; its actual length is extremely variable, in some instances not amounting to half an inch, in others exceeding an inch.

The inferior part of the internal oblique and of the transversalis muscles, which alone is concerned in the anatomy of this part of the abdominal wall, may be distinguished into two parts, viz., their muscular portion and their aponeurosis. The muscles are both, but more particularly the latter, very thin, though of great width; they are placed the one within the other, and the internal oblique, which is superficial to the transversalis, also descends a good deal lower, so that its inferior margin approaches very close to the crural arch, leaving only sufficient space between them for the escape of the spermatic process, which it covers beneath the aponeurosis of the external oblique, and which in some instances passes between its fibres,* while the margin of the transversalis is at some distance from the arch, and rarely covers the process, at least to any extent, the process escaping from the deep ring, for the most part below the margin of the muscle; Cloquet has even seen the margin of the muscle so far as two fingers' breadth above the point of escape of the cord, and its fibres are usually pale, fine, and scattered. The muscular fibres of the lower part of the two muscles are attached to the anterior extremity of the crest of the ilium and to its spinous process, also to the superior aspect of the outer part of the crural arch, the oblique to nearly the outer half of the arch, the transverse to the outer third or fourth, but the ultimate attachment of the latter is to the surface of the fascia iliaca above the arch, to which they adhere very intimately as they pass forward from the fascia; they run inward nearly transversely, but convex forward in proportion to the prominence of the abdomen, those of the oblique over the deep ring, and the spermatic process within the inguinal canal, those of the transverse above the ring, until they have both passed that point; they then descend along the inside of the process, and at the same time recede from the surface so that they become posterior to it, and terminate as they descend in a thin irregular aponeurotic expansion common to the fibres of both muscles, and thence denominated "the conjoined tendon;" though designated by an especial name, this is in reality only the inferior part of the general conjoined tendon of the two muscles which terminate between the umbilicus and the pubis in a common expansion; this is placed superficial to the rectus muscle, and is inserted into the linea alba, the anterior margin of the crest of the pubis as far as its spinous process, and thence outward into the pectineal line of the bone, there forming the "conjoined tendon" of the anatomy of hernia. This structure is situate behind the spermatic process,

* Cloquet.

between it and the fascia transversalis; it approaches very near to the inner margin of the deep ring, and at its insertion into the pectineal line it meets and is identified with Gimbernat's ligament; it is closely adherent to the surface of the fascia transversalis, and hence that fascia presents an appearance of thickness and strength upon the inside of the deep ring, which it does not really possess. From the inferior margin of the internal oblique and from the superior side of the crural arch the cremaster muscle descends upon the anterior and external part of the spermatic process, forming one of the coverings of the process within the inguinal canal, of course concealing it after the division of the aponeurosis of the external oblique, and requiring to be detached from the arch along with the lower fibres of the internal oblique in order that the process may be fairly exposed.

The deep structures of the anterior wall of the iliac fossa are also three, viz., the fascia transversalis, the fascia propria, and the peritoneum.

1. The fascia transversalis is most remarkable in the iliac region, but it is not confined to it, being to be traced upward to the surface of the diaphragm, and backward round the interior of the lateral walls of the abdomen. In the iliac region this fascia is inferiorly first identified with the fascia iliaca from a short distance behind the anterior superior spinous process of the ilium to the outer side of the external iliac artery, or about the middle of the crural arch; the line of its connection with the fascia iliaca runs downward, forward, and inward, at a short distance within the crest of the ilium and the crural arch, approaching the latter, however, as it descends, until at the outside of the artery it touches it; it is separated along this line into two laminæ which enclose the circumflex iliac artery between them; there is, therefore, an interval between the arch and the line of connection of the two fasciæ in which the fascia iliaca intervenes, and to the surface of this part of the fascia it is that the internal oblique and transverse muscles are attached. In the second place the fascia transversalis descends into the thigh beneath the crural arch, between it and the iliac vessels, and forming the front of their sheath; and, thirdly, it is attached upon the inside of the vessels, along the pectineal line of the pubis posterior to the conjoined tendon of the internal oblique and transverse muscles, between it and the peritoneum, and separated by it from the spermatic process, which is in front of both.

Internally the fascia transversalis is connected to the edge of the tendon of the rectus.

Midway between the superior anterior spinous process of the ilium and the spinous process of the pubes, and at from half to three-fourths of an inch above the crural arch, the spermatic process escapes from the abdomen, descending within a cylindrical prolongation of the fascia by which the process is enclosed, and which thus forms a sheath for the process. By detaching this prolongation from the fascia around the process, a circular aperture is formed in the fascia, which is the deep inguinal ring, the situation of which has been just defined. On the inside of this opening are situate the epigastric vessels, the artery, and vein or veins, the artery in the former case being next the ring, in the latter at times the outer of the two veins.

2. The fascia propria is a cellular stratum interposed between the peritoneum and the structures of the abdominal walls which it lines; it varies in thickness and condition at different parts and in different subjects; at times it contains adeps, at others it is purely cellular, or forms a condensed expansion; in the iliac region it is thicker upon its posterior than its anterior wall; on the latter it increases in thickness as it descends towards the crural arch, being so thin towards the umbilicus that the peritoneum adheres very closely to the tendinous expansion of the muscles; at the deep inguinal ring it is more dense, and the peritoneum, the fascia transversalis, and it, are more intimately connected than at either side; external to the ring, between it and the spinous process of the ilium, it is so free that the peritoneum may be separated without difficulty from the interior of the fascia transversalis, and along the crural arch it forms, from the external iliac artery outward, a soft mass, sometimes thick, occupying the interval left between the peritoneum and the fascia transversalis, at the reflection of the former from the iliac fossa to the anterior wall: upon this wall it encloses the epigastric vessels, the umbilical ligament, and the spermatic vessels, and not only does it extend universally over the interior of the abdominal walls but it is prolonged through their several apertures upon the parts which pass through them, as in the case of the spermatic vessels.

From the anterior wall of this region it passes to the posterior, where it lines the iliac fossa, and connects the peritoneum or the viscera to the iliac fascia; at the outer part of the fossa it is remarkably free, soft, and easily lacerated, so that the peritoneum can be detached, probably with greater facility at this than at any other situation; at its inner part it is even more abundant, thicker the nearer to the crural arch, forming the investment by which the iliac vessels are inclosed, and descending thence into the pelvis.

Lastly, the peritoneum of the anterior wall is continuous inferiorly with that of the iliac fossa, being reflected from the one to the other at the distance of five or six lines above the crural arch—a fact deserving of much attention, since it permits the external iliac artery to be secured without disturbing the membrane. In its reflection from one wall of the region to the other it leaves immediately above the crural arch, between itself, the fascia transversalis, and the fascia iliaca, a triangular interval of some lines, occupied by the fascia propria, and at times at least by one or more lymphatic glands; this space is widest at the iliac artery and diminishes as it extends outward; this fact also deserves attention, inasmuch as it points out where the fascia transversalis may be divided, if necessary, in the operation of exposing the external iliac with least danger to the peritoneum, viz. on the outside of the deep inguinal ring and close as possible to the crural arch. The peritoneum of the anterior wall of the fossa is weaker toward the middle line than externally; it presents toward the abdomen two depressions or recesses denominated by Velpeau "fossettes inguinales," internal and external; these depressions vary very much in their depth, sometimes hardly perceptible, at others of considerable depth and capacity, more especially the external, which is much the larger; they are produced by the projection of the umbilical ligament from the interior of the abdominal wall, and the reflection of the peritoneum round the ligament, by means of which a triangular fold, wide in proportion to the degree to which the ligament projects, is formed, the base of which is below, the apex above toward the umbilicus, and in the free edge of which the ligament is contained; this fold separates the depressions, one being external to it, the other internal, between it and the urachus; the external one, the bottom of which tends forward and inward, corresponds to some point of the posterior wall of the inguinal canal, but its precise relation to it is uncertain, because of the irregularity of the position of the umbilical ligament; at times it is identical with another slight depression situate on the outside of the epigastric vessels, which marks the situation of the deep inguinal ring, the ligament in such case being behind these vessels; at others it corresponds to the wall of the canal, to the superficial inguinal or the deep femoral rings, the ligament being in these latter cases internal to the epigastric vessels.

The branches of the external iliac artery deserving of particular attention are usually two, the anterior or circumflex iliac and the epigastric arteries; throughout the superior part of its course the artery gives only minute branches to the peritoneum, the cellular tissue, the psoæ muscles, and the lymphatics; the other two, which have been mentioned, are given off immediately before the artery escapes from the abdomen. They arise at a very short distance above the crural arch, sometimes so high as three-fourths of an inch from it, at others at it, and sometimes again below the arch from the femoral; they proceed one from the outer and the other from the inner side of the vessel, sometimes opposite to each other, at others indifferently one above the other; occasionally they are given off from a trunk common to both; they are nearly of equal size, but for the most part the epigastric is larger than the circumflex.

1. The *anterior or circumflex iliac artery*, (*arteria circumflexa iliaca* or *ilii;* Fr. *artere circonflexe iliaque*, ou *iliaque* ou *antericure*,) arises from the outer side of the external iliac on a level with or somewhat lower than the epigastric; it runs outward and upward above and parallel to the crural arch as far as the superior anterior spinous process of the ilium; during this course it lies upon the fascia iliaca superficial to the psoas and iliacus muscles and the anterior crural nerve, and it is inclosed in a triangular canal, formed behind by the fascia iliaca, below and above by laminæ of the fascia transversalis, which divides at its union with the former, in order to inclose the artery. When the anterior abdominal wall has been thrown down, and the peritoneum with the fascia propria removed from the iliac fossa, the course of the vessel may be traced by a white line, which marks the union of the two fasciæ, extending from the middle of the crural arch upward and outward within about three-fourths of an inch of the spinous process of the ilium; by the division of the fascia transversalis along this line the artery will be exposed.

During its course toward the spinous process the artery gives branches to the psoas and iliacus, the transversalis and oblique muscles, and to the inguinal glands; near the process it gives upward a considerable branch, which ascends in the anterior wall of the abdomen between the internal oblique and transversalis muscles, in front of the spinous process, serving with its accompanying veins as a guide in dissection by which to distinguish between the two muscles; it divides into branches, which are distributed to the muscles, as also to the structures, which cover and line them, and communicate with branches of the epigastric, lumbar, and intercostal arteries.

The circumflex artery pursues its course and runs backward around and within the crest of the ilium, internal to the transversalis muscle; during its course it gives branches inward to the iliacus muscle which anastomose with similar branches from the iliolumbar, and upward to the lateral abdominal muscles, which are partly distributed to them, partly turn over the crest of the ilium and communicate with the gluteal artery, and in part communicate with the lumbar or intercostal arteries. Finally, the artery, very much reduced in size, anastomoses freely with the termination of the iliolumbar, which pursues a similar course in a contrary direction around the interior of the crest of the ilium.

The circumflex artery has been found by Monro to present an irregularity deserving of notice; he has seen a branch from it, nearly as large as the epigastric, pass under the crural arch, about two inches from the symphysis pubis, and there divide into branches, which were distributed upon the symphysis and the fat and skin over the arch.

2. The *epigastric artery*, (Fr. *artere epigastrique, A. sus-pubienne)* arises from the internal and rather anterior part of the iliac artery, near to the crural arch; the distance of its origin from the arch, however, is liable to variety; for the most part it occurs about half an inch above it, but it is frequently nearer to it, or even at it, and occasionally it is below it, arising from the femoral artery; it is given off, as has been stated, from that part of the iliac, which is left uncovered by peritoneum, and its point of origin is posterior to, sometimes above, sometimes on a level with, and at others below the reflection of the mem-

brane from the posterior to the anterior wall of the abdomen. Its course is tortuous; it passes forward and inward; when its origin is low, or very near to the arch, at once upward; but when its origin is high, at first downward in front of the external iliac vein, and then changing its direction, when it has reached the reflection of the peritoneum, it ascends inward toward the outer margin of the rectus muscle, in front of the membrane, between it and the fascia transversalis; it reaches the margin of the muscle from one and a half to two inches above the pubis, and then passing behind it enters its sheath, and continues its course upon the posterior surface of the muscle toward the umbilicus, and terminates by dividing into branches, which anastomose freely with descending branches of the internal mammary artery; the main course of the vessel is therefore oblique upward and inward; and it may be defined by a line drawn from the junction of the middle and inner third of the crural arch to within half an inch upon either side of the umbilicus.

The artery, when its origin is high, is situate, at its outset, behind the peritoneum, posterior to the deep inguinal ring; in the rest of its course it is at first beneath and then before it, in immediate contact with it from the crural arch to the edge of the rectus, and enclosed in the fascia propria, but in the remainder separated from it by the back of the sheath of the muscle; it therefore forms in this case a curve in which the reflection of the peritoneum is contained, and through which the vas deferens forms a similar curve,—the aspect of the curves being however different, the convexity in the former directed downward, and in the latter outward and somewhat upward—the two cords hooking round each other; in its ascent from the crural arch it is contained in the posterior wall of the inguinal canal, between the fascia transversalis and the peritoneum, crossing the canal nearly at right angles, and intermediate to the two rings, being distant from the outer part of the superficial one, according to the size of the aperture, from half an inch to an inch and a half, and in its relation to the deep ring varying from the margin of the aperture itself to four or five lines distance from it. It is accompanied sometimes by one, at others by two veins; in the former case the artery is always external and next to the margin of the ring; in the latter, one of the veins is at times between it and the aperture.

The relation of the artery to the inguinal rings indicates at once that which it must hold to the neck of the sac in the two original forms of inguinal hernia; in the oblique or external inguinal hernia it is, as a matter of course, placed beneath and on the inside; and in the direct or internal inguinal, upon the outside of the neck; but in the former it must, in consequence of its natural vicinity to the ring, and the dilatation of the latter, be close to and surround the neck upon the two sides mentioned, while in the second, unless the aperture be much enlarged, it will be at a greater or less distance from it; the risk of danger to the vessel from cutting to the side, at which it lies, in a strangulation at the neck of the sac, must therefore be much greater in the former than in the latter. In the case of a hernia originally oblique and become direct by long continuance, the artery carried inward along with the deep ring, from the displacement of which the hernia assumes the character of the direct form, the artery is of course situate still upon the inside of the neck, which at the same time it surrounds to a greater extent than in the former instances; this third, though secondary, form of inguinal hernia presents another case, in which the relation of the vessel to the neck of the sac demands attention the more that the true nature of the case being obscure and the hernia originally and secondarily direct, being thence liable to be confounded, it is most important that it should be borne in mind that the artery may be to the one side or the other, according as the hernia has been originally or secondarily direct. The epigastric artery is also situate, in its ascent, external to the deep femoral ring; its distance from it, in the natural state, is about half an inch; but when hernia is present, and the neck at all large, the epigastric vessels are close to its outer and anterior side, the vein, however, being between the artery and the ring; when the obturator artery arises from the epigastric, the propinquity of the latter to the ring is increased.

The branches of the epigastric artery are numerous, and some of them important. Its first branches are two given off between its origin, and the deep inguinal ring, higher or lower, according to the situation of the origin of the epigastric itself; they arise, in some instances separately, in others by a single origin, and they run over to the posterior surface of the pubis, the other to anastomose with the obturator artery; the former, the pubic branch, runs inward above Gimbernat's ligament, sometimes along its anterior, sometimes along its posterior margin, to the back of the pubis, and according to its course is liable to be situate before or behind the neck of a femoral hernia. The second, the obturator branch, runs backward, downward and inward toward the superior aperture of the pelvis, i.e. in the direction, which the obturator artery when arising from the epigastric takes; having descended into the pelvis it joins the obturator at a variable distance between the origin of that vessel from the internal iliac and the subpubic foramen; frequently it divides at the brim of the pelvis into two, of which one joins the obturator and the other runs backward along the brim and anastomoses with the ilio-lumbar artery. This branch holds precisely the same relation to femoral hernia which the obturator when arising from the epigastric does; it is very variable in size, and it is upon its development as compared with that of the origin of the obturator from the internal iliac that depends, whether the former shall seem a branch of the latter, or of the epigastric; when the origin of the obturator from the iliac has become wanting, this branch takes its place and becomes the obturator.

2. The epigastric artery in passing the deep inguinal ring gives a branch, which goes out through the ring in company with the spermatic process, descends to the scrotum and is distributed to the structures of the cord, to the tunica vaginalis, and to the cremaster, and anastomoses with branches of the spermatic artery; it is denominated by some *the inferior spermatic artery*.

3. As the artery ascends in the abdominal wall it gives to either side numerous branches, which are distributed among the structures of the wall, anastomosing externally with branches of the circumflex iliac, of the lumbar and the inferior intercostal arteries, and internally with those of the artery of the other side; many of these branches ultimately become superficial, passing through the muscles, and through apertures in the aponeurosis of the external oblique; they terminate in the superficial structures, anastomosing with the other superficial vessels.

4. Finally, the epigastric artery terminates by two or more long ascending branches, which meet and anastomose with branches from the internal mammary artery.

Methods of operation for the ligature of the iliac arteries.—The methods of operation for the internal and primitive iliacs being but modifications of those adopted for the external, I propose to detail the latter first.

The operation in each case may be resolved into three stages, viz. 1, the division of the structures of the abdominal wall; 2, the displacement of the peritoneum with the intervening viscera; 3, the management of the artery and the parts immediately related to it. Several plans have been proposed for exposing the external iliac artery; these may be regarded as, all, modifications of the same; yet their number, the existence of points of difference leading to results of some importance, and the advantage to be derived from a clear apprehension of them, render it desirable to distinguish them so far as they present distinctive characters deserving notice. I propose, therefore, to particularize five methods, between which operators may have occasion to select. In the first the line of incision is straight, and corresponds to the course of the artery. In the second the line of incision is also straight, and inclines away from the course of the artery toward the superior anterior spinous process of the ilium. In the third the line of incision is curved, convex downward toward the thigh, and crosses the course of the vessel. In the fourth the line of incision is straight, and transverse to the artery's course. The fifth, which I would specify, is a modification of the third, by which that plan may be rendered more generally applicable. The first is, that which was adopted by Abernethy, by whom the artery was first tied, A.D. 1796, and is now generally known as his method, of which the following is his own account:—"I first made an incision, about three inches in length, through the integuments of the abdomen, in the direction of the artery, and thus laid bare the aponeurosis of the external oblique muscle, which I next divided from its connection with Poupart's ligament, in the direction of the external wound, for the extent of about two inches. The margins of the internal oblique and transversalis muscles being thus exposed, I introduced my finger beneath them for the protection of the peritoneum, and then divided them. Next, with my hand I pushed the peritoneum and its contents upwards and inwards, and took hold of the artery."*

The second method seems due to several, and first also to Abernethy. This may seem doubtful, from the account of his second operation originally given by himself, in which he says merely that "an incision of three inches in length was made through the integuments of the abdomen beginning a little above Poupart's ligament, and being continued upwards; it has more than half an inch on the outside of the upper part of the abdominal ring, to avoid the epigastric artery."† But in his collected works‡ of different dates it is expressly stated of this and his subsequent operations that the incision "began just above the middle of Poupart's ligament, and consequently external to the epigastric artery, and was continued upwards, but *slightly inclined towards the ilium.*" The plan adopted by Frere differed not much from this. This method appears however more particularly attributable to Roux, who seems to have been the first to give specific instructions for it, recommending that the beginning of the incision should never be further than half an inch from and a very little higher than the anterior superior spine of the ilium, and that it should be carried very obliquely downwards to the middle of Poupart's ligament.§

The third method is that of Sir A. Cooper, in which the incision is begun just above the abdominal ring, and is extended downward in a semilunar direction to the upper edge of Poupart's ligament, and again upwards to within an inch of the anterior superior spinous process of the ilium. This incision exposes the tendon of the external oblique muscle: in the same direction the above tendon is to be cut through, and the lower edges of the internal oblique and transversalis muscles exposed: the centre of these muscles is then to be separated from Poupart's ligament: the opening by which the spermatic cord quits the abdomen is thus exposed, and the finger passed through it is directly applied upon the iliac artery above the origin of the epigastric and circumflex ilii arteries: the next step of the operation consists in gently separating the vein from the artery by the extremity of a director or the end of the finger; the aneurismal needle is then passed under the artery.‖

The fourth is that of Bogros, in which the line of incision is, as I understand it, straight, from two to three inches long, immediately above the crural arch, and has its extremities

* Surgical Works, 1830, v. 1, p. 292.
† Surgical Observations, 1804, p. 214.
‡ Surgical Works, 1830, p. 396.
§ Cooper's Dictionary, and Nouveaux Elemens de Med. Op.
‖ Cooper's Lectures by Tyrrell, v. 11.

equidistant, the external from the spine of the ilium, and the internal from the symphysis of the pubis. The aponeurosis of the external oblique muscle having been laid open in the direction of the crural arch upon a grooved director, the spermatic cord with the cremaster is to be drawn upward beneath the superior lip of the wound; the deep ring dilated with the point of the finger; the epigastric vessels, if a guide be necessary, followed toward their origin; the cellular structure and lymphatic glands situate above the arch upon the artery separated; and the vessel exposed and isolated.*

In the fifth method, which is but a modification of Cooper's, the outer extremity of the incision as directed by him is prolonged to, or beyond the superior spinous process of the ilium in proportion to circumstances.

Before these methods be contrasted with each other, a few additional remarks seem required in reference to the operation however performed.

1. The posture of the patient should be such as will most relax the abdominal muscles in order to prevent as much as possible their pressure upon the viscera, and to allow the more easy separation of the edges of the wound. The shoulders should be raised and the legs bent upon the pelvis.

2. It seems desirable that unless the superficial wound be longer than has been stated, the division of the aponeurosis of the external oblique should be of equal extent.

3. The recommendation to divide that aponeurosis upon a director appears judicious as a means both of facility and safety.

4. Where it can be used the finger seems a safer instrument with which to separate the internal oblique and transversalis muscles from the structures beneath, for it will be readily understood that the extremity of a director might be easily thrust through the peritoneum in the execution of this step.

5. It must be borne in mind that between the muscles and the artery there are to be expected beside the peritoneum two other structures: 1. the fascia transversalis; 2. the immediate investment of the vessels. The fascia transversalis may either be treated in the manner directed by Cooper, viz. by dilating the deep ring, or be lacerated with the nail, as recommended by Guthrie, but it is to be recollected that a prolongation of the fascia descends upon the spermatic cord, and that therefore there exists no opening, and that the fascia varies in strength, and may at times be found so strong as to require more force to lacerate it than it may be deemed proper to exert. In such case an opening may be made through it with the knife, and enlarged upon a director if necessary. This may be effected by either of two methods, viz. either by dividing the prolongation of the fascia, which descends upon the spermatic process, "having been first raised with a forceps, to a sufficient extent to admit the forefinger to pass upon the cord into the internal abdominal ring,"—a proceeding adopted by Mott, and which offers a safe mode of opening that structure; or by cutting the fascia upon the outside of the ring, in the direction toward the superior spine of the ilium, to such an extent as may allow the introduction of the director or the finger: the section cannot be attempted safely inward, because of the vicinity of the epigastric artery, which is so near to the inner side of the deep ring that it must in such case be exposed to imminent danger, situate as it is between the fascia and the peritoneum; on the other hand the more close attachment of the fascia to the latter membrane in proportion as it recedes from the crural arch forbids the section of the fascia directly upward; while the existence of the triangular interval, which has been described, between the fascia and the peritoneum immediately above the arch renders the membrane safe from injury in a division outward near to the arch: it must however be recollected that in approaching the arch the circumflex ilii artery is also approached and endangered, so that the incision should not be brought too near to that part, but made in the direction mentioned, nor in any case be larger than will suffice for the introduction of the finger or the director.

6. The immediate investment of the vessels frequently opposes great resistance to the separation of the artery and vein, and to the isolation of the former; this impediment is due not merely to the strength of the investment, but also to the absence of a resisting support behind the vessel as it recedes from the pubis, in consequence of which it yields to the pressure exerted to separate it. In such case the nail, the director, or the knife has been recommended for the division of the expansion; Abernethy made a slight incision on either side of the artery. The nail does not seem the best instrument in this instance, because, by the use of it the vessel must be a good deal disturbed, a circumstance to be avoided whenever it can be; the knife again must be attended with risk unless used with great caution and in steady hands, and the risk is the greater when the incision is made at one side of the artery, since the vein is thereby endangered; it would seem a safer proceeding and one less likely to disturb the artery unnecessarily, if, when it can be done, the investment were pinched up with a forceps over the middle of the artery and then divided to the extent to which it may have been raised, after which, with the director or the blunt aneurism-needle, the artery may be isolated with facility while the investment is drawn to either side with the forceps.

7. It is to be borne in mind that one or more lymphatic glands usually lie in front of the artery imbedded in the cellular structure which forms its investment, and that these may be to be displaced.

8. In operations upon the iliac arteries, more particularly when performed after the method of Abernethy, or upon the internal or primitive vessels, a protrusion or bearing down of

* Archives Générales de Méd., t. iii. p. 408.

the abdominal viscera is to be expected which has been found a great obstruction to the operation: this will be most effectually prevented by the use of purgatives previous to the operation; by posture, the abdominal muscles being thereby relaxed as much as possible; and during the operation, if it occur, by the use of curved spatulas of considerable width and curve, as used by Mott, with which the viscera may be supported.

9. In the passage of the ligature it will always be necessary to be assured that the genito-crural nerve is not included; but it may be avoided without difficulty, and can seldom require to be divided. Its situation should be borne in mind, viz. above external to the artery, below external or anterior.

Lastly, it would seem the safer plan to pass the needle and ligature from within outward, inasmuch as the vein is internal to the artery. In Cooper's Lectures edited by Tyrrell, it is directed to pass the needle from without; by so doing there is less risk that the genito-crural nerve shall be included, and in high operations, since the vein is situate so much beneath the artery at the superior part of their course, it will not be thereby much endangered, but at the lower part the vein must certainly be more exposed by that mode of passing the ligature than by the contrary one, while the nerve may be avoided without difficulty.

We shall next consider the comparative merits of the several plans of operation. In the method of Abernethy the direction of the line of incision is attended with the following consequences. 1. It requires a more extensive division of the oblique and transversalis muscles, and hence is more likely to be followed by weakness of the abdominal wall. 2. Falling, as first performed by him, nearly upon the course of the epigastric artery, it exposes that vessel to be divided, though in the method adopted by him in his latter operations this risk must be very much diminished, if not removed. 3. The extent to which it is necessary to divide the internal oblique and transversalis muscles must expose the peritoneum lining the anterior wall of the abdomen to be lacerated or divided during their separation. 4. The parallelism of the vessel and the wound must render it necessary to expose a greater length of the former, in order to effect its separation from the contiguous parts and to pass a ligature round it. 5. It is therefore necessary to detach the peritoneum in all cases, and to a greater extent than may be necessary or required by a different method. 6. The peritoneum must be detached to an equal extent from both walls of the abdomen—from the anterior as much as, or it may be more than, from the posterior. 7. The protrusion of the viscera must be more likely to occur.

It is asserted by some* that the spermatic cord is more exposed to injury in this method; but it appears to me that it cannot be more so than in others, and that it ought to be more safe.

* Velpeau.

The second method is free from many objections to which others, and especially the first, are exposed. 1. It does not endanger any vessel but the superficial epigastric. 2. It does not endanger the spermatic cord. 3. Probably it does not tend to weaken the abdominal wall as much as the first method. 4. It renders necessary a much less extensive detachment of the peritoneum, since the line of incision falls so much nearer to the inferior reflection of the membrane. Add to these that by it the artery may be reached at as high a point as by the first, and no doubt can remain that it is to be preferred to it; and in cases requiring a high ligature of the vessel there is none, save the modification of Cooper's method, which can be considered equally eligible. It is still, however, subject to the same conditions with the first, only in less degree. In the method of Cooper, on the contrary, the internal oblique and transversalis muscles are divided to but an inconsiderable extent, and the division of the aponeurosis of the external oblique approaches more to the course of its fibres. The direction of the incision being transverse to that of the artery, the vessel may be exposed, and a ligature passed round it without stripping it to a great extent and with little disturbance of it. Again, for the same reason and because of the vicinity of the incision to the crural arch, the vessel may be exposed either without displacing the peritoneum at all, or displacing it but little; and when it is necessary to displace the membrane, that may be effected with the least possible disturbance of it, inasmuch as, because of the propinquity of the line of incision to the reflection of the membrane, it is not necessary to detach the latter from the anterior wall of the abdomen. It must also be less exposed to the protrusion of the viscera, and when the vessel is tied below, the reflection of the peritoneum must be exempt from it. This method permits the artery to be reached at from an inch to an inch and a half above the crural arch.

On the other hand this method endangers the epigastric artery and spermatic cord more than the others; the former because the line of incision crosses the vessel's course, commencing internal to it, and the latter because the line of incision crosses and sweeps over the cord in describing its curve. Velpeau considers that there is greater danger to these parts in the method of Abernethy, but I cannot concur in this opinion, for the lower extremity of the incision alone can fall upon the situation of the cord, and in the mode adopted by him in the majority of his operations, the line of incision was external to that of the epigastric artery. Experience too proves that there is greater danger of dividing the epigastric artery in the method of Cooper, since the accident has occurred more than once in it, and in the most dexterous hands; thus Averill relates that the artery was wounded by Dupuytren, and Guthrie also states that he has seen the artery divided in the performance of this operation, while I am not aware of an instance in which the trunk of the artery has been divided in the method of Abernethy. But these objections to the method of Cooper, however serious in themselves, seem of insufficient weight when contrasted with those to which the plan of Abernethy is subject, more especially since they only require caution to be effectually obviated, while the others are inseparable from the plan to which they apply. And hence the preference has been given to his method, by the greater number of those* who have had opportunities of experimentally testing the comparative claims of the two in all cases where it is applicable; i. e. in those instances in which the aneurismal tumour has so little encroached upon the crural arch, or in which there is so much reason to consider the artery in a healthy condition immediately above the arch, that it may be with propriety tied near to that part. Sabatier is of opinion that the method of Abernethy should be preferred in every case; but the number of authorities in favour of the other is so great, that we must consider its greater eligibility as a decided question. And the method of Cooper possesses the additional and great recommendation that it may at any time be so modified by the prolongation of the upper extremity of the incision, as to be adapted to every case, so that in instances, in which it may be found necessary to tie the artery at a greater distance from the arch than the original plan will permit, this modification of it may be adopted even in the course of the operation: for the most part surgical writers recommend a preference of Abernethy's first plan in such circumstances; but to this all the same objections which have been already stated, apply, and forbid its adoption, while another less subject to them and not less efficacious presents for selection. Abernethy's plan certainly promises one advantage, viz. that the line of incision being nearer to that of the artery the depth of it from the surface is likely to be less, unless where the abdomen is very prominent, than in the latter, in which the obliquity of the direction must increase the depth of the wound, and for the same reason it may be more easy to obtain a view of the vessel, and to direct the operation by the sight, which must be more difficult in the latter, and in proportion as the point at which the operator aims is higher; yet, notwithstanding this circumstance in favour of the method of Abernethy, and the preference given by several to it in such cases, the method of Cooper, modified as has been explained, appears to me still preferable, inasmuch as the greater disturbance of the peritoneum, the risk of injuring it in front, and the greater debility of the abdominal wall likely to be the consequence of Abernethy's method, seem to outweigh its advantages: there is beside another disadvantage attending the latter and a corresponding advantage attending Cooper's plan, which must be experienced when an aneurismal tumour occupies the iliac fossa, viz. that, by the former the peritoneum must be detached from all the front of the tumour, while in the latter the lower and inner part of it may be left undisturbed, and this I consider a matter of some importance.

* Norman, Todd, Velpeau.

The method of Bogros has been proposed as an improvement upon that of Cooper, under the impression that in the latter the incision, which makes nearly a right angle with the artery, corresponds to the vessel only by its internal extremity, while in the one which Bogros proposes the middle of the incision corresponds directly to the artery; by this plan he further maintains that greater facility in the operation is obtained, and the artery may be exposed nearly an inch above the crural arch without disturbing the peritoneum, while in Cooper's the membrane must be always displaced, and the ligature can be applied at only a very short distance from the arch. Bogros plainly understands Cooper's incision to commence at the internal abdominal ring, and in such case his objections would be well founded. It is certainly to be regretted that Cooper has used an ambiguous expression, which has led others beside Bogros to mistake his meaning; but if reference be made to his description of the anatomy of hernia it will be found that by the "abdominal" he intends the superficial inguinal ring, and if so, that the sole difference between his and Bogros' plan is that in one the line of incision is straight while in the other it is curved, whence the comparative results must be the reverse of those inferred by Bogros, so far as the facility of securing the artery and of reaching it at a greater distance from the crural arch is concerned. If however it be desired to secure the artery immediately above the crural arch, between it and the reflection of the peritoneum, as may occur in cases of femoral aneurism, the method of Bogros furnishes a plan fully adequate to the intention, free from the necessity of disturbing the peritoneum and easy of execution; at the same time that it is subject to the objection, that, unless care be taken to prevent it by tracing the vessels to their origin, which must render the operation more complicated and delicate, the artery is more likely to be tied below the origin of the epigastric and circumflex arteries by this than by any other plan, and this upon two accounts had better be avoided, so that all things considered this plan appears to me not so eligible as that of Cooper, in which it is altogether optional with the operator whether he shall disturb the peritoneum or not, or whether he shall tie the vessel immediately above the arch or farther from it, the one method being applicable to all cases, and not requiring, perhaps during the operation, a transition to another, after that the first has been found insufficient.

The modification of Cooper's plan, which has been enumerated as a fifth method, can be required only in those cases, in which it may be necessary to reach a very high point of the external or the primitive iliac. In such it will be a question whether to adopt Abernethy's original method, the second method, or the one under consideration: for myself it appears to me that the first ought to be abandoned in operations upon the external or primitive iliacs, unless there be something peculiar in the particular case to justify its adoption. The advantages of the second method have been partly stated; to these is to be added that the line of incision will be made to correspond more to that of the artery than by the last method, and consequently the wound will be less oblique in depth, whence probably there will be less difficulty experienced in holding aside the parts which intervene between the surface and the vessel; and certainly the operator, who may be apprehensive of injuring the epigastric and circumflex iliac arteries or the spermatic process, will do well to adopt it. Still for some reasons I feel disposed to prefer the last, for 1, it requires less disturbance of the peritoneum; 2, it appears to me that the exposure of the vessel must be greatly facilitated by carrying the lower extremity of the incision across the course of the artery to its inner side, which is not accomplished by the second method; 3, a semilunar line of incision furnishes a wound of greater length, and capable of being more widely opened than a straight one, while caution will secure the spermatic process and the epigastric artery from injury; and if a branch of the circumflex ilii be, as it is likely to be, divided, it may be tied with ease. This was the method adopted by Mott in the operation, in which he tied the primitive iliac artery; a case which sufficiently establishes the adequacy of this plan for the high ligature of the vessel, at the same time that it displays in a strong light the difficulties for which the operator must be prepared. In such cases the method of dividing the internal oblique and transversalis used by Mott may be adopted with advantage, viz. after having opened the fascia transversalis to insinuate the finger between it and the peritoneum, and guided by it to divide both muscles at once from within. It must not be forgotten that it is not uncommon to find the ureter crossing the internal iliac artery, upon the right side, near its origin.

Operations for the ligature of the internal iliac artery. — The method adopted in this operation by Stevens, by whom the artery was first tied, and that recommended by the majority of writers, is similar in principle to the first plan of Abernethy for the external iliac, and differs from it only in the length of the incision, which, according to Guthrie, should be five inches, beginning about half an inch above Poupart's ligament and about the same distance to the outside of the inner ring; it should be nearly parallel to the course of the epigastric artery, but a little more to the outside, in order to avoid it and the spermatic cord, and have a gradual inclination inwards toward the external edge of the rectus muscle: according to Hodgson the centre of it should be nearly opposite the superior anterior spinous process of the ilium. The aponeurosis of the external oblique, and the internal oblique and tranversalis muscles having been divided with the same precautions to avoid the peritoneum, as in the other case, the fascia transversalis is to be torn through at the lower and outer part, so that the fingers may be passed outward towards the ilium, and the peritoneum detached from the iliac fossa, and turned with its contents inward by a gradual and sidelong movement of the fore and second finger inwards and upwards, until passing over the psoas muscle the external iliac artery is discovered by its pulsation. This is then to be traced upward and inward toward the spine, where the origin of it and the internal iliac from the common iliac trunk will be felt. The artery is to be traced downward from its origin and separated with care from its connections, and more especially the vein. The sides of the wound should now be separated and kept apart with curved spatulæ in order that the surgeon may, if possible, see the artery, and have sufficient space for passing the ligature. Great care must be taken to avoid every thing but the artery; the peritoneum which covers, and the ureter, which crosses it, must be particularly kept in mind; the latter may be separated with ease, and usually accompanies the former as it is being detached from the artery. The situation of the external iliac artery and vein, which have been crossed to reach it, must be always recollected, and, if possible, they should be kept out of the way and guarded by the finger of an assistant.* This method has in this case a recommendation, which it does not possess for the other iliacs, viz. that, as it is necessary in tying the internal iliac to descend more or less into the pelvis, it is desirable that the external wound should be as near as possible to the aperture of the cavity, but the danger to the peritoneum must be even greater because of the greater extent to which it must be separated, and the closer attachment of it to the tendinous than the muscular structure of the abdominal wall. It, therefore, seems to me a question whether even in this case the line of incision here recommended should be adopted, and whether it would not be better to have recourse to that either of Roux or Cooper. Of the two perhaps the former may be best adapted to the internal iliac for the reason just assigned; though, if the inferior extremity of the incision be not carried beyond the middle of Poupart's ligament, difficulty must be experienced in exposing the vessel and passing the ligature; therefore here again I am disposed to prefer the semilunar line of Cooper, only not brought so close to the crural arch as for the external iliac, and prolonged, as directed by Velpeau, two inches at its external extremity.

It is recommended to pass the ligature from within outward because the internal iliac vein is posterior to the artery; this appears to me, however, not the most judicious plan, by it the point of the needle must be first carried outward and then forward and inward in order to pass round the vessel: now the external iliac vein is immediately external to and crossed by the artery; the junction of the two iliac veins is also external to the artery, and the internal one, though posterior, is at the same time rather external to it. In such a case the course

* Guthrie on Diseases of Arteries, p. 371-2.

to be pursued must be very much influenced by the convenience of the moment; but it would seem the better plan, where a choice can be made, to pass the needle first backward between the artery and the external iliac vein, and then inward behind the artery toward the pelvis, by which plan the veins will be more surely avoided, and more space will be obtained for seizing the ligature.

In this as well as every operation upon the iliac arteries, the spermatic vessels must be kept in mind, inasmuch as they require attention as much as the ureter; they are usually, however, like it, removed with the peritoneum. Velpeau suggests the possibility of rupturing the ilio-lumbar artery in isolating the internal iliac, and the risk ought not to be overlooked.

Ligature of the primitive iliac artery.—Any of the methods recommended, whether for the internal iliac or the external at a high point, will answer for the ligature of the primitive iliac. Guthrie gives the preference to that upon Abernethy's first plan in this as in the case of the internal iliac; but it appears to me that here, at all events, the method of Roux or the modification of Cooper's operation is to be preferred; for, beside that there does not exist in this case the reason for approximating the line of incision to the aperture of the pelvis, which applies to the internal iliac artery, the situation of the aneurismal tumour in front must render the direct line of incision less convenient than a lateral one, and by the adoption of the former there must be incurred a great exposure of the peritoneum without a commensurate advantage; the necessity also of stripping the membrane from all or a great part of the front of the aneurism, incurred by this plan, must be very objectionable. The length of incision recommended by Guthrie is five inches at the least, and may be required of even greater extent; thus Mott was obliged to extend it in his case upward and backward, about half an inch within the ilium, to eight inches: he adopted the principle of Cooper, commencing his first incision " just above the external abdominal ring, and carrying it in a semicircular direction half an inch above Poupart's ligament until it terminated a little beyond the anterior superior spinous process of the ilium, making it in extent about five inches." It is likely that a longer incision may be necessary in this method when applied to the primitive iliac than in that recommended by Guthrie; the greater length of the external incision is doubtless an objection of secondary importance; but it is probable that, when the primitive artery is to be tied, little will be gained by commencing the incision so low as was done by Mott, and that it would be more advantageous to carry it upward rather than downward; such appears to have been the design of Crampton in the operation performed by him for the ligature of the primitive iliac, in which the line of incision was curved, concave toward the umbilicus, and extended from the anterior extremity of the last rib downward beyond the superior anterior spinous process of the ilium, and since unnecessary division of the abdominal parietes is of course to be avoided, and the leaving them entire at the lower part must be attended with two good results, viz. avoidance of the aneurism and less subsequent danger of pecuniary protrusion, I cannot but regard this plan as a desirable addition to the methods of proceeding when the primitive iliac is the vessel to be tied. In passing the ligature the difference of the relation between the vein and artery of the opposite sides is to be borne in mind, the former being external to the artery on the right and internal on the left, on both sides however being upon a posterior plane.

The obstruction to the course of the operation caused by the protrusion of the viscera is to be expected; in that of Mott it is described as very great, while no mention is made of it in Crampton's. This difference was probably the consequence of the difference in the site of the wounds. The separation of the artery and vein is more easily effected than in the case of the external iliacs, because their investment is less thick and resisting.

The diversity presented by the arteries of the opposite sides suggests a difference as to greater practicability and probability of success on one as compared with the other; the artery of the right side being longer than the left presents greater room for the application of a ligature at a sufficient distance, whether from the seat of the disease or from the origin of the vessel, while that of the left being more perpendicular in its course and nearer to the left side of the body ought to be more easily exposed; but it is to be recollected that this disposition is not uniformly present.

Before undertaking an operation upon any of the iliac arteries it will be advantageous to determine, so far as possible, the relation of the vessel, which is to be the subject of it, to the superficial points of the abdominal wall. This must be understood to be intended only as an approximation, but by attention to the following circumstances it will prove sufficiently close to serve the desired purpose. The mean point, at which the aorta divides and the primitive iliac commences, is half an inch below the umbilicus at its left side, and that at which the external iliac terminates is midway between the symphysis pubis and the superior anterior spinous process of the ilium: of course a line connecting these points will define the general course of the primitive and external iliac arteries. The length of the primitive iliac being from two to three inches, the extent of its course may be determined by the subdivision of this line. The point of demarcation between the primitive and external iliacs, and which will serve to mark the origin of the internal and external, as well as the termination of the primitive, may be further determined by a line extending from the crest of the ilium about one inch and a half behind its anterior superior spinous process to a similar point on the other side; such a line will traverse the sacro-vertebral articulation posterior to the division of the primitive iliac, and by its decussation with that before mentioned will mark more particularly the point of division of the vessel,* which will also correspond nearly to the centre of a line drawn from the anterior superior spinous process of the ilium to the umbilicus.†

The practicability and success of these operations have been so long established that they do not now require to be insisted upon.

When the external iliac has been tied below the origin of the epigastric and circumflex ilii branches, the circulation of the limb is maintained through the communications of the branches of the internal iliac with those of the femoral, of which the principal have been ascertained by Sir A. Cooper‡ to be the gluteal with the external circumflex, the obturator with the internal circumflex, and the ischiatic with the profunda, and through those of the circumflex iliac with the same. (See FEMORAL ARTERY.) When the ligature has been applied above the origin of these branches, the circulation is established also through their communications with the internal iliac, the internal mammary, the inferior intercostal and lumbar arteries.

The ligature of the internal iliac artery can cause little interruption of the supply of blood to the parts to which it is distributed; its communications are so numerous and free, externally and inferiorly with the external iliac and femoral arteries; inward with that of the other side, and upward with the aorta through the middle sacral and hemorrhoidal arteries, that the obstruction of the main trunk can affect it but little.

When the primitive iliac has been tied the circulation must be restored by means of the communication which exists between the arteries of the upper and lower extremities through the internal mammary and epigastric arteries, of that between the aorta and the iliac arteries, through the intercostal, lumbar, middle sacral, hemorrhoidal, and the branches of the latter, and of that between the iliac arteries of both sides.

For BIBLIOGRAPHY, see ANATOMY and ARTERY.

(B. Alcock.)

ARTERIA INNOMINATA, (in human anatomy) Fr. *Tronc brachio-cephalique.*

The innominata or brachio-cephalic artery is situated to the anterior and right side of the thorax, extending from the arch of the aorta to the sterno-clavicular articulation.

Of the three large vessels proceeding from the arch of the aorta, the innominata is the most anterior, the shortest, but of the largest calibre; it takes its origin at a point corresponding and very nearly parallel to, the upper edge of the cartilage of the second rib almost immediately from that part of the arch of the aorta where it alters its direction from the right towards the left side, or rather from the commencement of what is termed the transverse portion of the arch, and hence the cause of its being at this point not only to the right side but also anterior and rather superior to the other two, which arise from the remainder of the transverse division of the arch, the left carotid and subclavian arteries. It immediately ascends obliquely upwards, outwards, and very slightly backwards, to opposite the right sterno-clavicular articulation, where it divides into the right sub-clavian and carotid arteries, the latter of which, although the smallest in diameter, appears from direction to be its continuation. The innominata, therefore, is but a short trunk, rarely exceeding from an inch and a half to two inches in length. Nevertheless instances are upon record in which it has attained above two inches and a half; but these may be considered more in the light of anomalies than regular occurrences.

We now proceed to consider the various relations which this vessel bears to the several important organs in its neighbourhood, and we shall then the more readily be able to account for the many distressing symptoms usually accompanying its enlargement. At its origin, it lies upon the trachea and at its division corresponds, although at a considerable distance, to the longus colli muscle separated from it by glands and cellular tissue. Internally, or on its left side from below upwards, are the commencement of the left carotid artery and the trachea, the latter, however, lying upon a plane posterior to the artery, a quantity of cellular tissue and glands being usually met with between them. Externally or to its right the relations are more complicated and consist of parts of very great importance. It is here connected to the right pleura and the middle and inferior cardiac branches of the great sympathetic nerve; the internal jugular vein lies above it and on its right side, whilst the right brachio-cephalic vein is to its right but somewhat anterior. Behind this vein and crossing the subclavian artery at right angles very close to its origin, we find the pneumo-gastric nerve entering the thorax and giving back its recurrent branch which winds round the subclavian artery; still more externally is the phrenic nerve conducted into the thorax upon the anterior border of the anterior scalenus muscle, and between the two latter the internal mammary branch of the subclavian artery. The parts covering the vessel are studied with greatest advantage from the integuments backwards; and the best method of effecting this is as follows, as it enables us at the same time to take a clear view of the attachment of the various layers of the cervical fascia to the first bone of the sternum and the inter-clavicular ligament.

Having placed the subject with a block underneath the shoulders, and the head hanging down, thus drawing the vessel as much as possible out of the thorax, carry an incision of about five inches upwards, commencing at the middle of the sternum opposite the cartilage of the second rib. Through this incision carry another of the same length at right angles, commencing at the left sterno-clavicular articulation, and extending along the right clavicle as far as its centre. This crucial incision should merely divide the skin, the triangular flaps of which are next to be raised and re-

* Guthrie.

† Harrison.

‡ Medico-Chirurgical Transactions, vol. iv.

flected to the right and left, thus exposing a layer of fascia separating the skin from the platisma muscle; this fascia is thin externally, but where it corresponds to the interval between the two sterno-mastoid muscles it becomes dense and more or less loaded with fat; reflect this fascia and the platisma will next appear, behind which is that usually described as the superficial fascia of the neck covering the sterno-mastoid muscle, containing the external jugular vein, and increasing considerably in density above the sternum, over which it passes down in front of the pectoral muscles. Like the previous layer its thickness is augmented by fat. If this be raised the sterno-mastoid muscles and the first layer of the deep cervical fascia, extending between their two anterior margins, are brought into view, together with some small superficial vessels and nerves. This latter fascia should be carefully examined above the sternum to the anterior margin of which it strongly adheres; it is very dense, so much so that if we endeavour to force a finger into the thorax at this point, it effectually resists our efforts. Behind this fascia is a space corresponding in depth to the thickness of the upper edge of the first bone of the sternum, containing fat and usually a gland, and in addition a vein rather larger than a crow-quill, extending across the neck about half an inch above the sternum; this communicates with a vein on either side of the neck running down on the anterior margin of the sterno-mastoid muscle, and should be carefully avoided by the surgeon in the operation for tying the innominata, as it is of sufficient size to cause embarrassment if wounded. If the fat and gland be now removed we come down upon the second layer of this fascia, which is also very dense and adheres to the inter-clavicular ligament. Having examined these parts and the triangular space existing between the sternal and clavicular insertions of the sterno-mastoid muscles, the sternal insertions of the latter should be detached and the first bone of the sternum removed; this will expose the remains of the thymus gland and the sterno-hyoid and thyroid muscles, which being cut through and reflected upwards are found to cover the deep or third layer of the cervical fascia, which may be traced from the anterior scalenus muscle to its union with its fellow of the opposite side, binding down the cervical vessels, &c. Upon removing this fascia we come down upon the arteria innominata covered by the following parts; inferiorly the left brachio-cephalic vein passes nearly horizontally across the root of the artery to form the vena cava superior by uniting with the corresponding vein of the right side. Although the commencement of the vena cava, strictly speaking, has a closer relation to the arch of the aorta than the innominata, it is nevertheless sufficiently near the latter to render it of considerable importance in operations performed upon that vessel. Superiorly the first or upper cardiac nerve in its course towards the thorax crosses the innominata opposite its bifurcation; we next observe the right inferior thyroid vein, which, emanating from the lower portion of the thyroid gland, and having formed with its fellow of the opposite side the thyroid venous plexus runs, obliquely downwards from the gland towards the right side directly in front of the innominata artery, and empties itself into the vena cava superior between the two brachio-cephalic veins. The middle thyroid artery, when it exists, may now be seen ascending in front of the trachea. These several objects, viz. the left brachio-cephalic and thyroid veins with the cardiac nerve, are all enveloped in a quantity of loose cellular tissue and glands serving to connect them to the vessel, which may now be fully exposed and its different relations studied; when we shall observe that on its right side there is a space bounded superiorly by the right subclavian artery, inferiorly by the left brachio-cephalic vein, to the right by the right brachio-cephalic vein, and to the left by the innominata artery itself; this is the situation where the aneurismal needle should be introduced in the operation for tying this vessel, as we thus run less risk of wounding the veins.

From the above description it is evident that the coverings of the innominata may be arranged into ten layers, which, enumerated from the surface, consist of

1. The skin. 2. Layer of superficial fascia. 3. Platisma myoides muscle. 4. Superficial fascia. 5. First bone of the sternum, sternal extremity of the right clavicle, sterno-mastoid muscle, with its accompanying vein the sterno and inter-clavicular ligaments and anterior layer of deep cervical fascia. 6. Cellular tissue, fat, containing large vein and a gland; the second layer of deep cervical fascia. 7. Sterno-hyoid muscle. 8. Sterno-thyroid muscle. 9. Third layer of deep cervical fascia. 10. Cellular tissue containing the first cardiac nerve, right inferior thyroid, and left brachio-cephalic veins, glands, &c.

Arrivéd opposite to the right sterno-clavicular articulation and to the interval between the sternal and clavicular insertions of the sterno-mastoid muscle, the arteria innominata usually divides into the right carotid and subclavian arteries. It rarely gives off any branches antecedent to its division, but a small third branch is frequently observed proceeding from it to distribute itself in front of the trachea, and terminate in the thyroid gland. Mr. Harrison, in his work on the Surgical Anatomy of the Arteries, has named it the "middle thyroid artery." The French anatomists give M. Neubauer the credit of discovering it, and consequently term it "l'artère thyroidienne de Neubauer" It is, however, as frequently given off from the aorta between the arteria innominata and left carotid.

When we consider the relation which the innominata bears to the important organs surrounding it, we can scarcely be at any loss to account for the apparently remote symptoms present in aneurism of this vessel; such, for instance, as œdema and blueness of the upper extremities, head and neck, cough, difficulty of breathing and swallowing, vertigo, failure of sight, &c. Where the tumor extends towards the right side it presses upon the right brachio-cephalic vein, preventing the return of blood from the right arm and side of the head and neck; if upwards in that direction the carotid and subclavian arteries become implicated, and consequent interruption to the circulation ensues; if forwards, the passage of blood is stopped through the left brachiocephalic vein and the inferior thyroid venous plexus; if to the left, it encroaches upon the left carotid artery and trachea, whilst by enlarging backwards it acts immediately upon the trachea and mediately upon the œsophagus.

Although the above facts are interesting, as serving to elucidate the various phenomena occurring in this malady, I fear that we must not attach too much importance to them as means of diagnosis, inasmuch as many, if not all, of the above symptoms may result from enlargement of other vessels and other causes, indeed we have only to turn to the admirable work of Mr. Allan Burns on the Surgical Anatomy of the Head and Neck, to be at once aware of the probability of deception in this respect.

Anomalies.—There are perhaps few arteries in the body which present so many varieties and anomalies as the innominata, whether studied with respect to its extent, course, situation, or the number of branches which it gives off. In the first place, it is frequently met with extending up into the neck as high as the thyroid cartilage before it divides into its ultimate branches, and sometimes lying in front of the trachea. It is scarcely necessary to remark in how great a degree this anomaly increases the difficulties and dangers attending the operation of tracheotomy. Secondly, the most remarkable variety occurring in the course of this artery is described by M. Velpeau, who, in his Elémens de Médecine Opératoire, mentions three instances in which it passed to the left side in front of the trachea, and subsequently wound from before backwards over this organ, returning between the œsophagus and vertebral column, to its usual points of division opposite the right sterno-clavicular articulation. Thirdly, the innominata is also occasionally irregular as to situation. It has been found arising from the centre of the transverse portion of the arch of the aorta instead of its commencement, and dividing into right and left carotid arteries, the right subclavian taking its origin from the spot usually occupied by the innominata. Again, instead of being placed on the right it has been met with given off from the left or posterior part of the arch dividing into the right and left carotids and left subclavian, in other instances into left subclavian and left carotid. Cases are also on record in which the innominata was altogether absent, the right carotid and subclavian arteries arising directly from the arch of the aorta. Fourthly, it is frequently anomalous in the number of branches it gives off. Occasionally the left carotid arises from it in addition to its usual branches, sometimes it divides into the two carotids instead of the subclavian and carotid; and Tiedemann mentions an instance where it gave off the right internal mammary.

The considerations of the functions, size, and situation of the innominata, as well as its relations not only to the heart and aorta but also to the surrounding parts, at all times rendered the study of this vessel a subject of interest and importance in the eyes of the operative surgeon; but it is comparatively of later years since Mr. Allan Burns first directed the attention of the profession to the fact that circulation through this vessel might be suddenly arrested without the functions of the brain, and power of the superior extremity being of necessity destroyed, that surgeons have been found bold enough to attempt placing a ligature upon it.

There are three cases upon record in which a ligature has been placed upon the trunk of the innominata itself. The first operation was performed by Professor Mott, of New York, on the 11th of May, 1818. The patient died on the 26th day after the operation from repeated hemorrhage resulting from ulceration and yielding of the vessel.

The second was by Professor Graeff on the 5th of March, 1829. The patient died on the sixty-seventh day after the operation from repeated hemorrhage.

The third was by Mr. Lizars at the Edinburgh Royal Infirmary, on the 31st of May, 1837. The patient died on the twenty-first day after the operation, likewise from hemorrhage.

This artery was likewise tied by Mr. Bland on the 25th March, 1832. The patient died on the 13th of April, three weeks after the operation.

The following are the steps of the operation. The patient being placed in the horizontal position with the shoulders raised and the head thrown back, make an incision of about two inches upwards along the anterior margin of the sterno-cleido-mastoid muscle of the right side, commencing at the upper edge of the sternum: from the inferior extremity of this carry another of similar extent outwards upon the right clavicle; these should divide the skin and subcutaneous tissue: next dissect this flap from below upwards and reflect it, exposing the platisma muscle; cut through this muscle and the superficial fascia beneath it, and then carefully detach the sternal insertion of the sterno-mastoid muscle and anterior layer of deep fascia, and should there not be sufficient space a portion of the clavicular fibres of the muscle. Having proceeded thus far, cut through the second layer of deep fascia, avoiding the vein already described as crossing this space, and subsequently divide the sterno-hyoid and thyroid muscles upon a director; this will expose the third layer of deep fascia covering the vessel; a portion of this should be pinched up by forceps and an opening very cautiously made in it, after which, with the handle of a scalpel, clear the artery of its surrounding cellular tissue, draw the thyroid veins to the left side, the right pneumo-gastric nerve and internal jugular vein to the right, and pressing the left brachio-cephalic vein downwards, carry the ligature obliquely upwards and inwards, or from the right to the left side, keeping it close to the vessel to avoid implicating the cardiac nerves.

Other plans of operation have been recommended, but the above appears to me to be the best, as it gives the surgeon room and opportunity to see the state of parts through which he cuts, and enables him, if necessary, to tie either the subclavian or carotid, or both, without further trouble or inconvenience.

It has been recommended to remove a portion of the first bone of the sternum; but the idea will scarcely be entertained by any surgeon possessing a proper knowledge of the parts, or who is competent to perform the operation.

In the year 1827 Mr. Wardrop introduced a new method for treating aneurisms of the innominata in imitation of Brasdor's plan of tying the vessel beyond the aneurismal tumour. He tied the subclavian artery, having found that the circulation through the carotid was very weak if not quite obliterated.

The patient was a Mrs. Denmark. The results of this case have been recorded as favourable, but erroneously so. Mrs. Denmark died in the year 1829 of the same malady on account of which she underwent the operation.

Altogether his example has been followed in six cases, with various results.

In the first, Mr. Evans, of Belper in Derbyshire, in the year 1828, tied the carotid for aneurism of the innominata and commencement of the carotid. The patient recovered.

In the second, M. Dupuytren, on the 12th of June, 1829, tied the subclavian for aneurism of the innominata. The patient died nine days afterwards.

In the third, Professor Mott tied the carotid for aneurism of the innominata on the 26th of September, 1829. The patient recovered.

In the fourth, Dr. Hall, of Baltimore, tied the carotid for aneurism of the innominata on the 7th of September, 1830. The patient died five days afterwards.

In the fifth, M. Morrisson, of Buenos Ayres, tied the common carotid for aneurism of the innominata on the 8th of November, 1832. The patient died twenty months afterwards.

In the last, Mr. Fearn, of Derby, tied the carotid for the same complaint in the year 1836, the circulation through the subclavian being almost obliterated. Subsequent to the operation the patient suffered from repeated attacks of bronchitis, with difficulty of breathing and cough upon the slightest exertion, so much so that on the 26th of July, 1838, she was again placed under Mr. Fearn's care. That gentleman concluding, after a careful examination, that, in consequence of the circulation having been renewed through the subclavian artery, the previous operation had not cured the aneurism (which he now found implicated the commencement of the subclavian artery) determined upon placing a ligature upon this vessel where it passes over the first rib, and performed the operation on the 2d of August, 1838, apparently with complete success.

Here then are the results of the two plans of operation hitherto performed in connection with the innominata. In Hunter's all the patients were lost from repeated hemorrhage, although, as we have seen in one instance, the individual survived the operation above two months. Mr. Pattison, in his account of Mr. Mott's case, appears to attribute the loss of the patient to the fact of that gentleman's having commenced by exposing the subclavian artery, thereby depriving the vessel of nourishment by the unnecessary destruction of the vasa vasorum; this might in some degree have led to the result; but I am more inclined to believe that it occurred from other causes over which the surgeon unfortunately has no controul, I allude to the situation, origin, and direction of the vessel itself. We have already observed that it arises from the commencement of the transverse portion of the arch of the aorta, and is consequently in a direct line with the aorto-ventricular opening, being in point of direction the continuation of the ascending portion of the arch of the aorta. It thus receives the undiminished impetus bestowed upon the blood by the contraction of the ventricle at a distance, barely of three inches; hence, when a ligature is placed upon it, the force of the ventricle is directed more immediately upon this part of the artery, a coagulum can scarcely, if at all, be formed here, and the ligature being subjected to the constant efforts of the blood to overcome it, instead of ulcerating its way out, cleanly dividing the vessels, produces inflammation and ulceration in its neighbourhood by constant friction, and thus gives rise to the fatal results.

If I have here taken a correct view of the causes which have led to the fatal termination in all the cases where Hunter's method has been adopted, (and I have no reason to doubt having done so, as we learn from the accounts of the post-mortem examinations both in Mott's and Lizars' cases, that the coagulum was very imperfectly formed, and that extensive ulceration of the vessel had ensued in the neighbourhood of the ligature,) I am quite justified in adding that it is an operation which should never be performed unless in those cases where it presents the only chance of lengthening the patient's existence.

This remark, however, does not apply to the plan introduced by Mr. Wardrop in imitation of Brasdor. Out of the seven cases in which it has hitherto been employed, and which I have here cited, three were successful, and of the other four one lived for a period of twenty months, and another (Mrs. Denmark) for about two years after the operation.

(H. Hancock.)

INSECTA.—(εντομα; Fr. *Insecte;* Germ. *Insecten.)* A class of Invertebrate animals, which, as constituted by Linnæus, formerly included several remarkable groups, which are now arranged as distinct classes. Besides the true Insecta these were Crustacea, Arachnida, and Myriapoda. Modern naturalists have been almost unanimous in separating these groups from Insects, which, in their perfect state, differ from them in being constantly Hexapods. Besides this very marked character, Insects differ from Crustacea in respiring atmospheric air by means of ramified tracheæ—from Arachnida in the body being constantly divided into a distinct head, thorax, and abdomen—and from Myriapoda, in the body being composed in general of thirteen segments.

Insects, therefore, may be characterized as a class of hexapodous invertebrate animals, which possess antennæ, and have the body composed of several segments, united into three and sometimes four distinct parts, articulated together, consisting of head, thorax, and abdomen. They breathe atmospheric air by means of lateral spiracles and tracheæ, and pass through a succession of changes of form, or shed their external covering before they arrive at their perfect state. They also possess other characters in common with the Myriapods and Arachnidans, as the circulation of the nutritive fluids by means of a pulsatory dorsal vessel, divided into distinct chambers or compartments, and the respiration of atmospheric air by means of spiracular orifices, and with the Crustaceans in being in general oviparous.

Anatomically considered, Insects, as remarked by Professors Grant* and Owen,† bear a remarkable analogy amongst invertebrated animals to Birds amongst the vertebrated. They constitute the most beautiful, most active, and most highly organized of any of the Invertebrated classes. Like Birds, they are inhabitants of the air, the earth, and the waters, and the dominion of some of them is even extended to the bodies of other animals. Physiologically considered, they also resemble "the feathered tribes of air." Like them they have a more voluminous and extensive respiration, and a greater power of generating and of maintaining a higher temperature of body than any other class in the division of animals to which they respectively belong. The number of species is greater than is known in any other division of the animal kingdom, and is only exceeded, as in Fishes, by the almost countless myriads of individuals which every species produces. The metamorphoses which most of them undergo before they arrive at the perfect state, and are able to fulfil all the ends of their existence, are more curious and striking than in any other class, and in the greater number of species the same individual differs so materially at its different periods of life, both in its internal as well as external conformation, in its habits, locality, and kind of food, that it becomes one of the most interesting investigations of the physiologist to ascertain the manner in which these changes are effected,—to trace the successive steps by which that despised and almost unnoticed larva that but a few days before was grovelling on the earth, with its internal organization fitted only for the reception and assimilation of the grossest vegetable matter, has had the whole of its external form so completely changed as now to have become an object of admiration and delight, and able to "spurn the dull earth" and wing its way into the open atmosphere, with its internal parts adapted only for the reception of the purest and most concentrated aliment, now rendered absolutely necessary for the support and renovation of its redoubled energies. But this condition of insect life is greatly modified in the different families. Thus the most active species are diurnal insects, and are those which have the greatest development of the organs of locomotion, accompanied, as in birds of flight, by a more voluminous respiration, and a greater force and rapidity of circulation, and consequent muscular energy and necessity for a constant supply of food, as is well exemplified in the hive-bee and its affinities. But although many species are furnished with wings for flight, these organs are not universally met with in the species of every order, neither are they constant in the two sexes of the same species. In these instances it is always the male individual that is furnished with them. These exceptions occur among the beetles, as in the glow-worm (*Lampyris*, *fig.* 335 & 336), in the *Blattæ* or cock-roaches (*fig.* 343), in some species of of moths (*Bombycidæ*), and in the plant-lice (*Aphides*), while in other species, the ants, the individuals are furnished with wings only at a particular season of the year, and lose them immediately after the fulfilment of certain natural functions. In each of these instances, as noticed by Mr. Owen* in the ostrich and other birds unaccustomed to flight, the extent to which the respiratory organs are developed is in proportion to the habits of the species, being greatest in those of flight and least in those which reside constantly on the ground. Indeed, so varied are the forms, so different the habits and modes of life, that the division of Insects into families and tribes has afforded no small amount of difficulty to the scientific naturalist in arranging them according to their most natural affinities, and hence a great variety of systems have been proposed for this purpose, all of which perhaps are open to many objections.

But it is not in the mere division of Insects into families and tribes that the philosophic naturalist meets with the greatest difficulty, but in assigning the situation which the whole class ought to occupy in the animal kingdom, both in regard to Insects themselves, and in their relations to other animals. Whether naturalists adopt as the basis of arrangement the development and perfection of the nervous system or that of the skeleton, with the organs of circulation and digestion, as compared with similar parts in other classes, they have usually been led to admit that while Insects are superior to many groups, which have been placed above them, in the former respects, they are inferior to them in the latter; and hence, although that portion of the animal body which is so all-important to active existence, the nervous system, is employed without hesitation as the fundamental type and principle of arrangement, and in the vertebrated classes is scarcely ever departed from, it has become in the hands of many naturalists only of secondary importance in the invertebrated, and the greater perfection

* Lectures on Comp. Anatomy, Lancet, 1833-34.
† See AVES, vol. i. p. 246.

* See AVES, vol. i. p. 341.

of the circulatory and digestive organs in the molluscous classes has induced them to place these, which in other respects are inferior in development, above the Articulated. We cannot, however, agree with those who consider the organs of nutrition alone of sufficient importance to allow of this deviation from the fundamental principle of arrangement, neither can we admit with others that the nervous system of the higher Articulata is inferior to that of the higher Mollusks, the Cephalopoda, while we ourselves claim for the higher Articulata the most decided superiority in the next essential character of arrangement—the development of the skeleton and organs of locomotion.

Without entering further upon this difficult subject, we will simply state our conviction with Carus, Burmeister, and others, that the articulated ought to stand at the head of the invertebrated classes, seeing that they contain among them some of the most completely organized of invertebrated animals. We shall reserve for the present our explanation of the steps by which we propose to pass from the lowest vertebrated forms to these, in our estimation, the highest of the invertebrated, and proceed to consider the arrangement of Insects, as a class, as proposed by different naturalists, before we enter upon an examination of the peculiarities of these animals.

The principles upon which naturalists have attempted to arrange this interesting class have been almost as various as the systems proposed. Aristotle among the ancients arranged Insects with reference to the presence or absence of the organs of flight; and although he was far more successful than many of his successors in separating from Insects the Crustacea, as a distinct class, his arrangement of Insects is not entirely natural, since it separates some of the most nearly connected families. Among the moderns, Aldrovandus, in the beginning of the seventeenth century, divided them into *land* and *water* Insects, and subdivided these groups into families according to the structure of their wings and legs. Swammerdam many years afterwards first proposed to arrange Insects with reference to their *metamorphoses;* first, those which undergo only a partial or incomplete metamorphosis, and, secondly, those which undergo a true or complete one. The latter he again divided into those which undergo a slight change of form, but are active during the pupa state; secondly, those which have distinct limbs but are inactive in that condition; and, lastly, those which have no external development of wings or legs, but remain as inactive ovate pupæ. This was the first step towards arranging Insects upon a truly natural system; since, as Messrs. Kirby and Spence have justly observed,* although the employment of the metamorphoses taken alone leads to an artificial arrangement, it is of the greatest use in connexion with characters taken from the perfect Insect, in forming a natural system. Our illustrious countryman Ray, in the beginning of the eighteenth century, followed the example of Swammerdam in arranging Insects primarily according to their metamorphoses; and Lister, in 1710, followed with a modification of Ray's classification, after which nothing further was proposed until Linnæus published the first edition of his Systema Naturæ in 1735. His arrangement was based upon the form and structure of the wings. By these he divided Insects into three groups. First, those with *four* wings, in which he included in three divisions those Insects which now constitute his orders Coleoptera, Hemiptera, Lepidoptera, Neuroptera, and Hymenoptera. In the second group he placed Insects with two wings, his single order Diptera; and in the third, Insects without wings, his order Aptera. In this arrangement, founded partly upon that of Aristotle, Linnæus was particularly successful in establishing some very natural series, although in including the Crustacea among his Aptera, like Swammerdam and Ray, he receded a little from a natural system. After Linnæus, Degeer and Geoffroy each proposed a new arrangement, but it was not until an entirely new set of organs had been selected by Fabricius that Insects began to be arranged upon truly natural principles. The parts from which Fabricius drew his characters were those of the mouth, by which he divided Insects primarily into two sections, the *Mandibulated*, or those furnished with jaws for comminuting their food, and the *Haustellated*, or those which take their aliment by means of a flexible elongated proboscis, without distinct manducatory organs. But the difficulty of forming a strictly natural system still existed, so long as the characters employed were derived only from particular sets of organs, and not from a consideration of the whole. Cuvier, by founding his arrangement upon an examination of *all* the external organs, and thereby establishing natural families, advanced very far towards the object desired, and was followed by Latreille, Lamarck, Dumeril, Leach, Kirby and Spence, and MacLeay, who continued to improve the arrangement of the class. These have been followed by Messrs. Stephens and Curtis, and very recently by Mr. Westwood, the indefatigable Secretary of the Entomological Society, each of whom has proposed a different arrangement. But none of the systems hitherto proposed are entirely satisfactory, so great indeed is the difficulty of discovering the connecting links of families, which, distributed over the whole globe, are believed to include from 100,000 to 150,000 distinct species; and this difficulty will probably continue until the internal as well as the external organization is better known in a greater number of insects than it is at present, and applied to their arrangement, as has lately been done by Burmeister. In the succeeding pages we shall adopt the arrangement of Mr. Stephens, giving a synoptical view of the families, with the addition of some of the recently established foreign ones, and shall also add particular descriptions of some of the most remarkable, referring our readers for more minute descriptions of them to Mr. Stephens's admirable

* Introd. to Entomol. vol. iv. p. 442.

" Illustrations," and also to the valuable work " An Introduction to the Modern Classification of Insects," now in course of publication by Mr. Westwood, from which work we shall in part derive the characters by which the different tribes are distinguished.

Table of the Arrangement of Insects according to the System of Mr. Stephens.

CLASS *INSECTA.*

SUB-CLASS I.

MANDIBULATA.

COLEOPTERA.

- Sectio 1. Pentamera.
  - Tribe 1. Adephaga. *(Gluttons.)*
    - Sub-tribe 1. Geodephaga. Predaceous ground-feeders.
      - Cicindelidæ *Tiger-beetles.*
      - Brachinidæ
      - Scaritidæ
      - Carabidæ, *fig.* 329, *Ground-beetles.*
      - Harpalidæ
      - Bembidiidæ
      - Elaphridæ
    - Sub-tribe 2. Hydradephaga. Predaceous water-feeders.
      - Diticidæ *Water-beetles.*
      - Gyrinidæ *Whirlgigs.*
  - Tribe 2. Rypophaga. *(Cleansers.)*
    - Sub-tribe 3. Phylhydrida. Water-lovers.
      - Heteroceridæ
      - Parniidæ
      - Limniidæ
      - Helophoridæ
      - Hydrophilidæ, *fig.* 330, *Water-beetles.*
      - Sphæridiidæ
      - Anisotomidæ
    - Sub-tribe 4. Necrophaga. Carrion-feeders.
      - Scaphididæ
      - Silphidæ, *fig.* 331, *Carrion-beetles.*
      - Nitidulidæ
      - Engidæ
      - Paussidæ, *West.*
      - Dermestidæ
- Sectio 2. Pentamera.
  - Helocera 1.
    - Byrrhidæ *Sand-beetles.*
    - Histeridæ *Dung-beetles.*
  - Lamellicornes 2.
    - Lucanidæ *Stag-beetles.*
    - Scarabæidæ
    - Geotrupidæ, *fig.* 332, *Dung-beetles.*
    - Aphodiidæ
    - Trogidæ
    - Dynastidæ, *fig.* 333, *Rhinoceros-beetles.*
    - Rutelidæ
    - Anaplognathidæ
    - Melolonthidæ *Cockchaffers.*
    - Glaphyridæ
    - Cetoniadæ *Sun-beetles.*
  - Subsectio 3. Macrosterni, *West.* Sternoxi. *Lat.* (pointed sternum).
    - Buprestidæ *Gold-beaters.*
    - Eucnemidæ, *West.*
    - Elateridæ, *fig.* 334, *Springing beetles.*
  - Sub-sectio 4. Aprosterni, *West.* Malacodermi, (soft skin.)
    - Cebrionidæ
    - Cyphonidæ
    - Lampyridæ *figs.* 335 & 336 *Glow-worms*
    - Telephoridæ
    - Melyridæ
    - Tillidæ
    - Ptinidæ *Death-watches.*
    - Lymexylonidæ
    - Bostricidæ *Wood-borers.*
    - Scolytidæ

Pseudo-Tetramera, *West.*	Sectio 3.		Rhinchophora 1.	Curculionidæ *fig.* 337 *Hog-beetles.* Attelabidæ, *West.* Salpingidæ
		Longicornes.	Sub-sectio 2.	Cucujidæ Prionidæ *fig.* 338 *Goat-beetles.* Cerambycidæ Lepturidæ
		Phytophaga, Kirby.	Eupoda 1.	Crioceridæ
			Cyclica 2.	Galerucidæ Chrysomelidæ *fig.* 339 Cassidæ *Helmet-beetles.*
Coleoptera. Pseudo-trimera, *West.*	Sectio 4.		Trimeri 3.	Coccinellidæ *Lady-Cows.* Endomychidæ Hispidæ
Hetero-mera.	Sectio 5.			Tenebrionidæ Blapsidæ *fig.* 340 Pimelidæ Helopidæ Lagriidæ, *West.* Melandryidæ Horiidæ, *West.* Mordellidæ Œdemeridæ Pyrochroidæ Cantharidæ *Oil-beetles.* Notoxidæ Scydmænidæ
	Sectio 6.	Brachelytra.		Pselaphidæ Tachyporidæ Staphylinidæ *fig.* 341 Stenidæ Omalidæ — *Rove-beetles.*
Dermaptera.				Forficulidæ *Earwigs.*
Orthoptera.				Gryllidæ *Grasshoppers.* Locustidæ *Locusts.* Achetidæ *fig.* 342 *Crickets.* Phasmadæ Mantidæ, *Praying Insects.* Blattidæ *fig.* 343 *Cock-roaches.*
Neuroptera.		Panorpina 1.		Boreidæ Panorpidæ *fig.* 344 *Scorpion-flies.*
		Anisoptera 2.		Ephemeridæ *fig.* 345 *May-flies.*
Neuroptera.		Libellulina 3.		Agrionidæ Libellulidæ, *Drogon-flies.*
		Termitina 4.		Myrmeleonidæ *Lion-ants.* Hemerobidæ Psocidæ Raphidiidæ Mantispidæ, *West.* Termetidæ, *White Ants.*
		Megaloptera 5.		Sialidæ Perlidæ
Trichoptera.				Philopotamidæ Leptoceridæ Phryganidæ *Caddis-flies.*

HYMENOPTERA.	Terebrantia 1.	Tenthredinidæ *fig.* 355 B.	*Saw-flies.*
		Xiphydriidæ	
		Uroceridæ	
	Pupophaga 2.	Evaniidæ	
		Ichneumonidæ	*Ichneumon-flies.*
		Braconidæ	
		Alysiidæ	
	Aculeata 3.	Formicidæ	*Ants.*
		Mutillidæ	
		Scoliidæ	
		Sapygidæ	
		Pompilidæ	*Sand-wasps.*
		Sphecidæ	
		Larridæ	
		Bembecidæ	
		Crabronidæ	
		Vespidæ *fig.* 346	*Hornets & Wasps.*
		Apidæ	*Bees.*
		Andrenidæ	*Sand-bees.*
HYMENOPTERA.	Tubulifera 4.	Chrysididæ	*Golden wasps.*
		Chalcididæ	
		Proctotrupidæ	
		Cynipidæ	*Gall-flies.*
STREPSIPTERA.		Stylopidæ *fig.* 347	

SUB-CLASS 2.

HAUSTELLATA.

LEPIDOPTERA.	Diurna 1.	Papilionidæ	*Butterflies.*
		Nymphalidæ	
		Lycenidæ	
		Hesperiidæ	
	Crepuscularia 2.	Zygænidæ	*Hawk-moths.*
		Sphingidæ *fig.* 348	
		Sesiidæ	
		Ægeriidæ	
	Pomeridiana 3.	Hepialidæ	*Moths.*
		Notodontidæ	
		Bombycidæ	
		Arctiidæ	
	Nocturna 4.	Lithosiidæ	
		Noctuidæ	
	Semidiurna 5.	Geometridæ	
		Platyptericidæ	
		Pyralidæ	
	Vespertina 6.	Tortricidæ	
		Ypuonomeutidæ	
		Tineidæ	
		Alucitidæ	
DIPTERA.		Culicidæ	*Gnats.*
		Tipulidæ	*Long-legs.*
		Asilidæ *fig.* 349	
		Empidæ	
		Dolichopidæ	
		Rhagionidæ	
		Mydasidæ	
		Tabanidæ	*Blood-suckers.*
		Bombylidæ	

DIPTERA (*contin.*)		Anthracidæ	
		Acroceridæ	
		Stratiomydæ	
		Xylophagidæ	
		Syrphidæ	
		Stomoxydæ	
		Conopidæ	
		Œstridæ	*Gad-flies.*
		Muscidæ	*House-flies, &c.*
HOMALOPTERA.		Hippoboscidæ *fig.* 350	*Forest-flies.*
		Nycteribidæ	
APHANIPTERA.		Pulicidæ	*Fleas.*
APTERA.		Pediculidæ,	*Lice.*
		Nirmidæ *fig.* 351	*Bird-lice.*
HEMIPTERA.	Terrestria 1.	Cimicidæ	*Bugs.*
		Pentatomidæ	
		Coreidæ	
		Reduviidæ	*Masked bugs.*
		Acanthiidæ	
		Hydrometridæ	*Skip-jacks.*
	Aquatica 2.	Nepidæ *fig.* 352	*Water-scorpions.*
		Notonectidæ	*Water-boatmen.*
HOMOPTERA.		Cicadiidæ *fig.* 353	*Tree-hoppers.*
		Cercopidæ	
		Psyllidæ	
		Thripidæ	
		Aphidæ	*Plant-lice.*
		Coccidæ	

CLASS INSECTA, (Insects.)

Animal Invertebrated, hexapodous, undergoes metamorphoses.

Body in general winged, and composed of segments divided into three distinct regions.

Skeleton external, formed of the dermal coverings.

Antennæ two, respiration aerial, sexes distinct.

Sub-class 1. MANDIBULATA.

Order I. *COLEOPTERA.*

Wings four, anterior ones (elytra) hard, coriaceous, covering the abdomen, divided by a longitudinal suture, not employed in flight; posterior ones usually jointed, with their apex acute. Metamorphosis complete.

The *Beetles* constitute by far the most numerous and varied tribes in any order, and differ as much in habits and size as in general form. They include every variety of conformation and bulk from the minute but rapacious *Staphylinidæ*, to the gigantic phytophagous *Dynastidæ* and *Cetoniidæ*. So numerous are the species that, according to Burmeister,* there are 28,000 in the Berlin collection alone, while the whole that is known is supposed to exceed 36,000. In Mr. Stephens's arrangement they have been divided into families which amount to more than one-third of the whole class, and these families are grouped into six sections. The first section includes most of the predaceous beetles, and is divided into two tribes, *Adephaga* and *Rhypophaga*, and these are divided into four *sub-tribes*.

* Manual of Entomology (Translation), p. 583.

The first sub-tribe, *Geodephaga*, includes the predaceous Ground-beetles, which are characterized by the elegance of their form and alacrity of their movements. They have six projecting palpi,* their mandibles are strong, curved, and pointed, and their legs slender and formed for running, (*fig.* 329.) Some of

Fig. 329.

Carabus monilis, (Ground-beetle, male.)

* The third pair of palpi are maxillary, and are the analogues of what we shall hereafter describe as the *Galea*.

this division, the *Cicindelidæ*, are extremely voracious, and most of them feed upon dead animal substances, although some of the *Harpalidæ* are known to be vegetable feeders. The second sub-tribe, *Hydradephaga*, includes the predaceous water-beetles, and the third, *Philhydrida*, a variety of families allied to each other by similarity in general structure, by inhabiting water or damp situations, and by subsisting upon decaying animal and vegetable substances, fungi, &c. Amongst the aquatic species is one of the largest British beetles, *Hydröus piceus* (*fig*. 330).

Fig. 330.

Hydröus piceus, (Great water-beetle, male.)

All the water-beetles are characterized by their four posterior legs being formed peculiarly for swimming; they are ciliated along the tarsal joints, the last of which is furnished with a very minute claw. The insects of the third sub-tribe, the predaceous water-beetles, *Dyticidæ*, are distinguished from those of the second by the latter having long and slender instead of clavated antennæ, and by their possessing *six* instead of only *four* palpi. The males of both sub-tribes have one or more joints of their anterior tarsi (*fig*. 330, A.) very much dilated, by means of which they attach themselves strongly to the females. Their larvæ are active

Fig. 331.

Necrophorus vespillo, (Burying-beetle).

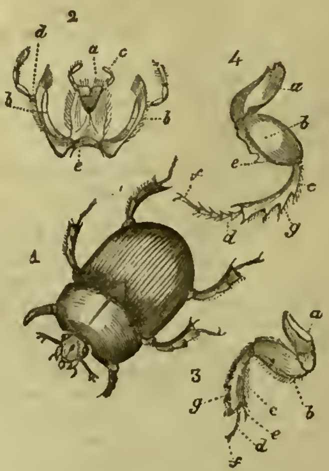
and voracious. The fourth sub-tribe, *Necrophaga*, includes the carrion and burying-beetles (*fig*. 331), so called from their habit of burying small dead animals in the ground, by digging away the earth from beneath them, and thus allowing them to sink down, and then depositing their eggs in the bodies. The genera of this division differ considerably from each other, but may be characterized as in general possessing abruptly clavated antennæ, an oval or oblong body, with the elytra often truncated, and the legs strong and formed for running.

The second section is also divided into four tribes, which include insects of different habits and conformation.

In the first tribe, *Helocera*, the insects are of an oval shape, and have the antennæ geniculated, and terminated by an oval club. Their legs are flattened, broad, and formed for burrowing, and are terminated by very minute tarsi. Their bodies are exceedingly hard; they feed upon decaying animal matter, and when touched simulate the appearance of death.

The second tribe, *Lamellicornes*, are a very natural group. They are distinguished by the club of the antennæ being divided into plates or lamellæ. Their legs are thick, strong, and deeply notched, and the tarsi of the anterior pair in some families are very minute. They are either stercoraceous or vegetable feeders, subsisting, like the common dung-beetle, *Geotrupes stercorarius** (*fig*. 332), upon decomposing vegetable substances, or like the chaffer-beetles, *Melolonthidæ*, upon the foliage of shrubs or trees, or like the *Dynastidæ*†

Fig. 332.



Geotrupes stercorarius, (Dung-beetle).

* This drawing is of a specimen captured by the writer of the present article in the summer of 1829, and affords a curious instance of malformation of the anterior extremities with the tibiæ lunated and acuminated, without dentations, the tarsi entirely wanting. It is now in the cabinet of the Rev. F. W. Hope.

† It is asserted that the *Dynastes Hercules* grasps

(*fig.* 333) upon the sap that flows from the wounded bark or roots.

Fig. 333.

Dynastes Hercules.

a, the epicranium; *b*, the clypeus; *c*, labrum; *d*, mandibles; *e*, maxilla and palpi; *f*, labial palpi; *g*, antennæ; *h*, the eye; *i*, prothorax and horn; *k*, scutellum; *l*, elytra; *m*, abdomen; *n*, femur; *o*, tibia; *p*, the tarsus; *q*, unguis.

The third tribe, *Macrosterni*, Westw. includes a family of insects, *Elateridæ*, (*fig.* 334),

Fig. 334.

Elater noctilucus, (Click beetle, female.) West-Indian fire-beetle.

or springing-beetles, which are commonly known in their state of larvæ, as the *wire-worm*, and are often exceedingly injurious to meadows and corn-fields. In some counties many acres of meadow-land have occasionally been destroyed by these insects attacking the roots of the grass, which then quickly perishes.* They are characterized in their perfect state by having an elongated body, with the head sunk deeply into a notch in the prothorax; by their fan-shaped or serrated antennæ, and by a long spine or process directed backwards from the pro-sternum or under-surface of the prothorax, and received into a groove in the meso-sternum. By means of this spine they are enabled, on bending the body and then suddenly retracting it, to spring to a considerable distance. From this act they have derived their name. Some species of the family are remarkable for shining brilliantly at night, and are the noted fire-flies of the West Indies.

In the fourth tribe, *Aprosterni*, Westw., there are insects equally curious and destructive as in the preceding. The true Aprosterni are distinguished chiefly by their soft flexible elytra, by an entire absence of any process from the sternal surface of the prothorax, and by the dilatation of the margins of the pro-

the branch of a tree between its frontal (*a*) and thoracic horn (*i*), and then whirls itself round to cut through the bark and occasion a flow of sap, upon which the insect is said to subsist. Improbable as the statement appears, from the circumstance that the thoracic horn is wanting in the female, we were once assured of its correctness, by a gentleman who affirmed to us he had witnessed the fact. A similar act is attributed to the male stag-beetle, *Lucanus cervus*, which is furnished with mandibles nearly half the length of its whole body, while in the female they are not larger than in other insects of the same size.

* The Rev. F. W. Hope has ascertained that the larvæ of this family were exceedingly destructive to the potato crops in the West of England during the summer of 1838, an account of which was read at the meeting of the Entomological Society, April 1st, 1839.

thorax, which anteriorly covers the base of the head. Some exceptions exist to these characters in the *Bostricidæ* and their congeners, which ought perhaps to be removed to another tribe. In the *Lampyridæ* (glow-worms), (*figs.* 335 and 336), there is an example of a circum-

Fig. 335. *Fig.* 336.

Male. *Female.*
Lampyris noctiluca, (Glow-worm).

stance not uncommon among insects, the possession of wings by the male sex and their entire absence in the female. The *Ptinidæ* or death-watches, and other Xylophagous insects of this tribe, although small, are exceedingly destructive to furniture and the wood of houses; and the *Bostricidæ* aud *Scolytidæ* to living trees. It is an insect of this family, *Scolytus destructor*, that of late years has occasioned incalculable mischief to the elms in St. James's Park and Kensington Gardens, and in the park at Brussels. So lately as the summer of 1836 nearly eighty fine elms were cut down at the latter place and its neighbourhood, in consequence of decay occasioned by this pest.* Another species *S. pygmæus*, which attacks the oak, has destroyed many thousands of young trees in the *Bois de Vincennes.*† Another genus, *Tomicus typographus*, was so destructive in the Hartz Forest in Germany during a series of years from the beginning of the last century to 1783, that the number of trees destroyed by it in that forest alone was calculated at a million and a half.‡

In the third section, *Pseudo-tetramera*, WESTW., the species have one false and four distinct tarsal joints to their legs, with pulvilli or hairy cushion on their under surface, and the ante-penultimate joint is bilobed and broader than the others. The section is divided into two tribes.

In the first tribe, *Rhynchophora*, (*fig.* 337), the head is elongated in the form of a snout or rostrum, at the extremity of which is the mouth, and at the sides are inserted the antennæ which are usually geniculated and club-shaped. The larvæ of these insects are generally apodal, and many species are exceedingly injurious to the blossoms of the apple, pear, and other fruit-trees. Both the larva and perfect individual of one minute species, well known as the "weevil," *Calandra granaria*, closely allied to *fig.* 337, occasion immense losses in the storehouses of the factor by attacking and destroying his corn. The parent insect not

Fig. 337.

Calandra longipes, male.

only feeds upon the corn itself, but deposits a single egg in every grain, and the larva when hatched devours the whole excepting the husk.

The second tribe, *Longicornes*, (*fig.* 338),

Fig. 338.

Cerambyx latipes.

are known chiefly by the great length of the antennæ, which usually exceeds that of the whole body. Their mandibles are strong and pointed; the body elongated and depressed; and the prothorax, which is often tuberculated or spined, is narrower than the abdomen. Their larvæ are short, thick, and apodal, and are furnished with strong mandibles, and live beneath the bark or in the wood of trees.

The third tribe, *Phytophaga*, KIRBY, is also composed of pseudo-tetramerous insects, with pulvilli on their tarsi, and is divided into two sub-tribes. In the first, *Eupoda*, the body is of an elongated oval form, the head is sunk deeply into a narrow prothorax, and the thighs of the posterior legs are greatly enlarged. In the second sub-tribe, *Cyclica*, the body is of a rounded or oblong oval (*fig.* 339), the base of the prothorax is narrower than that of the elytra, and the antennæ, which are of moderate length, are inserted widely apart from each

* Trans. Ent. Society, vol. ii. p. xvi.
† Annal. Soc. Ent. France. 1836, pp. xvi. and xxx. 1837, p. iv.
‡ Latreille, Hist. Nat. tom. ii. Gmelin, Abhand. über die Wurmtroekniss. Leipz. 1787. Westwood, Introduction, &c. vol. i. p. 352.

Fig. 339.

Timarcha tenebricosa.

other. It is an insect of this tribe, *Haltica nemorum*, that often occasions so much injury to the agriculturist by destroying his crops of turnips immediately after the young plant appears above ground. The perfect beetle, scarcely larger than a millet-seed, deposits its eggs upon the under surface of the first leaves, and the larva when hatched penetrates into the substance of the parenchymatous tissue, between the cuticle of the upper and under surface of the leaf, where it lives until it is ready to undergo its transformations in the ground.* In some years the plants are attacked by such prodigious numbers of these insects that many thousand of acres are destroyed in a few days. The loss sustained by the devastations of this insect in Devonshire in 1786, is said to have been not less than £100,000.†

In the fourth section, *Pseudo-trimera*, West. the insects have only three distinct joints in their tarsi, although a fourth one, exceedingly minute, and which like the additional one in the Tetramera was first noticed by Messrs. Kirby and Spence,‡ exists at the articulation of the last joint, as in the insects of the third section. The *Pseudo-trimera* are distinguished by their tarsi, by their oval or hemispheric shape, and by the antennæ ending in a three-jointed club. The larvæ are hexapodous and active; those of the common lady-cow, *Coccinella*, feed upon aphides, and other genera upon fungi.

In the fifth section, *Heteromera*, there are five joints in the first and second pairs of legs, but only four in the third, (*fig.* 340). The palpi, four in number, are large and projecting, and the antennæ, usually filiform or moniliform, are never terminated by a pectinated club. It includes many genera of dissimilar habits, the darkling-beetles, *Blapsidæ*, the meal-beetles, *Tenebrionidæ*, and the *Cantharidæ*, the oil-beetles and blister-flies.

Fig. 340.

Blaps mortisaga, (Darkling-beetle).

In the sixth section, *Brachelytra*, (*fig.* 341),

Fig. 341.

Creophilus maxillosus, (Rove-beetle).

the body is elongated, and terminated by two exsertile papillæ, the elytra short, quadrate, and often covering only the meso- and metathorax; the true or posterior wings, folded beneath the elytra; head broad and flattened, mandibles large, hooked, and pointed, antennæ often enlarged towards their extremities, and the tarsi of all the legs five-jointed. The larvæ are active and voracious, and undergo a complete metamorphosis.

The situation assigned to this group of insects by different systematists has varied considerably. Many authors have placed them with the pentamerous insects, unto which from their habits and number of joints in their tarsi they appear to belong. Thus Dejean assigned them a position between the *Hydradephaga* and *Phylhydrida*; Dr. Leach* between the *Silphidæ* and *Dermestidæ*; Mr. Kirby, in his recent work,† between the *Adephaga* and *Necrophaga*; and, lastly, Mr. Westwood‡ between the *Dermestidæ* and *Byrrhidæ*. On the other hand Mr. Stephens, after Linné and Fabricius, has placed them at the end of his Coleoptera, thinking, probably, as Mr. Kirby has remarked, that they are connected with the following orders, *Dermaptera* and *Orthoptera*, by their abbreviated elytra, and by their anal papillæ or styles; as they are also, probably, by the shortness and structure of their alimentary canal, which in many respects as much resembles that of the *Forficulidæ* or *Blattidæ*, as the *Adephaga* or *Necrophaga*.

Order II. *DERMAPTERA*.

Wings four, anterior ones (elytra) crustaceous, quadrate, and divided by a straight suture; not employed in flight; posterior ones membranous, folded longitudinally and transversely, only partially covered by the elytra; *anus* armed with large moveable forceps. *Larva* active, resembles the perfect insect. Metamorphosis incomplete.

The single family of this order, *Forficulidæ*, (Earwigs) are readily distinguished from the

* Le Keux, Trans. Ent. Society, vol. ii. p. 24.
† Kirby and Spence, Introduct. to Entom. vol. i. p. 185.
‡ Id. vol. iii. p. 683, 4.

* Article Entomology, Edin. Encycl. vol. ix.
† Insects, Fauna Boreali-Americana, p. 85 et seq. 1837.
‡ Introduc. to the Modern Classification of Insects, &c. 1838-9.

Brachelytra by the forcipated anus, the great length of the antennæ, and the breadth and circularity of the wings when expanded, compared with the narrow and acute ones of the latter insects.

Order III. *ORTHOPTERA.*

Wings four, anterior ones coriaceous, reticulated, and overlapping each other, posterior ones partly coriaceous partly membranous, reticulated, and folded longitudinally; head vertical; mandibles, thick, strong, and dentated; *palpi* four, maxillary ones in most genera five-jointed. Metamorphosis incomplete. The larvæ are active, and resemble the perfect insect.

In this Order are included many remarkable families. The *Locustidæ*, Locusts; the *Achetidæ*, the House and Mole-crickets (*fig.* 342);

Fig. 342.

Gryllotalpa vulgaris, (male). Mole-cricket.

the *Mantidæ*, or praying insects; and the *Blattidæ* (*fig.* 343), or destructive Cock-roaches.

Fig. 343.

Blatta Orientalis (male.) The Cock-roach.

Order IV. *NEUROPTERA.*

Wings four, linear, naked, membranaceous, and minutely reticulated; all employed in flight; head large, eyes projecting; body linear.

This Order is divided into five sections.

In the first section, *Panorpina*, or Scorpion-flies (*fig.* 344), the head is produced anteriorly

Fig. 344.

Panorpa communis (male). Scorpion-fly. (Samouelle.)

into a short rostrum, at the extremity of which is the mouth, as in some of the *Curculionidæ;* the antennæ are long and filiform, and the body is slender, and terminates in the female in an acute ovipositor, and in the male in an articulated claw (*a*) like the tail of the Scorpion, from which the insect derives its name. The larva is unknown, but is supposed to undergo a complete metamorphosis. The pupa or nymph is inactive.* The perfect insect is predaceous.

In the second section, the *Anisoptera* or *Ephemeridæ*, May-flies (*fig.* 345), are distinguished

Fig. 345.

Ephemera vulgata. May-fly. (Samouelle.)

by the smallness of their posterior wings, by the shortness of the antennæ, and by the long setæ at the extremity of the abdomen. The larvæ are active, and much resemble the perfect insect. They reside constantly beneath stones, or in burrows at the bottom of running streams,† and undergo an incomplete metamorphosis. The pupa is active like the larva. In the perfect insect, which takes no food, and is proverbially noted for the shortness of its existence, which is seldom more than a few hours, the parts of the mouth are almost entirely obliterated.

In the third section, *Libellulina*, Dragon-flies, all the wings are of equal size, eyes large and prominent, antennæ minute, body slender,

* Westwood, Introduction to Entomology, vol. ii. p. 53.

† Ibid. vol. ii. p. 29.

and tarsi with only three joints. The larva and pupa are active, voracious, and aquatic, and like those of the Ephemera, resemble the perfect insect. Metamorphosis incomplete.

The fourth section, *Termitina*, have large and nearly equal sized wings, either disposed horizontally or erect, with the antennæ rather long and filiform, as in *Hemerobidæ*, lace-winged flies, or club-shaped, as in the ant-lions, *Myrmelionidæ*. The larvæ are active and predaceous. The ant-lion lives at the bottom of a minute pit-fall, which it digs to entrap other insects. The *Hemerobius* lives among crowds of *Aphides*, plant-lice, upon which it feeds, while the larvæ of the *Termites*, or white ants, live in societies of almost innumerable individuals. The first two of these families undergo a complete metamorphosis, and the insects in the condition of nymphs are inactive in the earlier stages of the pupa state. In the latter family the larva and pupa greatly resemble the perfect insect, and are active at every period of existence.

The fifth section, *Megaloptera*, have the posterior wings rather larger than the anterior, the head and pro-thorax large and quadrate, and the antennæ long and setaceous. Metamorphosis incomplete. According to Mr. Westwood * the larva and pupa are active, and not inclosed in a case, are aquatic, and greatly resemble the perfect insect.

Order V. *TRICHOPTERA*.

Wings four, deflexed, hairy, not reticulated; texture slightly coriaceous; posterior pair plicated, broader than the anterior; antennæ very long, setaceous; ocelli three; maxillary palpi long; "mouth unfitted for mastication; mandibles rudimental." Metamorphosis complete.

The perfect insects of this Order, called by fishermen "stone-flies," † are found on water-plants, stems of trees, and palings by the side of rivers. The larvæ, the caddis, or case-worms, are aquatic, and reside in little cases which they carry about with them, and construct by uniting bits of wood, minute shells, and fragments of stones, which are woven together with threads of fine silk. The pupa is semi-complete, and quiescent during the greater part of its period, but becomes active, and creeps out of the water upon the stems of plants before changing to the perfect insect.

Order VI. *HYMENOPTERA*.

Wings four, membranous with large areolar cells; posterior pair smaller than the anterior; antennæ longer than the head; eyes large; ocelli three. Mandibles strong, and generally dentated; maxillæ largely developed; labium and ligula together forming a long proboscis sheathed by the maxillæ. Female armed either with a borer or sting. Metamorphosis complete.

This Order is divided into four sections.

In the first, *Terebrantia*, borers, the abdomen is sessile or united to the thorax by its whole breadth. In one family, the saw-flies, (*fig.* 355, B), the abdomen is armed with two serrated partially concealed plates, with which the insect cuts through the bark or pierces the leaves of plants to deposit her eggs. In another family, *Uroceridæ*, the true borers, the abdomen is armed with a strong projecting cylindrical spiculum, which is grooved on its under surface, and contains two smaller dentated spicula, analogous to the plates of the saw-fly, with which the insect bores into timber-trees and deposits its eggs. The larvæ are active and extremely voracious. Those of the saw-flies, *pseudo-caterpillars* (*fig.* 355, A,) devour the leaves of plants, and are sometimes exceedingly injurious to the agriculturist, as has been the case with those of *Athalia centifoliæ* to the turnip crops during the last few summers,* while the larvæ of *Uroceridæ* are said to be equally destructive to living trees.†

In the second section, *Pupophaga*, the ichneumon flies, the body is long and slender, and the abdomen is petiolated, or connected only by a constricted neck with the thorax, and the antennæ are long and setaceous. The larvæ are apodal, and are parasitic on other insects.

In the third section, *Aculeata*, the body is short and pedunculated, and furnished with a true aculeus, which is used as a weapon of defence. The larvæ are apodal, are fed by the parent or by sterile females, and generally reside in cells. Some species are solitary, and feed their young with the bodies of other insects, *Crabronidæ*; others live in society, and are either omnivorous, as the *Formicidæ*, ants, and *Vespidæ*, hornets (*fig.* 346) and wasps, or

Fig. 346.

Vespa crabro. The Hornet. (Samouelle.)

mellivorous, as the humble and hive bees, (*Apidæ*), which feed their young upon a mixture of pollen and honey.

In the fourth section, *Tubulifera*, the body is short, slightly convex, and often compressed laterally; the posterior wings are almost entirely destitute of nervures, and the abdomen is

* Introduct. to Entom. vol. ii. p. 23.

† Yarrell's British Fishes, vol. ii. p. 84.

* Prize Essay of the Entomological Society on the Anatomy, Habits, and Economy of Athalia centifolia, 1838, by G. Newport.

† Westwood, Introd. &c. vol. ii. p. 119. Mr. Ruddon in Trans. Entomological Society, vol. i. p. lxxxv.

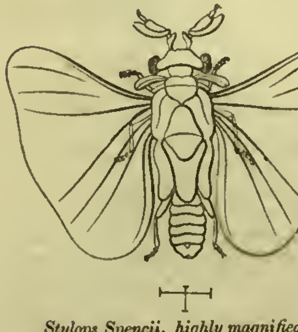
furnished either with a telescopic, jointed tube, as in the *Chrysididæ*, golden wasps, or with a spiculiferous ovipositor, which is partly retractile within the abdomen, as in the *Cynipidæ*, gall-flies. The former of these insects deposit their eggs either in the cells of other Hymenoptera or in the bodies of active Lepidopterous larvæ, before their change to the pupa state, and thus resemble in habits the true *Ichneumonidæ*. The *Cynipidæ* puncture the leaves or bark of trees and plants, and deposit their eggs, at the same time injecting into the wound a fluid which occasions the growth of galls or excrescences, the interior of which is both food and habitation for the young larva. In their habits, as Mr. Westwood has well observed, the *Cynipidæ* very closely approach the *Terebrantia*, and seem to form a link of communication between them and the true *Ichneumonidæ*.

Order VII. *STREPSIPTERA*.

Wings four, the anterior ones (pseudelytra) very minute, twisted, and projecting transversely from the sides of the meso-thorax like little scales; posterior pair very large, fan-shaped, with radiating nervures, and plicated when folded. Body linear, abdomen compressed, metathorax very large; meso- and prothorax very short; head transverse, broader than the pro-thorax; eyes slightly pedunculated; antennæ inserted into an excavation in the front, and terminated by two branches; mouth unfitted for taking food; maxillæ minute, projecting, stiliform; labial palpi very large.* Metamorphosis complete.

These insects, *Stylopidæ*, are parasitic and exceedingly minute; they undergo their transformations in the bodies of perfect wasps and bees, and pass out between the abdominal segment. Latreille has aptly designated them the Œstri of insects. It is entirely unknown where the eggs are deposited, whether in the body of the wasp or bee, or in that of its larva. Four distinct genera of these minute parasites have already been discovered. *Stylops Spencii (fig.* 347) is one of the largest species, but is scarcely more than two lines in length, while the smallest species yet known, *Elenchus Templetonii*, West.* is not more than two-thirds of a line, or scarcely a line in breadth with its wings expanded.

Fig. 347.



Stylops Spencii, highly magnified. Westwood, Ent. Trans.

The anomalous structure of these insects has been a matter of great difficulty to entomologists. Rossi, who first discovered an insect of this order, placed it with the Hymenoptera. Mr. Kirby at first thought that it ought to follow the Coleoptera, on account of its elytra and kind of metamorphosis; Mr. Mac Leay† placed it between the Coleoptera and Hymenoptera, to both of which, as Mr. Kirby had remarked, it is connected by its metamorphosis. Dr. Leach placed it between the Coleoptera and Dermaptera, while Mr. Newman, who at first thought it belonged to Hymenoptera,‡ afterwards placed it with the Diptera,§ between which two Orders it was also placed by M. Samouelle.‖ It has, however, been satisfactorily shown by Mr. Westwood¶ that it is an imperfectly mandibulated insect, and that if the structure of its oral apparatus, the shortness of its first thoracic segments, and its kind of metamorphosis be considered, it ought to be placed between the Hymenoptera and Lepidoptera, at the end of the *Mandibulata*, which situation it occupies in Mr. Stephens's arrangement.** But the existence of elytra, and the peculiar structure of its wings, ought not to be disregarded, and should any species sufficiently large for minute dissection be hereafter discovered, it is not improbable that an examination of its internal organs may lead to a different opinion.

Sub-Class II. HAUSTELLATA.

Order VIII. *LEPIDOPTERA*.

Wings four, covered with minute scales; mouth proboscidal, formed of two elongated organs, approximated laterally to form a tube; when at rest spirally convoluted. Labial palpi large, hairy. Metamorphosis complete.

The Order is divided into six sections.

First the *Diurna*, day-fliers or butterflies, are distinguished by their long clavated antennæ, which in a few are also slightly hooked at the apex. The wings are large and erect when the insect is at rest. The larva or caterpillar has sixteen feet. Pupa quiescent and complete.

In the second section, *Crepuscularia*, (*fig.* 348,) the sphinges or hawk-moths, the antennæ are prismatic, and generally thickest in the middle, the body large, and tapering towards its extremity, which is often bearded, and the wings are elongated and slightly deflexed when at rest. The pupa is smooth, and inclosed in a cocoon,

* Kirby in Lin. Trans. vol. xi. p. 86. Kirby and Spence, Introduct. vol. iv. p. 378.

* Westwood, Transact. Ent. Society, vol. i. p. 169.

† Horæ Entomolog. p. 371.

‡ Mag. Natur. Histor. No. 23.

§ Ent. Mag. vol. ii. p. 326.

‖ Entomol. Compendium, 1819, p. 288.

¶ Trans. Ent. Society, vol. i. p. 169 et 172.

** This is also the place assigned to it by Mr. Westwood. "Introduction," &c. vol. ii. p. 287, June 1, 1839.

Fig. 348.

Deilephila elpenor, the Elephant Sphinx.

or in a cell of the earth. The perfect insects fly very swiftly, and are mostly abroad at twilight.

In the third section, *Pomeridiana*, which includes the silkworm-moths, the body is short and thick, proboscis in general very short, antennæ tapering, and much pectinated or feathered in the males, and the wings, when at rest, deflexed and horizontal. The larva before changing incloses itself in a case, which in the *Bombycidæ* is composed entirely of fine silk.

In the fourth section, *Nocturna*, night-moths, the antennæ are setaceous, the proboscis long and spirally convoluted, the palpi compressed and terminated abruptly by a minute joint, and the wings, when at rest, folded horizontally upon the abdomen. It is a larva of this section, *Agrotis segetum*, that of late years has been almost as injurious to the agriculturist by attacking the full-grown turnip as that of the saw-fly, *Athalia*, or the beetle, *Haltica*, by attacking the plant in the earliest stages of its growth.

In the fifth section, *Semidiurna*, the body is slender, the antennæ in general setaceous, the proboscis short, and the wings broad and expanded horizontally, as in the *Geometridæ*, or deflexed and forming an angle with the body as in the *Pyralidæ*.

The sixth section, *Vespertina*, is composed of minute species, among which are the destructive clothes-moths, *Tineidæ*.

Order IX. *DIPTERA*.

Wings two, membranous, naked, and situated anteriorly to two minute pedunculated bodies *(halteres)*, the analogues of the posterior wings in the preceding orders;* mesothorax very large, and forming nearly the whole of the thoracic region; head rounded, distinct from the thorax; mouth rostriform; metamorphosis complete; pupa coarctate.

Among the families of this extensive order are the *Culicidæ*, gnats, the *Asilidæ (fig.* 349) and *Tabanidæ*, bloodsuckers, the *Œstridæ*, gad-flies, and *Muscidæ*, common house-flies. In most of the families the larvæ are active and

Fig. 349.

Asilus crabroniformis (Samouelle).

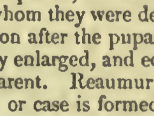
apodal, or are furnished only with abdominal feet. It is doubtful whether any of them cast their skins during their growth. In most species it becomes the outer covering of the pupa.

Order X. *HOMALOPTERA*.

Wings two, or entirely absent; head sunk into the anterior part of the thorax, or divided from it only by a suture; abdomen flat, broad, and obtuse; anus notched; claws large, bidentate or tridentate; metamorphosis complete: pupa coarctate.

In this remarkable order, the forest-flies *(fig.* 350) and ticks, the larva is nourished, and un-

Fig. 350.



Hippobosca equina, the Forest-fly (Samouelle).

dergoes its change into the pupa state within the abdomen of the parent, as was first noticed by Reaumur, by whom they were designated "spider-flies." Soon after the pupa is deposited, it becomes greatly enlarged, and equals in size the body of the parent. Reaumur found that its outer envelope or case is formed of the skin of the larva, as in the true Diptera, and he also succeeded in detecting within it the proper covering of the nymph. The type of the order, the forest-fly *(fig.* 350) is exceedingly troublesome to horses in the summer, and abounds in the New Forest in Hampshire.

Order XI. *APHANIPTERA*.

Wings none; body oval, compressed; head small, rounded, and compressed; eyes simple, orbicular; thighs strong; posterior legs the longest; tarsi five-jointed.

The *Pulicidæ*, fleas, undergo a complete metamorphosis. The larva is an active elongated worm, which spins itself a case or coccoon, in which it becomes a nymph, and at the end of a few days assumes the perfect state. One species, *Pulex penetrans*, is exceedingly troublesome in the West Indies by introducing itself beneath the toe-nails or under the skin, where it occasions malignant ulcers. Most of the species are of diminutive size, and seldom exceed a line in length. Mr. Kirby,

* Kirby and Spence, Introduction, &c., vol. ii. p. 354.

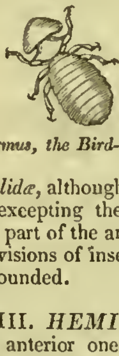
however, has recently described one species, *P. Gigas*,* which is two lines in length.

Order XII. *APTERA.*

Wings none; body ovate, flattened; head distinct from the thoracic segments, which are narrower than those of the abdomen; mouth either haustellated or mandibulated; metamorphosis incomplete.

This order, which is formed of the *Pediculi* of Linnæus, and is based upon the entire absence of the wings and an incomplete metamorphosis, affords a striking proof that we ought not in our arrangements to place too much dependance upon the presence or absence of any one particular set of organs, or kind of metamorphosis; else, as well remarked by Burmeister, we ought to include among the Aptera the female Blatta and the common Cimex, insects which evidently belong to different orders. But it may be further observed that dissimilarity in the structure of *one* particular kind of organs is not alone sufficient to authorise the separation of genera which in other respects are closely united; otherwise the *Nirmidæ (fig.* 351) ought to be separated

Fig. 351.



Nirmus, the Bird-louse.

from the *Pediculidæ*, although resembling them in every thing excepting the structure of the mouth, the very part of the animal upon which the two great divisions of insects in the present arrangement is founded.

Order XIII. *HEMIPTERA.*

Wings four, anterior ones partly leathery, partly membranaceous, decussating each other at the apex; posterior wings entirely membranaceous; pro-thorax and scutellum very large; mouth rostriform, composed of elongated setæ; ocelli three; metamorphosis incomplete.

Fig. 352.

Nepa cinerea, the Water-scorpion (Samouelle).

This order is divided into two sections, *Terrestria* and *Aquatica.*

The larva and pupa are active, and most species subsist upon the juices of other animals. The *Terrestria* are distinguished chiefly by the length of the antennæ, which exceeds that of the head, and by their three-jointed tarsi. The *Aquatica* have the antennæ in general shorter than the head (which in some species *(fig.* 352) is sunk into the pro-thorax), the eyes are large, the rostrum short, and the tarsi with only two joints.

Order XIV. *HOMOPTERA.*

Wings four, anterior pair either entirely coriaceous or membranaceous, not decussating each other; pro-thorax very short; head large and transverse; antennæ shorter than the head in most genera; abdomen in some furnished with a compound serrated ovipositor; metamorphosis incomplete.

This order is considered by many authors as only a section of the preceding. It is, however, composed of several distinct families. The types of the order, the *Cicadiidæ (fig.* 353), tree-hoppers, in possessing a serrated

Fig. 353.

Cicada hæmatodes (female). (Samouelle).

ovipositor seem to approach to the *Terebrantia*, while the *Thripidæ*, which in the structure of the mouth resemble mandibulated insects, have recently been formed into a distinct order,* and have been placed by Mr. Westwood before the Neuroptera. Perhaps a closer examination of the remaining families, *Aphidæ* and *Coccidæ*, the plant-lice, &c., might lead to a similar removal.

In the preceding remarks we have closely adhered to the arrangement proposed by Mr. Stephens, but it cannot be denied that much remains to be done before the entomologist will be able to form an arrangement so far natural as to be free from serious objections. The principal divisions of the last two orders, in possessing ocelli, in the size of the thorax, the connexion of the wings during flight (which we shall hereafter show exists in some of the *Cercopiidæ*,) and in the serrated terebral ovipositor, seem to be more nearly connected with the Hymenoptera than with the wingless and less perfectly developed Aphanïptera and Aptera.

From the above remarks on the orders it will

* Fauna Boreali-Americana, 1837, p. 318.

* Thysanoptera. Haliday, in Entom. Magazine, vol. iii. & iv.

be seen that a large majority of insects have four states of existence,—the egg, the larva, the pupa, and the imago or perfect state. Until very lately, it was supposed that this peculiarity of existing at different periods under such different forms belonged only to this class of the Invertebrata, but recent observation,* as shown in the article CIRRHOPODA, &c.,† has made it appear that there are other classes also which undergo metamorphoses, although in no instances do the animals continue so long in their preparatory states, nor undergo such remarkable changes of form in passing from one state to another, as insects.

The egg.—In the egg, or earliest stage of extra-uterine existence, the insect continues for a longer or shorter time according to external circumstances. We have at present only to notice the external form, markings, and colour of the egg, which vary as greatly in the different species as the locality in which it is placed by the parent. The greatest variety of these occurs among the Lepidopterous insects. In some, as in the butterfly, *Pontia brassicæ*, the egg is of an obtuse conical figure, like a Florence flask, and is beautifully ribbed and beaded on its exterior surface; in others, as in one of the night-moths, *Acronycta Psi*, it is ribbed, and is flattened like a lens;‡ in the small but beautiful butterfly, *Thecla betulæ*, it is shaped like a turban;§ in *Clisiocampa neustria*, which glues its eggs together like a ring around the small branches of fruit-trees, it is cylindrical, and flattened at both ends, and in the puss-moth, *Cerura vinula*, its form is compressed and lenticular. Among the Neuroptera, Hemiptera, and Diptera there are other forms equally curious. The lace-winged fly, *Chrysopa perla*, suspends its egg in the air upon a long pedicle;|| the egg of the water-scorpion, *Nepa cinerea* (*fig.* 352), is encircled at one extremity by a coronet of rays or processes,¶ while in one of the dung-flies the egg has two projecting appendages which have somewhat the appearance of ears. The *color* and *markings* of the egg are not so various as its form. In the common green grasshopper, *Acrida viridissima*, it is green, like the seeds of some plants. In *Pedicia rivosa* and *Tipula oleracea* it is perfectly black, and in other instances, as in *Odonestis potatoria*, it is beautifully encircled with bands of white and green, or is speckled with darker spots, like the eggs of birds, as in *Lassiocampa quercus*. The prevailing colours, however, are yellow, as in the cylindrical eggs of the oil-beetles, the *Meloe* and *Proscarabæi*; or white as in the flesh-flies, *Musca vomitoria* and *domestica*; or perfectly translucent, as in the saw-fly of the turnip, *Athalia centifoliæ*. The external markings and sculpture on the egg are not less remarkable than its general form and colour. Sometimes the egg, as above stated, is ribbed and beaded, sometimes excavated over its whole surface into regular cells like a honey-comb, at others it is imbricated like the tiling of a house, but in the greater number of instances it is smooth as in other animals.

These peculiarities of form and color appear in many instances to have relation to the circumstances under which the egg is deposited by the parent, to its preservation, or to the locality in which it is placed. The egg of *Scatophaga stercoraria*, KIRBY, is only partially inserted into recent cow-dung,* with its auricular processes, through which it is supposed to respire, exposed to the influence of light and air; that of *Chrysopa perla*, K., the lace-winged fly, is attached by its pedicle in the midst of crowds of Aphides, upon which the young larva is to subsist;† while the coronetted eggs of *Nepa* (*fig.* 352) are inserted into the stems of water-plants, with their processes only exposed,‡ probably for the purposes of respiration, until the enclosed germs are stimulated into active existence by the vivifying influence of light and air, without which perhaps they would perish. This indeed happens with the eggs of the great water-beetle, *Hydröus piceus* (*fig.* 330) which, according to Lyonet, are deposited in a little nest that floats upon the surface, and from which the larvæ escape into the water immediately they are developed. We have found that if the eggs of this insect be allowed to fall to the bottom of a vessel of water, and remain there for some days, organisation proceeds in them for a day or two, after which they perish. For a similar purpose the eggs of *Athalia centifoliæ* (*fig.* 355), which require a high atmospheric temperature for their speedy development, are inserted into little spaces between the cuticle and parenchymatous tissue of the leaf of the turnip. In each of these instances the object to be insured is the safety of the egg itself; either its preservation from external injury, or its full exposure to atmospheric influence to accelerate its development. It may be remarked as a general rule, that those eggs from which the larvæ are most rapidly developed are those which require the highest temperature and fullest exposure to the atmosphere. These are the external circumstances which greatly influence the development of the germ into the state of larva.

The larva.—Immediately the insect is liberated from the external coverings of the egg it is called a larva. It is so designated from its then being as it were under a *mask* or in disguise, and unable to fulfil one of the principal objects of its existence, the continuation of its kind. In some species, as among the Aptera, it has at this period the form of the parent, from which it differs in nothing externally but size, being always very much smaller. Instances of this kind occur in the *Pediculi* and *Nirmi* (*fig.* 351). In other species, examples of which are seen in the *Cimices*, *Blattæ* (*fig.* 343),

* Phil. Trans. part ii, 1835.
† Vol. i. p. 692.
‡ Sepp.
§ Id. quoted by Burmeister, Manual of Entomology (Trans.), p. 633.
|| Reaumur, Kirby and Spence, vol. iii. p. 95.
¶ Swammerdam Bib. Nat. t. iii. figs. 7 and 8.

* Kirby and Spence, vol. iii. p. 97.
† Reaumur, tom. iv. p. 376.
‡ Kirby and Spence, vol. iii. p. 95.

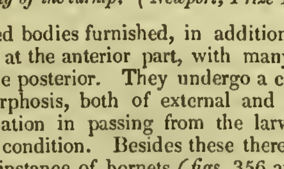
Forficulæ, and *Cicadæ* (*fig.* 353), the insect is very much smaller, but has the general form of the parent, without any rudiments of wings or elytra. Another description of larva is that in which the insect comes from the egg either as a fat sluggish grub, or as an active and voracious one, with an elongated body very different in form from that of the parent, and is furnished with but six legs, which are attached to the anterior part of the body, in addition in some instances to two processes employed as legs at its posterior extremity. Examples of the last of these occur in the voracious water-beetles, *Dyticidæ*, in the *Carabidæ* or ground-beetles (*fig.* 354) and many others; and of the

Fig. 354.

Larva of Calosoma Sycophanta (Burmeister).

first, in the Chaffer-beetles *Melolonthæ*, and stag and dung-beetles, *Lucanidæ* and *Geotrupidæ* (*fig.* 332). Other kinds of larvæ, to which the term is more strictly applicable, are known to every one, as the caterpillars of butterflies and moths. These and the *pseudo-caterpillars*, the larvæ of the saw-flies, *Tenthredinidæ*, (*fig.* 355, A), are active and have

Fig. 355.



A, *larva, and* B, *perfect state of Athalia centifoliæ, the saw-fly of the turnip*. (*Newport, Prize Essay.*)

elongated bodies furnished, in addition to the six legs at the anterior part, with many others along the posterior. They undergo a complete metamorphosis, both of external and internal conformation in passing from the larva to the perfect condition. Besides these there are, as in the instance of hornets (*figs.* 356 and 357) and bees, larvæ which are entirely destitute of organs of locomotion, and exist simply as elongated maggots; and others, as some of the flesh-flies, *Muscæ*, and the tailed maggots that inhabit the most noisome puddles, *Eristalis tenax*, which are entirely destitute of the true or anterior legs, and have only those which are attached to the abdomen.

These kinds of larvæ were formerly referred by Fabricius, under special designations, to different kinds of metamorphoses, which those designations were supposed to indicate; but, as remarked by Burmeister,* neither were the terms employed in strict accordance with the conditions of the larvæ themselves, nor always indicatory of the metamorphoses they were about to undergo. We fully agree, therefore, in the opinion expressed by Burmeister, that the different kinds of larvæ are referable to only two kinds of metamorphoses; the one a *metamorphosis incompleta*, which consists simply in the insect shedding its skin and increasing in size, and in some cases acquiring new organs, but in all stages of its existence continuing active, and having the form of the parent, as in the instances above noticed; and the other a *metamorphosis completa*, including all insects which in the larva state have a form different from the parent, and undergo a complete change, both of external and internal conformation, before they arrive at the perfect state.

But whatever be the form or changes of the insect, the larva state may be looked upon as its most voracious period of life. In many species it is also its longest period. Those which do not hybernate in the perfect state exist but for a very short time as larvæ; while those which continue for a long period in the larva state, as the *Lucanidæ* and *Melolonthidæ*, some of which are said to continue for four years, pass but a little while in the perfect. But these periods are not always equally long in different species of the same families. Thus among the *Apidæ*, the *Bombus terrestris*, or common humble-bee, exists but for a short period in the larva, but a long one in the perfect state; while in a closely allied genus *Anthophora retusa*, one of the solitary bees, that form separate nidi in vertical sections of dry banks exposed to the sun, the insect often continues through the whole winter in the larva state, and only exists for a few weeks of the following summer in the perfect. On the other hand the numerous species of *Muscidæ* exist but a short time as larvæ, or maggots, but a very long time as active flies.

External anatomy of the larva.—The body of a larva is in general composed of thirteen distinct segments, or divisions; the first constitutes the head, with the organs of manducation, the second, third, and fourth, and, as we shall hereafter see, in part also the fifth, together form the thorax of the future *Imago*, while the remaining ones form the third division of the body, the abdomen. In most insects in the larva state, the whole of these segments from the second to the thirteenth are equally developed, and differ but little from each other in their general appearance. The second, third, and fourth segments have each a pair of short scaly feet, the rudiments of the future limbs, and the segments of the abdomen are often furnished with soft membranaceous ones, which disappear entirely when the larva undergoes its metamorphosis. On each side of the body there are in general *nine* oval apertures, the

* Manual, Trans. p. 34.

spiraculæ, or breathing holes. These are situated in the true larva, or caterpillar, in the second, fifth, sixth, and following segments to the twelfth. This is the general structure of the larva, but there are modifications of it in every particular. Thus, in the larva of those *Hymenopterous* insects which are entirely destitute of feet, there are fourteen distinct segments in the body, besides an anal tubercle, and ten spiraculæ on each side (*fig.* 356). These are

Fig. 356.

Lateral view.

Fig. 357.

Inferior view.

Larva of Vespa crabro, magnified.

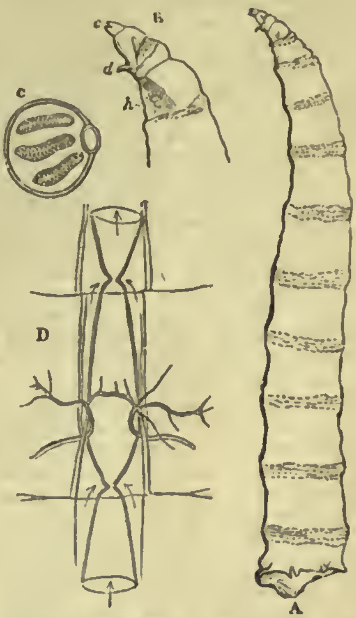
situated in the second, third, fourth, and remaining segments to the twelfth, so that in these insects the thoracic portion of the body contains an additional spiracle, while the abdomen has one additional segment. This fact is particularly interesting from the circumstance of its apparently disturbing the opinions hitherto advocated by naturalists respecting the normal number of segments, which has been thought to be constantly thirteen in this class of invertebrata, while it derives a greater importance from the additional segment belonging to the abdomen, as we shall hereafter prove. This additional number of segments, as constantly occurring in apodal Hymenoptera, was first pointed out by Mr. Westwood,* and has been observed by ourselves in every instance in the larvæ of *Vespa Crabro*, (*fig.* 356.) *Bombus terrestris*, *Anthophora retusa*, *Ichneuman Atropos*, and other species. In the common maggots or larvæ of the flesh-flies, *Muscidæ*, the body is elongated, and tapering at its anterior extremity, and consists of fourteen segments.† In the larva of a species of *Musca* which infests bacon and other dried provisions, and in that of the common flesh-fly, *Musca vomitoria*, we have distinctly

* Trans. Ent. Soc. vol. ii. p. 124.

† *Fifteen*, if we include the anterior portion of the third segment, which appears like a distinct part. Since these observations have been in print the XII. and XIII. Parts of Mr. Westwood's "Introduction" have been published, and it is gratifying to observe that he has found fifteen segments, including the head, in the larva of *Odynerus*, *Colletes*, and *Anthidium*.

noticed fourteen (*fig.* 358). The first four of

Fig. 358.



A, *Apodal larva of Musca*; B, *head of do.: a, mandibular hooks; b, the anterior branchia; c, the labrum;* C, *organs of respiration;* D, *a portion of the dorsal vessel.*

these appear to constitute the head of the larva, since in them are contained the palpi and oral apparatus, besides two remarkable orange-coloured organs, which project from the sides of the fourth segment, and on a cursory view appear to be the organs of vision, but are in reality the branchiæ of the future pro-thorax (B *h*). In the larva of the sheep-bot, *Œstrus ovis*, which resides for many months in the frontal sinuses and roots of the horns of that animal, there are thirteen segments, but the terminal one is very indistinct, while the anterior one, which is exceedingly minute, is proved to form a large proportion of the head, by its containing the oral apparatus, and by the existence in it, at its anterior part, of two very distinct eyes. These larvæ respire by means of two sets of branchiated organs, (*fig.* 358, c) situated at the posterior part of the body, and not by lateral spiracles. The apparently anomalous condition of the head in these insects, like the additional segment in Hymenoptera, is a circumstance of much interest, but is not without its parallel in perfect individuals of other classes, as in *Myriapoda*, in which the head is most distinctly composed of at least three segments. We must not conclude, however, with Dr. Ratzeburg, as noticed by Mr. Westwood,* that in *Hymenoptera* the head of the *Imago* corresponds to the first two segments of the larva, because at the latter period of the larva state, just before the insect becomes

* Trans. Ent. Soc. vol. ii. p. 125.

a nymph, or pupa, the head is found to occupy the anterior part of the second segment. The true head of the hymenopterous larva, before its changes have commenced, is in reality the first segment; since, as remarked by Mr. Westwood, it has not only the usual conformation of the head, but contains also the rudiments of *all* the manducatory organs, and the antennæ. In addition to this, we may state that before the larva has discontinued to feed, and has begun to prepare itself for transformation, we have invariably found on dissection, that the first cerebral mass, the supra-œsophageal ganglion or brain is situated in the superior part of the first segment, and the first sub-œsophageal ganglion in the posterior part of the inferior surface; so that it is not until after the changes into the nymph state have commenced, beneath the skin of the larva, that the head becomes so greatly enlarged as to encroach upon the second segment.

Of the head. The head of a larva, excepting in Dipterous insects as above noticed, is usually of a rounded or oval figure, and of a harder texture than other parts of the body. At its inferior surface are situated the organs of manducation, and at its lateral and anterior the rudiments of the eyes and antennæ. In all true larvæ it is divided longitudinally into two halves, by a suture which extends from the vertex or *epicranium* to the face, the front of which is formed by a convex plate, the *clypeus*, or shield (*fig.* 359, *b*). This is generally of a

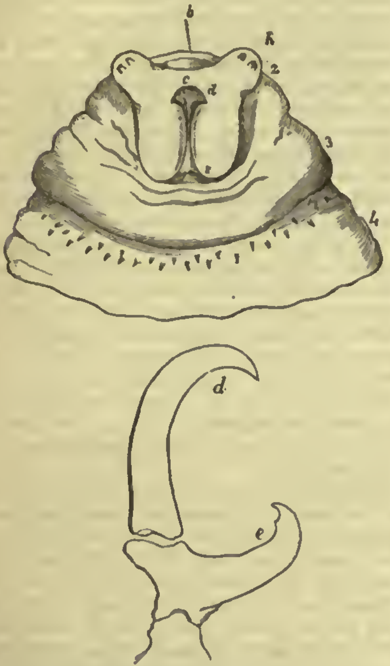
Fig. 359.

Head of larva of Athalia centifoliæ.
a, the epicranium ; b, the clypeus ; c, labrum ; d, the mandibles ; e, maxillæ and palpi ; f, the labium and labial palpi. (Newport, Prize Essay.)

semicircular, or a quadrangular form, but varies considerably in different species. Immediately beneath this plate is situated another, the *labrum* or upper lip (*c*). This also is of an elongated, quadrangular, and sometimes heart-shaped form, and constitutes the anterior boundary of the mouth. Beneath this plate are a pair of strong horny jaws, *mandibulæ* (*d*), which are in general thick, curved, and strongly indented or toothed, and are placed one on each side of the head. Beneath these are a pair of lesser jaws, *maxillæ* (*e*), placed in a similar manner, and with the mandibles form the lateral boundaries of the mouth. The maxillæ are soft, membranaceous and adapted for holding, rather than for comminuting the food like the mandibles. They are in general also furnished, as in the larva of *Athalia*, with two other jointed organs, *palpi* or feelers which are employed by the insect entirely as tactors. Behind these parts is situated a second transverse plate, the *labium* (*f*), or inferior lip, which bounds the posterior part of the mouth. This also, like the maxilla, is furnished with a pair of jointed palpi. The motions of the mandibles and maxillæ differ from those of the jaws in vertebrated animals, being always from side to side, and meeting, or passing across each other like the blades of a pair of scissors. Besides these parts, there is in many larvæ a projecting papilla situated within the mouth upon the soft membrane of the labium. This is conical and jointed, and is called by Messrs. Kirby and Spence the *spinneret*. It is the common excretory duct of the glands which secrete the materials with which the insect spins its coccoon, previously to undergoing its transformations. In all larvæ the *antennæ* (*g*) are but slightly developed. They are situated a little above the base of the mandibles, on each side of the clypeus, and are of a conical form, jointed, and usually terminating in a point. In some species they are three, but rarely more than five-jointed. The *eyes* in all larvæ are single, or *sessile*, and not compound, or aggregated together, as in perfect insects. In the pseudo-caterpillars, *Tenthredinidæ*, as in *Athalia centifoliæ*, there is only one large stemma on each side of the head (*h*), situated above the antennæ; but in the true caterpillars, *Lepidoptera*, as in the *Sphinx ligustri*, there are always six very minute ones, placed at a little distance from each other, in the form of an arc near the base of the mandibles and antennæ, at the lateral part of the head. In the apodal hymenopterous larvæ which constantly reside in the dark, the oral apparatus is developed, but the eyes are in general entirely absent.

The form of the oral apparatus in the maggots, or larvæ of the Dipterous insects, is entirely different from that of the insects we have just described. In the larva of *Œstrus ovis* instead of mandibles and maxillæ crossing each other transversely, the mouth is formed by two fissures, the one anterior and longitudinal, and the other posterior and transverse, the two meeting each other in the form of the letter T inverted thus ⊥ (*fig.* 360). In the anterior fissure (*c*) are situated two longitudinal powerful hooks, the mandibles (*d*) directed forwards and downwards, and employed by the insect both as organs of progression and nutrition. At the base of these in the transverse fissure (*e*), are two other hooks, maxillæ, of a similar description, directed both to the median line, but jointed like the mandibles in Myriapoda, and crossing each other like the mandibles of the true larva. The hooks thus include between them the cavity of the mouth, in this manner adapted both for wounding and tearing as well as suction, and it is curious to observe that we have here in the larva of a true insect an approach to the vermiform type of the permanent condition of the oral apparatus of the leech. In the maggot of the larder-flies and flesh-flies above alluded to, the mouth is formed somewhat differently. Behind the transverse hooks the mouth is bounded by a membranaceous labium, while at its anterior part it is furnished with a proboscidal lip (*fig*. 358, B *c*), divided into four very minute palpiform organs. There are also two processes situated one on each side of the mouth in the second segment. At the base of the fourth segment are the two projecting orange-coloured organs of a semicircular form, divided into what appear like single pedunculated eyes, but which are in reality external branchiæ, and correspond to the spiracles of the pro-thorax of the perfect insect (*h*). In the *Œstrus ovis* (*fig*. 360) the two sides of

Fig. 360.



Head of larva of Œstrus ovis.
2, 3, 4, *segment; a, optic nerve; b, epicranium; c, labium; d, mandibles; e, maxillæ.*

the fissure that forms the anterior part of the mouth are developed into very distinct organs of vision (*h*), in which may be traced the nerves of two separate but nearly approximated eyes. The existence of distinct eyes in this larva is the more remarkable, from the circumstance that the larva resides in the frontal sinus of the skull of the sheep, where we sought for, and found the identical specimens upon which our observations have been made.

Organs of locomotion. We stated above that the true organs of locomotion are six in number, both in the larva and perfect state, and that they are always attached to the second, third, and fourth segments of the body. They are distinguished from the false, or abdominal legs by their possessing distinct articulations or joints, by the strength and hardness of their texture, and by their general pointed form. In Coleopterous larvæ they are of considerable length, and the parts of which they are composed are readily distinguished. These

Fig. 362. *Fig*. 361.

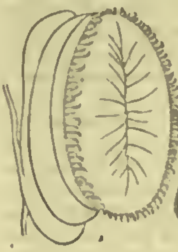


Fig. 361. *Thoracic leg of larva of Cossus ligniperda* (Lyonet).
a, Coxa; b, femur; c, tibia; d, tarsus; f, unguis.
Fig. 362. *Abdominal leg.*

are (*figs*. 361, 364 ***), as in the perfect insect, the *claw* (*f*), the *tarsus* (*d*), the *tibia* (*c*), the *femur* (*b*), and *coxa*, or hip (*a*). In all terrestrial larvæ the legs are attached to the inferior parts of the segments; but in one remarkable genus of water-beetles the great *Hydröus piceus*, they were supposed by Frisch to be attached so much nearer to the dorsal than the sternal surface as to have the appearance of being actually placed on the back. But this is erroneous, the mistake having arisen from the peculiar formation of the head, which is flat on its upper, but convex on its under surface. The whole of these thoracic legs, in all larvæ which possess them, are nearly equally developed, and do not present any marked difference of form or size, as is often subsequently found in the perfect insects. In the larvæ of Lepidoptera they are exceedingly short and pointed, and in many *Hymenoptera* and *Diptera* are entirely absent. The false or abdominal legs are totally different in appearance and structure from the true or thoracic ones. Although varying in number in different species, they are universally present in the Lepidoptera (*fig*. 364, †††) and in many Hymenoptera and Diptera. In some instances, as in many of the *Geometridæ*, there is only a single pair at the anal extremity of the body; while in others, as in some of the *Tenthredinidæ*, there are as many as eight pairs. In every instance they are soft and membranaceous, without distinct joints or articulations. In some of the Lepidoptera their structure is exceedingly curious, and has been beautifully illustrated by Lyonet (*fig*. 362), in his anatomy of the larva of *Cossus ligniperda*. In that insect their shape resembles an inverted cone, with its apex truncated to form a flat sole, or foot, upon which the caterpillar walks. The sole in its middle can be rendered concave at the will of the animal, while around its margin are several rows of minute hooks, directed outwards, and when the sole of the foot is pressed firmly upon any surface in walking these hooks attach themselves, and are released again when the sole of the foot is contracted, previously to the caterpillar's raising it to make another step forwards. In the *Sphingidæ* the abdominal feet are formed of two parts, the external one, broad, semicircular, and edged with minute hooks, directed inwards like a claw, and the internal one smaller, with its hooks directed outwards, so that two parts of the foot are opposed to each other, and grasp the surface upon which they are walking like the foot of a bird. It is with these that the Sphinx attaches itself so firmly to the stems and branches of plants, that it is often almost impossible to remove it without injury. In the Sphinx there are four pairs of these legs, attached to the seventh, eighth, ninth, and tenth segments, besides one pair at the thirteenth, or anal extremity. In some Dipterous larvæ the abdominal legs are the only organs of locomotion—as in the rat-tailed larva of *Eristalis tenax*.

In every instance these abdominal legs are only processes of the exterior covering of the insect, furnished externally with peculiar developments of the cuticle, in the form of hardened spines or hooks like the claws and nails of vertebrated animals, and internally with a greater development of certain portions of the muscles of the abdomen. We have full proof of this in those numerous apodal larvæ which are capable of locomotion, as in most of the *Muscidæ*, the common maggots. In all these, in which both the true and false legs are entirely absent, the whole external surface of the body is modified for this purpose. In the maggot of the flesh-fly the whole anterior part of every segment is surrounded and beset with numbers of very minute hooks, with their apices directed backwards. With these the larva attaches itself to the surface over which it moves, and carries itself along by the alternate contraction and relaxation of the longitudinal muscles of its body. A beautiful adaptation of these dermal hooks to the peculiar habits of the individual is observed on comparing their form and position on the bodies of the larvæ of two very distinct species of *Œstrus*, the one *Œstrus ovis*, parasitic in the head of the sheep, the other beneath the skin on the backs of oxen, *Œstrus bovis*. In the first of these larvæ, which moves about freely in its habitation, the hooks (*fig.* 360) are all directed backwards around the posterior margin of each segment, a direction rendered necessary for their employment as organs of locomotion; but in the latter insect, which is confined to one spot for many months, in the tumour occasioned by it on the back of the ox in the cellular tissue beneath the skin, the hooks are not required as organs of progression, but yet are rendered necessary for the purpose of retaining the larva in its nidus unaffected by the varied muscular movements of the parts around it. To accomplish this object each segment of the larva is provided with two sets of hooks. One of these is arranged around the anterior part of the segments, and consists of very numerous minute sharp-pointed spines, directed forwards, while the other is composed of strong flattened scales with curved points, very much larger but less numerous than the preceding. These are disposed around the posterior part of the segments, and have their points directed backwards. The effect of the spines thus placed in opposite directions evidently is that of retaining the larva in exactly the same position among the cellular tissue in the back of the animal, while the greater strength of the posterior spines enables it at will to penetrate deeper beneath the skin of its victim.

We have thus seen that in apodal larvæ endowed with powers of locomotion the place of the true organs of progression is supplied by peculiar developments of the cuticular covering of the body, analogous to the scales on the bodies of Ophidian Reptiles, and these are employed by the larvæ in all their progressive movements in the same manner as the scales on the body of the snake. But in those apodal larvæ which remain in the same locality until they have passed through all their changes, as the larvæ of the bee and wasp, these developments of the cuticular surface do not exist, but the body is perfectly smooth.

It is not always, however, that the spines on the bodies of larvæ are employed as organs of locomotion since they exist on many larvæ which possess both true and false feet, and are then either merely ornamental appendages or a means of defence. But whatever be their use in the economy of the larva, they are only developments of its external covering, and generally disappear when the insect undergoes its change into the pupa state, being thrown off with the skin.

Growth and changes of the larva.—The life of an insect that undergoes a true metamorphosis is one continued series of changes from the period of its leaving the egg to that of its assuming the perfect state. These are not merely from the larva to the pupa and from that to the perfect animal, during which the insect gradually acquires new organs, but consist also of repeated sheddings of its skin, which occur at certain intervals before the larva has attained its full size. These changes and the circumstances connected with them have been more particularly watched in Lepidopterous insects, and have been carefully noted by many naturalists, especially by those of the last century, Redi, Malpighi, Gœdart, Merian, Ray, Swammerdam, Reaumur, Lyonet, Bonnet, De Geer, and others, who concur in their statements respecting the manner in which these changes are effected.

Almost immediately after the insect is liberated from the egg it begins to feed with avidity, and increases much in size. According to the observations of *Count Dandalo** the common silk-worm, *Liparis mori*, does not then weigh more than one hundredth of a grain, and is scarcely a line in length, but at the expiration of about thirty days, when it has done feeding and has acquired its full size, its

* Count Dandalo on Silk-worms (Eng. Trans.) p. 326.

average weight is about ninety-five grains, and its length sometimes as much as forty lines. During this period, therefore, it has increased nine thousand and five hundred times its original weight, and has eaten sixty thousand times its weight of food. But observations on the larva of the privet hawk moth, *Sphinx ligustri*,* lead us to believe that this estimate of the amount of food eaten is a little too great. The larva of the sphinx at the moment of leaving the egg weighs about one eightieth of a grain; at about the ninth day it casts its second skin and then weighs about one-eighth of a grain: on the twelfth day it changes its skin again and then weighs rather more than nine-tenths of a grain. On the sixteenth day it casts its fourth skin and weighs three grains and a half, and on the twenty-second day enters its sixth and last skin and weighs very nearly twenty grains; but on the thirty-second day, when it has acquired its greatest size, it weighs nearly one hundred and twenty-five grains, so that in the course of thirty-two days this larva increases about nine thousand nine hundred and seventy-six times its original weight. At this period it is sometimes more than four inches in length. But this is not the greatest weight that the larva attains. One specimen which was bred in its natural haunts weighed one hundred and forty-one grains and seven-tenths, so that in this instance the insect had increased at the rate of eleven thousand three hundred and twelve times its original weight. But great as is this proportion of increase, it is exceeded by some other larvæ. Lyonet found that the larva of *Cossus ligniperda*, which remains about three years in that state, increased to the amount of seventy-two thousand times its first weight.† This amazing increase is occasioned chiefly by a prodigious accumulation of fat which exists in a greater quantity in this than in most other larvæ. We have ourselves removed forty-two grains of fat from one specimen, which was more than one-fourth of the whole weight of the insect. The occasion for this prodigious accumulation is chiefly to supply the insect during its continuance in the pupa state, while the muscular structure of the limbs and other parts of the body are in the course of development; and also to serve, perhaps, as an immediate source of nutriment to the insect at the period of its assuming the perfect state, and more particularly during the rapid development of its generative functions; since, when these have become perfected, the quantity that remains is very inconsiderable. But all larvæ do not increase in these amazing proportions, although their actual increase may be more rapid. Those in which the proportion of increase is the greatest are usually those which remain longest in the pupa state, as in the species first noticed. Thus *Redi*‡ observed in the maggots of the common flesh-flies a rate of increase amounting to about two hundred times the original weight in twenty-four hours, but the proportion of increase in these larvæ does not at all approach that of the sphinx and cossus. From observations made on the larva of one of the wild bees, *Anthophora retusa*, we believe that this is also the case with the *Hymenoptera*. The weight of the egg of this insect is about the one hundred and fiftieth part of a grain, and the average weight of a full-grown larva six grains and eight tenths, so that its increase is about one thousand and twenty times its original weight; which, compared with that of the sphinx of medium size, is but as one to nine and three-quarters, and to a sphinx of maximum size only as one to a little more than eleven.

The changes of skin which a larva undergoes before it enters the pupa state are more or less frequent in different species. In the generality of Lepidopterous insects it occurs about five times, but in one of the tiger-moths, *Arctia Caja*, according to Messrs. Kirby and Spence,* ten times. A few hours before the change is to take place the larva ceases to eat and remains motionless, attached by its abdominal legs to the under-surface of the twig or leaf upon which it has been feeding. Many species spin a slight web or carpet of silk in which they attach their posterior legs, as observed by Dr. Pallas of *Apatura iris*,† and in this manner await their change, which appears to be attended with much uneasiness to the insect. The whole body is wrinkled and contracted in length. In the sphinx this contraction occurs to so great an extent in some of the longitudinal muscles of the anterior and middle part of the body that the larva assumes that peculiar attitude from whence the genus derives its name. In this attitude the larva remains for several hours, during which there are occasionally some powerful contractions and twitchings of its whole body, the skin becomes dry and shrivelled, and is gradually separated from a new but as yet very delicate one which has been formed beneath it, and the three or four anterior segments are greatly enlarged on their dorsal but contracted on their under surface. After several powerful efforts of the larva the old skin cracks along the middle of the dorsal surface of the second segment, and by repeated efforts the fissure is extended into the first and third segments, and the covering of the head divides along the vertex and on each side of the clypeus. The larva then gradually presses itself through the opening, withdrawing first its head and thoracic legs, and subsequently the remainder of its body, slipping off the skin from behind like the finger of a glove. This process, after the skin has once been ruptured, seldom lasts more than a few minutes. When first changed the larva is exceedingly delicate, and its head, which does not increase in size until it again changes its skin, is very large in proportion to the rest of its body. In a few hours the insect begins again to feed most voraciously, particularly after it has entered its last skin, when its growth is most rapid. Thus a larva of *Sphinx ligustri*, which at its last

* Phil. Trans. 1837, part ii. p. 315.
† Traite Anat. de la Chenille, p. 11.
‡ De Generat. Insectorum, p. 27.

* Vol. i.
† Trans. Ent. Society, vol. ii. part ii. p. 138.

change weighed only about nineteen or twenty grains, at the expiration of eight days when it was full-grown weighed nearly one hundred and twenty grains. Most larvæ immediately after changing their skins remove to fresh plants, but some, as the larvæ of a beautiful moth, *Episema cæruleocephala*, devour their old skins almost immediately they are cast, and sometimes one another when deprived of food.

But it is not merely the external covering which is thrown off during these changes; the whole internal lining of the alimentary canal also comes away with the skin, as was formerly noticed by Swammerdam,* and repeatedly observed by ourselves and others. The lining of the mouth and pharynx with that of the mandibles, is detached with the covering of the head, and that of the large intestines with the skin of the posterior part of the body, and besides these also, the lining of the tracheal tubes. The lining of the stomach itself, or that portion of the alimentary canal which extends from the termination of the œsophagus to the insertion of the so called biliary vessels, is also detached, and becomes completely disintegrated, and appears to constitute part of the *meconium* voided by the insect on assuming its Imago state. Herold, however, has denied that this change ever occurs in the alimentary canal, and says that in the trachea it takes place only in the larger stems. But Swammerdam states that he saw it in the larva of the rhinoceros beetle, *Oryctes nasicornis*, which shed both the lining of the colon, and of the delicate as well as larger branches of the tracheæ,† and Bonnet‡ had witnessed a similar occurrence. Burmeister§ has also seen it, both with respect to the colon and tracheæ, in some of the Libellulæ, and we now add our own testimony to the fact of its occurring, not simply at the extremities of the canal, but throughout its whole extent, as we have distinctly seen during the changes of the nettle-butterfly, *Vanessa urticæ*.|| It is more distinctly observed when the larva is changing into the pupa state than at any other period, although we believe that it really does take place at every change of skin. Hence these changes are of the greatest importance to the larvæ, which often perish during their occurrence. They are undergone by all larvæ which possess the true organs of locomotion, but it has been questioned whether they are common also to the apodal larvæ, more particularly those which constantly remain in the same locality until they have changed into pupæ or nymphs. Reaumur and Huber¶ state that the larva of the common hive-bee does not change its skin, but only grows larger; Swammerdam,** on the contrary, asserts that it does, and also that he has observed the same thing in the alimentary canal of the hornet.* Burmeister† believes that it does not take place, and states positively that the larvæ of Diptera do not moult. We have watched for these changes in the larvæ of the wild bee, *Anthophora retusa*, but have been unable to observe them, although we believe they do really occur. But the universally acknowledged accuracy of most of Swammerdam's observations, supported as they are in this instance by analogy, fully warrants us in considering this subject as still open for enquiry.

When a full-grown larva is preparing to change into the pupa state it becomes exceedingly restless, ceases to eat, and diminishes much in weight. Many species spin for themselves a covering of silk, termed a *coccoon*, or case, in which they await their transformation. Others prepare little cavities in the earth and line them with silk for the same purpose, (*fig.* 363), and others suspend themselves by their anal prolegs to the under surface of a leaf. In each of these instances this important change takes place in the same manner. Before the larva thus prepares itself for metamorphosis its alimentary canal is completely evacuated of its contents, its body, as at the previous changes of skin, becomes dry and shrivelled, and much contracted in length, and certain enlargements at the sides of the anterior segments indicate the now rapidly developing parts of the future pupa. These changes take place in all insects in a similar manner, but have been most frequently watched in Lepidoptera, upon which also our own observations have been made. We have also observed the same changes in Hymenoptera. The larva of the sphinx, when it is ready to undergo its changes, penetrates the earth to the depth of a few inches, and there forms for itself a little chamber, in which it awaits its transformation. But the butterfly either fastens itself by a little rope of silk, carried across its thorax, to the under surface of some object, as a ceiling, &c., or suspends itself vertically by its prolegs, with its head directed downwards. as is the case with the common nettle butterfly, *Vanessa urticæ*. We have watched these changes with much care in

Fig. 363.

Section of the coccoon or winter nidus of Athalia centifoliæ, natural size and magnified. Newport, Prize Essay.

* Biblia Nat.
† Biblia Nat. p. 129, 134, 239, &c.
‡ Contemplation de la Nature, tom. ii. p. 48.
§ Manual of Entomology, (Trans.) 1836, p. 428.
|| Since these remarks were written, a paper by Mr. Ashton upon this subject has been read at a late meeting of the Entomological Society, Nov. 5, 1838, in which the statements of Swammerdam respecting these changes have been fully confirmed.
¶ Kirby and Spence, Introduc. vol. iii.
** Biblia Nat. p. 163, a.

* Ibid. p. 133, a.
† Transl. p. 432.

this insect, which frequently remains thus suspended more than ten or twenty hours before the transformation takes place. During this time the four anterior segments of the larva become greatly enlarged, and the segments assume a curved direction, occasioned by the contraction, or shortening of the muscles of the under surface of those segments, which are repeatedly slowly extended and shortened, as if the insect were in the act of laborious respiration. This generally takes place at short intervals during the two hours immediately preceding the change, and increases in frequency as that period approaches. When the period has arrived, the skin bursts along the dorsal part of the third segment, or *meso-thorax*, and is extended along the second and fourth, while the coverings of the head separate into three pieces. The insect then exerts itself to the utmost to extend the fissure along the segments of the abdomen, and in the meantime pressing its body through the opening gradually withdraws its antennæ and legs, while the skin, by successive contortions of the abdomen, is slipped backwards and forced towards the extremity of the body, just as a person would slip off his glove or his stocking. The efforts of the insect to get entirely rid of it are then very great; it twirls itself in every direction in order to burst the skin, and when it has exerted itself in this manner for some time, twirls itself swiftly, first in one direction, then in the opposite, until at last the skin is broken through and falls to the ground, or is forced to some distance from it. The new pupa then hangs for a few seconds at rest, but its change is not yet completed. The legs and antennæ, which when withdrawn from the old skin were disposed along the under surface of the body, are yet separate, and do not adhere together as they do a short time afterwards. The wings are also separate and very small. In a few seconds the pupa makes several slow but powerful respiratory efforts; during which the abdominal segments become more contracted along their under surface, and the wings are much enlarged and extended along the lateral inferior surface of the body, while a very transparent fluid which facilitated the slipping off of the skin, is now diffused among the limbs, and when the pupa becomes quiet dries, and unites the whole into one compact covering.* Exactly the same thing occurs in the changes of the sphinx. The limbs at first are all separate, each one inclosed in its distinct sheath, but within a very short period after the change they become agglutinated together by the fluid effused between them, and form the solid exterior of the pupa case. The body of the insect is now divided into three distinct regions, head, thorax, and abdomen. The first step towards this division is the contraction which takes place in all the longitudinal and diagonal muscles of the body, soon after the larva (*fig.* 364) has acquired its full size, by means of which each segment of the insect forms a slight intussusception, the anterior margin of one segment being drawn

Fig. 364.

*Section of larva of Sphinx ligustri; 1 to 13, (dorsal surface) segments; 1 to 12, (ventral surface) ganglia; a, dorsal vessel; b, its lateral muscle; c d, œsophagus and stomach; e, ilium; f, hepatic vessels; g, cæcum coli; h, colon and rectum; i, testis; * * * thoracic legs; † † † abdominal legs. Newport, Phil. Trans.*

under the posterior margin of the one which immediately precedes it. This occurs in all the segments which form the abdominal region of the future moth, the nine posterior ones of the larva. When the period of changing into the pupa state has arrived, a much greater shortening takes place in the muscles of the fifth and sixth segments, and in some insects this is carried to so great an extent that the whole body becomes constricted in the fifth segment like an hour-glass, and is thus divided into two distinct regions, thorax and abdomen. The same change takes place also in the muscles of the first and second segment, by means of which the region of the head is divided from that of the thorax (*fig.* 365). These duplicatures of the external covering are carried to a greater extent on the under surface of the first four segments than on the upper,

* See also Entomologist's Text-book, p. 298.

Fig. 365.

Section of pupa of sphinx ligustri; 1 to 13, dorsal surface, number of segments; 1 to 12, ventral surface, number and position of ganglia; a, dorsal vessel; b, its lateral muscles; c d, œsophagus and stomach; e, ilium; f, hepatic vessels; g, colon; h, rectum; i, double testis; k, brain. Newport, Phil. Trans.

Fig. 366.

Section of perfect state, Sphinx ligustri; letters and figures as in section of pupa. Newport, Phil. Trans.

and form the divisions between the legs of the perfect insect,—the bony processes of the sternal surface to which some of the principal muscles are attached. On the upper surface of the same segments they in like manner become the *phragmata*, or bony partitions of the dorsal surface. The fifth segment becomes almost entirely atrophied, and the sixth very much shortened. A part of the fifth segment forms a portion of the posterior surface of the thorax of the perfect insect, (*fig.* 366) while the remainder constitutes the petiole or neck which connects the abdomen with the thorax, the sixth being the first true segment of the abdominal region. Exactly the same changes take place in Hymenopterous insects, and in every other species in which we have had opportunities of watching them. We have before alluded to the opinion of Dr. Ratzeburg that the head in Hymenopterous insects is composed of two segments of the larva, because just before the change into the nymph or pupa state a portion of the head is found beneath the integuments of the second segment. The fact is indisputable, but the explanation of it appears to be this. The true head of the Hymenopterous larva consists of but one segment, which is provided with the organs of manducation and sensation the same as in the Lepidopterous. But the head in this larva ceases to become larger after a certain period, while the other segments of the body continue to grow, and ultimately acquire a diameter more than double that of the head. Now the parts which are to form the head of the future nymph continue also to grow beneath the unyielding cranium, from which, as the change approaches, they become detached, and are gradually developed backwards, and encroach upon the anterior portion of the second segment. This, in accordance with the laws of development, as established by Geoffroy St. Hilaire, that in proportion as one part of an organized body is increased beyond its ordinary size, the part or parts in its immediate vicinity are in a corresponding degree arrested in their development, becomes so much reduced, that in the nymph, this second segment, which in the larva is of the same size as the third and succeeding ones, has not half its original extent, and being still further reduced in that state constitutes at length the atrophied, and almost obliterated *pro-thorax* of the perfect insect. But while the second segment is thus encroached upon by the first it is in like manner encroached upon from behind by the third, the immense *meso-thorax*, which supports the chief organs of flight in the perfect insect. The fourth segment from the same cause is developed backwards, and the fifth, diminished to a very small size, exists only as in the sphinx as the petiole which connects the thorax with the abdomen, thus leaving the nine posterior segments of the larva to the latter region, as stated when alluding more particularly to the number of segments in hymenopterous larvæ. The necessity for this additional segment in the abdomen of these larvæ is a matter of much interest, and appears to be connected with the development of an *apparently* additional organ in the females of this class, a circumstance to which we shall return in our description of the skeleton of the perfect insect.

The Pupa.—We have seen that after leaving the larva or feeding condition, the insect assumes one of a very different form, which is called the *pupa*, *nymph*, *aurelia*, or *chrysalis* state. The two latter terms were applied by the older entomologists to this stage of transformation in butterflies and moths. The term aurelia was used, as expressive of the beautiful golden colours or spots with which many species are adorned, as *Vanessa urticæ*, *v. atalanta*, and others. The term *chrysalis* had a similar signification. Linnæus, desirous of employing a term that would be applicable to this stage of transformation in all insects, adopted that of *pupa*, because in a large majority of the class the insect is as it were *swathed* (*fig.* 367) or

Fig. 367.

Pupa of Deilephila Elpenor. Elephant hawk-moth.

bound up, as was formerly the practice of swathing children. This kind of pupa, in which the future limbs are seen on the outside of the case, is called *obtected*. The term *nymph*, which is sometimes employed, is applicable only to those species in which the limbs remain free, but are folded up, as in the pupæ of the butterfly and moth, and are not covered with a hard uniform case; as in many Coleopterous and most Hymenopterous insects (*fig.* 368). When the pupa is in-

Fig. 368.

Nymph or pupa state of Vespa crabo. Hornet. Magnified.

closed in a smooth uniform case, but no signs of the limbs or other parts of the body are visible, as in *Diptera*, it is called *coarctate*. In these insects the skin of the larva is not cast off at the period of changing, but becomes the covering or coccoon of the included pupa, which is also inclosed in its own proper skin within it. In all insects which undergo a complete metamorphosis, this is the period of quiescence and entire abstinence. Many species remain in this state during the greatest part of their existence, particularly the true pupæ of moths and sphinges, which often continue in it for nearly nine months of the whole year. But in most of those insects which assume the particular condition of nymph, in which the body remains soft and delicate, as the hornets, ants, and bees, the pupa state is the shortest period of existence, being often scarcely more than a week or ten days. In every species the length of this period is much affected by the influence of external circumstances. Thus if the larva of the common nettle-butterfly, *Vanessa urticæ*, change to a chrysalis in the hottest part of the summer, it will often, as we have found, be developed into the perfect insect in eight or nine days;* whilst if its change into the chrysalis takes place at the beginning of summer, it is fourteen days before the perfect insect appears; and if it enters the chrysalis state at the end of summer, it remains in that condition through the winter until the following spring. On the other hand, as was proved by Reaumur, if the chrysalis be placed in an ice-house, its development into the perfect insect may be retarded for two or three years. Again, if the chrysalis be taken in the midst of winter into a hot-house, it is developed into the perfect insect in from ten to fourteen days. This period of quiescence is absolutely necessary in all those species which undergo an entire change of form and habits, for the completion of those structural metamorphoses by which the creature is not only adapted to the performance of new functions, but is equally incapacitated for the continuance of some of those which it has previously enjoyed. During this period it is that new parts are developed, and the insect's mode of life is in consequence entirely changed. Whilst these alterations are taking place in the organic structures, the functions of the organs themselves are in a great measure suspended, and the condition of the insect becomes that of the hybernating animal. Respiration and circulation are reduced to their minimum,† and the cutaneous expenditure of the body is then almost unappreciable even by the most delicate tests.‡ Thus a pupa of *Sphinx ligustri*, which in the month of August, immediately after its transformation, weighed 71.1 grains, in the month of April following weighed 67.4 grains, having thus lost only 3.7 grains in the long period of nearly eight months of entire abstinence. The whole of this expenditure, therefore, had passed off

* Phil. Trans. 1834, part 2, p. 416.
† Phil. Trans. 1836, part 2, pp. 555-6.
‡ Idem. 1837, part 2, p. 323.

by the cutaneous and respiratory surfaces. But when the changes in the internal structures are nearly completed, and the perfect insect is soon to be developed, the respiration of the pupa is greatly increased, and the gaseous expenditure of its body is augmented in the ratio of the volume of its respiration, which is greatest the nearer the period of development. Thus in the same insect in which the diminution of weight was so trifling during eight months' quiescence and abstinence, it amounted in the succeeding fifty-one days to nearly half the original weight of the pupa, since the perfect insect, immediately after its appearance on the 24th of May, weighed only thirty-six grains.

This increased activity of function is attended with a correspondent alteration in the general appearance of the pupa. In the sphinx all the parts of the future *Imago* become more and more apparent on the exterior of the pupa case, the divisions into head, thorax, and abdomen are more distinctly marked, the eyes, the antennæ, and the limbs appear as if swollen and ready to burst their envelope, and the pupa gives signs of increasing activity by frequent and vigorous contortions of its abdominal segments. The naked pupa or *nymph*, in which, as we have seen, all the parts of the body are free, and encased only in a very delicate membrane, acquires a darker colouring and a firmer texture, while the species which undergo their metamorphoses into nymphs in the water, *Trichoptera*, the caddis-flies, acquire a power of locomotion as the period of their full development approaches, to enable them to creep up the stems of plants, and leave that medium in which it is impossible for them to exist as perfect insects.

In every instance the assumption of the perfect state is accompanied by a slipping off of the external covering. Before this can be effected, many Lepidoptera, like the Trichoptera, have first to remove themselves from the locality in which they have undergone their previous metamorphoses. When this happens to be in the interior of the trunks of trees, or in other situations from which it is difficult to escape, the abdominal segments of the pupa are often beset with minute hooks (*fig.* 367), similar to those on the feet of the larva. By means of these, by alternately contracting and extending its abdominal segments, the pupa is enabled to force an opening through its silken coccoon, or to move itself along until it has overcome the obstacles which might oppose its escape as a perfect insect.

The imago or perfect state.—Immediately after the insect has burst from the pupa case it suspends itself in a vertical position with its new organs, the wings, somewhat depending, and makes several powerful respiratory efforts. At each respiration the wings become more and more enlarged by the expansion and extension of the tracheal vessels within them, accompanied by the circulatory fluids. When these organs have acquired their full development the insect remains at rest for a few hours and gains strength, and the exterior of the body becomes hardened and consolidated, and forms, what we shall presently consider, the *Dermoskeleton*. This is what takes place in Lepidopterous insects. Some of the Coleoptera, as in the instance of *Melolontha vulgaris*, the common chaffer-beetle, remain for a greater length of time in their nidi before they come abroad after entering the imago state. This is also the case with the Humble-bees. When these insects first come from their cells they are exceedingly feeble, their bodies are soft, and covered with moisture, their thick coating of hairs has not acquired its proper colour, but is of a grayish white, and they are exceedingly susceptible of diminished warmth. They crowd every where among the cells, and among other bees, where there is most warmth. In a few hours this great susceptibility is diminished, and their bodies acquire their proper colours, but they do not become sufficiently strong to be capable of great muscular exertion, and undertake the labours of the nest until the following day.

When an insect has once entered its perfect state, it is believed to undergo no further metamorphosis or change of covering. But there exists an apparent exception to this general law in the *Ephemeridæ*, which are noted for the shortness of their existence in the imago state. When these insects have crept out of the water, and rid themselves of the pupa covering, and their wings have become expanded, they soon take flight, but their first movements in the air are performed with some difficulty, and they shortly alight again and throw off a very delicate membrane with which every part of the body has been covered, and then resume their flight with increased activity. The condition of the insect previously to this final change has been called by Mr. Curtis the *pseudimago* state. It was noticed long ago by Swammerdam, and has usually been thought to be peculiar to the *Ephemeridæ*, but occurs also in the *Lepidoptera* and *Diptera*,* but in them takes place at the same time with the change from the pupa state. Swammerdam thought the change peculiar to the males of the *Ephemeridæ*, but Mr. Westwood has seen it also in the females.

Many insects, of which the *Ephemeridæ* and *Bombycidæ* are known examples, take no food in the perfect state, and exist only for a few hours, or at most only a few days, the business of life being almost entirely devoted to the propagation of the species. In every instance of the entire abstinence of a species in the perfect state there is a corresponding atrophy of the parts of the mouth. This we shall find is the case in the Ephemera, in the gad-fly, *Œstrus*, and in the silk-worm moth. In the latter instance the parts of the mouth are simply so much diminished in size as to be unfitted for taking food; in the former they have almost disappeared. On the other hand, when the life of the imago is continued for a long period, all the parts of the mouth are fully developed. The duration of life in these species often extends for many weeks, or in some even months, and the quantity of food taken is consequently greater than is taken by the larva. In those

* Westwood's Introduction, &c. vol. ii. p. 28.

instances in which the life of the imago is extended beyond the usual period, it appears to result from one of the great objects of existence being unaccomplished; the insect is always in a state of celibacy, in which condition the life of an ephemera may be extended to several days, and perhaps even to two or three weeks.*

1. *Dermo-skeleton.*—The skeleton of insects is formed of a modification of the external coverings of the body, together with certain ossified portions situated within the head and thorax, to which some of the most important muscles are attached. Hence it is called a *dermo-skeleton*. The true organs of support are thus placed on the exterior instead of the interior of the body, and the solid skeleton, impacting the whole, as it were, in a coat of mail, gives additional strength to the delicate limbs by affording a larger surface for the attachment of muscles, while it more securely protects the bodies of these diminutive, but exquisitely formed little creatures, from the injuries to which they are constantly exposed. Thus, then, in the strength and position of the skeleton, insects have as striking affinities with the Chelonian Reptiles as they have, as we shall hereafter see, with Birds in the extent, distribution, and activity of their respiratory organs; and with the hibernating Mammalia in their maintaining an elevated temperature of body only when in a state of activity. Some naturalists, however, have contended that the analogies which were traced, first by our illustrious countryman Willis in the year 1692, and subsequently by Geoffroy St. Hilaire and other comparative anatomists, between the dermo-skeleton of insects and the proper skeleton of vertebrated animals, are incorrect, and that the structure ought rather to be regarded as the analogue of the skin than as that of the osseous system, and hence they have compared it only with the nails, horns, and other appendages of the epidermis. These objections receive additional weight and importance from the circumstance that one set of organs, the elytra, which form part of the hardened coverings, are actually derived from the respiratory structures. But it may be remarked in reply, that the skeleton of insects, both in its office and ultimate composition, resembles more the bones of Chelonian Reptiles, which, like it, are covered with a thin cuticular lamella, and placed on the exterior of the body, than the true skin or the epidermis. Hence we shall continue to regard and describe it as subservient to the same purposes in these diminutive creatures as the osseous system in vertebrata. This view of its real nature is justified, as we shall presently see, by analyses of its chemical constituents. The peculiar characteristic of bony structure is the presence of a large proportion of a particular kind of earthy matter, and this is also one of the great characteristics of the coverings of insects, which become consolidated during the changes, by the deposition of a quantity of the same kind of earthy matter within them. But we cannot regard the coverings thus formed as merely exsiccated non-vascular structures; on the contrary, we believe them to be nourished by the circulatory fluids, perhaps to as great an extent as the external skeleton of Chelonia. In support of this opinion it may be remarked that those internal processes which exist in the perfect state, and are developed during the metamorphoses from duplicatures of the external tegument, perform most important offices in the body as organs of support and attachment for powerful muscles. It can hardly be imagined that these internal processes are not nourished by the circulatory fluids like the muscles that are attached to them, while it is well known that every part of the external covering is penetrated by ramifications of the air-vessels, the course of which in the wings has recently been shown to be always indicative of the passages along which the blood circulates.* Hence it is fair to infer that every part of the animal supplied with tracheæ is also nourished by the circulatory fluid, as well in the exterior skeleton of the thorax and abdomen as in the hardened elytra and wings, in which the presence of the fluid has been actually detected by its movements.

Chemical composition.—The peculiar substance that constitutes the hard portion of the dermo-skeleton is called *chitine* by Odier, and *entomoline* by Lassaigne. The most generally received name is chitine. M. Odier, who first analysed the coverings of insects, and discovered this substance,† found that it constitutes about one-fourth part of their whole weight, and that the remaining three parts consist of albumen, extractive matter soluble in water, a coloured oil soluble in alcohol, and a brown animal substance soluble in potass, but insoluble in alcohol. The latter substance, which exists in considerable quantity, was found by Lassaigne to be analogous to the peculiar animal matter of cochineal, *coccine*, and that it forms the basis of the colouring matter of the skeleton. The composition of chitine has been differently stated by chemists, but by all it has been shown to be perfectly distinct from horn, the nails, and other appendages of the epidermis, in being quite insoluble in a hot solution of caustic potass, and in not fusing or swelling up like horn when burnt at a red heat, but leaving a white ash, which retains the original form of the part. This sufficiently proves that the coverings of insects cannot properly be compared with the mere epidermis or its appendages. According to Odier, chitine is obtained by digesting the hard parts of the skeleton in a hot solution of caustic potass, renewed several times, until it has ceased to have any action upon them. The solution, by removing the colouring matter and other constituents, becomes of a deep brown, and leaves the chitine nearly as transparent as horn, without any change of form. This substance, as we have before stated, constitutes about one-third or fourth of the weight of the whole skeleton, and was believed by Odier to contain no nitrogen,

* Op. cit. p. 27.

* Bowerbank, Observations on the circulation of blood and the distribution of the tracheæ in the wing of Chrysopa perla. Ent. Mag. No. 17, Oct. 1836.

† Mémoires de la Societé d'Hist. Natur. de Paris, tom. i. Zoological Journal, vol. i. p. 101, Mar. 1824.

on which account it was compared by him to lignin, the basis of woody fibre. He believed also that it contains no carbonate of lime, the earthy salts being chiefly phosphate of lime, with carbonate of potass and a little phosphate of iron. Mr. Children, however, by a more careful and different mode of analysis, proved that chitine is composed of carbon, hydrogen, nitrogen, and oxygen, in about the following proportions, the mean which we have deduced from his details of two careful analyses:

	Grs.
Carbon	46.08
Hydrogen	5.96
Nitrogen	10.29
Oxygen	37.41
	99.74

and that, in addition to the earthy salts mentioned by Odier, there are also small proportions of silica and magnesia, and a slight trace of manganese; and it has since been stated that there is likewise a trace of carbonate of lime.* Some authors still imagine that chitine contains no nitrogen;† but in the careful experiments of Mr. Children, who was assisted by Professor Daniell,‡ the formation of prussic acid, which took place during the analysis, was decisive of the fact of its existence.

Thus, then, in the distinctness of its chemical composition from that of horn and other dermal appendages, and in its similarity to that of true bone, in the greater proportion of its earthy matter being phosphate of lime, may we not venture to infer that chitine, the basis of the insect skeleton, is intermediate in its chemical condition between the ossific and dermal structures; or, in other words, is an imperfectly developed condition of bony matter, so modified that, while it is subservient to the great purpose of animal life, in affording strength and solidity to the parts in which it exists, it at the same time admits of their performing all the organic functions of the true skin?

If such be not the case, it will be difficult satisfactorily to account for the solidification of those internal processes which, in insects, occupy the position and perform the office of the true bones in vertebrata, but which are originally derived from the external teguments. Thus we shall find that in the cranium of some of the Coleoptera, the most perfect insects, the cerebral ganglia are protected on either side by more or less perfectly developed laminæ of this bone-like structure; that the first subœsophageal ganglion actually lies in a cradle of the same, and that the nervous cord itself, before passing out of the cranium, is not only protected laterally by continuations of these laminæ, but is often inclosed in a distinct bony ring. But it may be said that the exuviation of the coverings of insects during the early period of life, when undergoing their metamorphoses, and a like condition in other articulata, is opposed to this opinion. To this we reply, that in all true insects exuviation of the skeleton takes place only during the growth and metamorphoses of the individual, and that when these are completed, and the insect has arrived at its adult condition, when its body no longer continues to be enlarged, the then perfect skeleton is persistent throughout the remainder of life, which, as in the hive-bee, may continue for many months, and under some circumstances, as has been known among the Coleoptera, even for two or three years. The exuviation of the skeleton of Crustacea, which are said to continue to grow throughout the whole period of their existence, is similar to that of insects, and perhaps in both is induced, not alone, as usually supposed, by the mere incasement of the animal in a covering which prevents the further growth of its body, but by changes in the actual condition of the skeleton itself, dependent upon the same laws of existence which regulate the removal of the old and the deposition of new matter in the bones and other structures of the vertebrata.

Of the manner in which chitine is deposited in insects we have no direct information. Latreille considers it to be a solidification in the mucous tissue, and Dr. Grant affirms it to be a deposition upon the true skin. This appears also to have been the opinion of Odier, who found chitine in the exuviable skeleton of Crustacea, in which he says it exists in the form of lamellæ.* In whatever form it is deposited, it is intimately connected with the true corium, into the composition of which it appears to enter. It is covered by the colouring matter, and also with a distinct epidermis like the horny cuticle on the carapace of Chelonia. On comparing the experiments of M. Odier and Mr. Children the quantity of chitine appears to vary a little in different insects.† A curious circumstance mentioned also by Odier is that it appears to enter into the composition of the tracheæ of the wings, but not into that of their connecting membranes. If this be the case, it is a further proof that the skeleton ought not to be compared to the epidermal appendages of vertebrata.

The skeleton consists of thirteen distinct segments, which are believed to be its normal number in all insects. But recent observations on the larvæ of Hymenoptera and Diptera, before alluded to, render it probable that this is not the full amount, and that the number is at least fourteen, at all events in some species. Mr. Westwood has already shown this to be the case in Hymenoptera, and that in the perfect state of *Forficula*‡ there are thirteen distinct segments in the male, and, also in a rudimentary state, in the female, besides the anal forceps. We have ourselves invariably found fourteen in the apodal larvæ of Hymenoptera and in some of the Diptera; but we

* Professor Owen's Lectures at the Royal College of Surgeons, May 1837.

† Professor Grant, Lancet, Dec. 7, 1833, p. 393. Burmeister, Manual of Entomology, (translation,) 1836, p. 230.

‡ Zoological Journal, March 1824, p. 115.

* Zoological Journal, vol. i. March, 1824, p. 108.

† Op. cit.

‡ Trans. Ent. Society, vol. i. p. 157, et seq.

were not prepared to meet with anything like an approach to the same number in a perfect insect. In the female of the *Gryllotalpa vulgaris* we have found nine distinct segments in the abdomen, besides the post-scutellum, which resembles a tenth one in a rudimentary condition on the dorsal surface between the meta-thorax and base of the abdomen. In the male of the same species there are also nine distinct segments, but the penultimate and ante-penultimate are in a rudimentary condition, corresponding to those in the female Forficula. The post-scutellum at the base of the meta-thorax is as much developed as in the female, and is very distinct as a portion of the meta-thorax. We have also found the same number in a foreign species, *Gryllotalpa didactyla*. The similarity in the number of segments thus appears to connect the *Gryllotalpæ* with the *Forficulæ*. These variations in perfect insects lead us to hesitate in admitting *thirteen* to be the normal number of segments, especially as we shall presently endeavour to show that the head itself is composed of more than one. The varied forms of the body in the different classes are entirely dependent upon the extent to which these primary segments are developed, whatever be their true number, and chiefly upon the greater or less development of parts of the first four segments. But whether the changes in these segments be greater or less, they are always in reference to the habits or economy of the individual. Thus in the Coleoptera and Orthoptera the parts of the mouth are nearly equally developed, and are admirably fitted for all the purposes of manducation. In the Lepidoptera some of these parts are developed to their greatest possible extent, the consequence of which is that the neighbouring parts become atrophied, and leave scarcely a trace of their former existence. This is the case with the mandibles and lips, the most conspicuous parts of the mouth in the larvæ of this order. In the *imago* the maxillæ are greatly elongated, and altered in shape, to form a flexible tube, because the perfect insects are destined to take their food in a liquid state, and because still further, the food is produced in situations where it would be inaccessible to the insect, were the mouth of the same form as in those the food of which requires to be comminuted by the jaws, before it is passed into the stomach.* Then again in the same segment in which the oral organs are nearly equally developed, other parts are often enlarged, and in like manner encroach upon those which are in immediate connexion with them. In the rapacious Neuroptera which obtain their food solely by means of the organs of vision, and are constantly hawking in search of it in the brightest light, the corneæ of the eyes are expanded over nearly two-thirds of the whole surface of the head, and in consequence reduce to their minimum of development those parts which are most conspicuous in the head of Coleoptera, which usually obtain their food by the aid of other senses. The causes which regulate the development of the segments of the thorax are exactly those which influence the development of the head. In the mole-cricket, which burrows in the earth for its food, the second segment, or pro-thorax, with its appendages the anterior extremities, is enlarged to its greatest extent, because it is necessary that nearly the whole strength of the insect should be concentrated in this segment, to enable it to dig its way with ease and rapidity through a resisting medium, while the third and fourth segments, which bear the organs of flight, in this species of minor importance, are smaller than in most other insects. In the Coleoptera, *Geotrupidæ*, which not only burrow in the earth, but require to be transported from place to place in quest of food, the pro-thoracic, and the wing-bearing meta-thoracic segments are largely developed, and form a great proportion of the body, and the intermediate segment, the meso-thoracic, encroached upon by both, is almost atrophied between them. On the other hand, in the Hymenoptera, Lepidoptera, and Diptera, in which the principal organs of locomotion are the anterior wings, the meso-thoracic segment is enormously enlarged, and the pro-thorax and meta-thorax are reduced to a size of comparative insignificance.

These important modifications of structure, by means of which every part of the body is beautifully adapted to the habits and wants of the individual, and the insect itself becomes an agent employed by nature to work certain necessary effects on other parts of Creation, are accomplished during the metamorphoses by certain changes in the form of parts of the external teguments. By this means many insects which in their naked larva condition scarcely at all differ in their general external appearance, are made to assume forms, when they have undergone their metamorphoses, so totally distinct from each other as to be instantly recognisable by the most unpractised observer. The primary division of the body into segments is effected simply by a duplicature of the external covering. One margin of the fold is carried over the other, and a simple telescope articulation is produced. In this way the body of the larva in its earliest condition is first divided into its normal number of segments, and by a continuation of the same process, as we have before shown, into distinct regions.

The articulations of the limbs and organs of manducation are as much the result of changes in the form of the external surface as the division of the body into segments or regions. The folding, the intussusception, the depression, or the extension of certain portions of the integument, when solidified, at the completion of the metamorphoses, serve all the offices, and become parts of the different kinds of articulations, which in principle are precisely similar in insects to some of the more important ones in the Vertebrata. In the simple approximation of two surfaces, completely solidified, and allowing of no motion between them, we discover the common *sutural* connexion of some of the

* See Newman on the External Anatomy of Insects, p. 13.

bones in man. An instance of this occurs in the upper surface of the cranium of every insect, in the union of the clypeus posterior with the epicranium. In another duplicature, one surface of which is rendered concave, and the corresponding one opposed to it convex, and allowing of motion between them almost wholly in one plane, we perceive the true *ginglymoid* or hinge-like articulation; while the small intervening portion of tegument, by means of which the margins of these surfaces are connected, becomes thinned and atrophied, and forms their proper connecting ligament. Instances of this kind of articulation occur also in the head of most insects in the articulation of the mandibles with the cranium, as well as in the limbs of almost every species. Again, when a portion of the tegument which covers the developing organs of locomotion becomes constricted at the base of the organ, that surface of the duplicature which is nearest the body forms a hollow or cup-shaped cavity, into which the other surface of the duplicature, rendered convex, is inserted, and in this way a true *enarthrodial* or cotyloid articulation is developed, the connecting ligament between the two surfaces forming the internal ligament of the joint, which is thus rendered capable of most extensive rotation. The ligament thus formed in every instance is hollow, to allow a passage for the muscles and other structures of the limb. Examples of this kind of articulation occur in the coxæ or basial joints of the legs, in the *Cerambycidæ* and *Curculionidæ*. Lastly, where the tegument is simply reflected upon itself, and a sliding motion allowed of, we have the simple *squamous* articulation. In all cases the development of one portion of tegument takes place at the expense of another, as in the development of the segments themselves, and not by the introduction of a new element in the composition of the part. In this manner, in accordance with the law of *centripetal development* as pointed out by M. Serres in the vertebrated classes, every part of the body is formed in the so-called invertebrated.

We thus recognise *four* distinct kinds of articulation, although several more have been described by Straus-Durckheim in his excellent work on Melolontha,* but all of them appear to be reducible to these primary ones.

These principles will enable us to understand the cause of the presence or absence of those structures which form the internal skeleton, and also the manner in which the limbs of the imago are developed from the soft and uniform body of the naked larva. They may also tend to elucidate one of those hidden and mysterious processes of nature by which the exterior organization of the queen or female inmate of the hive is caused so materially to differ from that of the so-called neuter or sterile female, influenced as it is said to be in its whole system by the different quality of the food supplied to the larva during the first few hours of its existence.

According to the investigations of the most careful observers, Savigny, Audouin, Macleay, Kirby, Carus, Straus-Durckheim, Newman, and others, every segment of the perfect insect is made up of distinct parts, not always separable from each other or developed to the same extent, but existing primarily in all. It is also believed that the head itself is formed of two or more segments, but the exact number which enter into its composition is yet a question. So uncertain are the opinions held upon this subject, that while Burmeister recognizes only two segments, Carus and Audouin believe there are three, Macleay and Newman four, and Straus-Durckheim, even so many as seven. These different conclusions of the most able investigators appear to have arisen chiefly from too exclusive examinations of the head in perfect insects, without reference to the corresponding parts in the larvæ. It is only by comparing the distinctly indicated parts of the head in the perfect insect with similar ones in the larva that we can hope to ascertain the exact number of segments of which it is composed. In the head of the perfect insect there ought to be found some traces of all the segments which exist in the larvæ of the same species, and in that of the more perfectly developed larvæ that undergo a true metamorphosis, there ought in like manner to be found the rudiments of all the segments in the least perfectly developed. Now the common larva of the Dipterous insect, the maggot of the flesh-fly, is one of the lowest forms we have yet examined, and we have already seen that its head appears to be formed of four, and perhaps even of five segments. This is the greatest number yet noticed in the head of the larva of any species. If, therefore, we can trace the like number in the head of a perfect insect, we may fairly conclude that this is the normal number of segments throughout the class. The head of the great water-beetle, *Hydröus piceus*, is remarkably well-fitted for exemplifying the number of segments of which the head is originally composed, the remains of four of the segments being distinctly marked; and it also affords us a proof of the correctness of the opinions advanced by Savigny and others, that the organs of manducation are the proper articulated members of distinct segments, and are perfectly analogous to the proper organs of locomotion.

We shall first describe the parts of which the head is composed, and then endeavour to explain the manner in which these parts have been developed from separate segments to form the perfect cranium and its appendages. It has hitherto been customary with naturalists to designate the head the first segment of the body, and as every change in the nomenclature of a distinct part ought always to be avoided, unless positively required, through fear of creating confusion, we shall not deviate on the present occasion from the established mode, but when speaking of it as a whole shall consider it the first segment, while the aggregation of segments of which it is composed we shall designate individually *sub-segments*, distinguishing them numerically in the order in which they appear to exist in the earliest condition of the fœtal larva.

* Considerations, &c. p. 48 et seq.

TABLE OF THE PARTS AND APPENDAGES OF THE HEAD.

Fixed parts of the head—external surface.

(*a*) *occiput*, including the *foramen occipitale* and *base of the skull*, and forming part of
b, epicranium ....vertex, *Kirby* ....epicrâne, *Straus*.
(*b* 1) *ocelli* ....stemmata.
c, oculi ....cornées, *Straus*.
d, clypeus anterior .... } nasus, *Kirby* ....chaperon, *Straus*.
d,*clypeus posterior.... } clypeus, *Fabricius*
n, gula, *Kirby* ....pièce basilaire, *Straus*.

Moveable parts of the head.

e, labrum
f, mandibulæ

g, maxillæ, divided into ....
- 1, cardo, *Kirby* ......branche transversale, *Straus*. insertio, *Newman*
- 2, stipes, *Kirby* ......pièce dorsale, *Straus*; maxilla, *Newman*
- 3, palpifer, *Newman* ..squame palpifer, *Straus*. bears
  - 4, the maxillary palpus, *h*.
- 5, lacinia, *Macleay*, *Newman*; intermaxillaire, *Straus*. divided into—
  - 6, galea, *Fabricius*; lobus superior, *Kirby*.
  - 7, lobus inferior, *Kirby*.
  - 8, unguis, *Kirby*.

i, labium..........
- *i*, ligula, *Newman*; labium, *Macleay*.
- *k*, the labial palpi.
- *l*, mentum, *Macleay*; labium, *Newman* } pièce prebasilaire, *Straus*.
- *m*, submentum .... stipes, *Macleay*; insertio, *Newman* }

12, lingua, *Newman*....hypopharynx, *Savigny*.

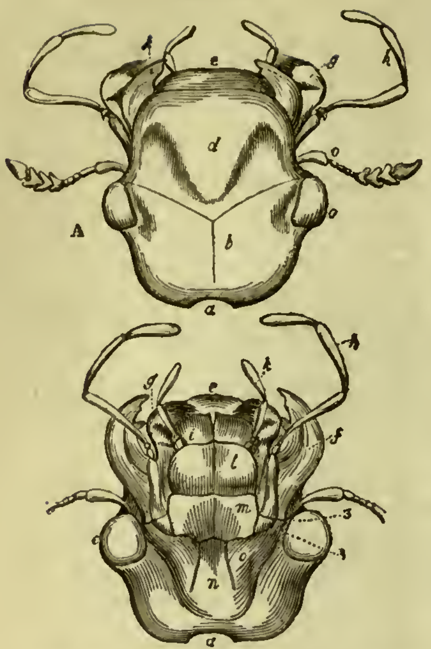
A, antennæ .... { scapus. pedicella. clavola. } *Kirby*.

Sub-segments of the head.	*Interior of the head.*
1st includes labrum and labium.	
2d includes clypeus anterior and mentum	os epipharyngeum, os hypopharyngeum anterius.
3d includes clypeus posterior and submentum ..	os hypopharyngeum posterius, *z*.
4th, obsolete, orbits and bones of the antennæ ..	laminæ orbitales, *w*; and ossicula antennarum or toruli, *r*.
5th includes epicranium and gula	sutura epicranii, *p*. os transversum, *x*. laminæ squamosæ, *s* and *v*; lames laterales, *Straus*. tentorium, *Burmeister*, *u*; arcade, *Straus*.

The above table exhibits the whole of the parts yet found in the cranium in the most perfect order of Insects, the *Coleoptera*; but it must be remembered that many of these parts are less perfectly developed in the other Orders, and in some of the species have not yet been discovered.

Commencing our examination of the head at the posterior part of its upper surface, we observe that the *occiput* (*a*, *fig.* 369) is that portion of its base which is articulated with the anterior margins of the prothorax. It is perforated by a large foramen, through which the organs of the head are connected with those of the body. It is very distinct in the Hydröus and most Coleoptera, and in some, the *Staphylinidæ*, *Carabidæ*, and *Silphidæ*, is constricted, and extended backwards so as to form a complete neck; but in others, as in the *Curculionidæ*, it is short and hardly distinguishable from the *epicranium* (*b*), of which it is the continuation and posterior boundary. The *epicranium* is the whole of the posterior and upper surface of the head, bounded posteriorly by the occiput, laterally by the corneæ and sides of the gula, and anteriorly by a triangular suture which extends from the anterior margin of the corneæ to the middle of the head between the eyes, where its apex unites with a longitudinal suture which extends along the median line to the occiput. This triangular suture is a marked character in the head of many insects, both in the larva and perfect state, and is of great importance in determining the number of the *sub-segments*. It is very distinct in the larvæ of Lepidoptera, and is as marked in the *Melolonthidæ* and the *Staphylinidæ* as in the *Hydröus*. In some of the beetles it is indistinctly marked on the upper surface, but forms elevated ridges on the interior surface. This is particularly the case in the Hydröus. In the *Dyticus* it is more distinctly marked by a lighter colour of the skull, while in the common dung-beetles, *Geo-*

Fig. 369.



External superior and inferior surface of the head of Hydröus piceus.

A, antenna; *a*, occiput; *b*, epicranium; *c*, oculi; *d*, clypeus anterior; *e*, labrum; *f*, mandibles; *g*, maxilla; *h*, its palpus; *i*, ligula; *k*, labial palpus; *l*, mentum; *m*, submentum; *n*, gula; *o*, mandibular ridge.

trupidæ, its existence is indicated by a slightly elevated ridge. This suture divides the epicranium from the posterior portion of the *clypeus* (*d*), the most conspicuous portion of the head. The proper boundaries of this part have been ascertained with tolerable precision in Coleoptera, but do not appear to have been traced correctly in some of the other orders, particularly in *Orthoptera*. The *clypeus* or shield, in Coleoptera, is that broad cover of the anterior surface of the head, bounded posteriorly by the epicranium and anteriorly by the labrum, with which it is freely articulated. It is the part called by Mr. Kirby the nose, and by Straus Durckheim *chaperon*. It appears originally to be formed of two portions, which we have called *clypeus anterior* and *posterior*, and which are completely united in some families, as in the *Lamellicornes*, without trace of their previous distinction, but in others with slight traces of their former separation, as in *Hydröus*, while both parts are distinctly articulated in some of the *Dyticidæ*, in which its anterior portion appears to be moveable, and has probably been mistaken for the whole clypeus, as has been the case in Orthoptera.* In some species the shield is curiously excavated, tuberculated, or armed with a long horn, as in *Copris*, *Typhæus*, and *Dynastes*, (*fig.* 333,) or is minute and inconspicuous as in the *Cantharidæ*. The original division of the shield into two portions in *Hydröus* appears to be indicated by two rough excavations situated between the triangular suture, its posterior boundary, and the anterior lip. The *labrum* or upper lip (*e*) is the most anterior portion of the upper surface of the head, bounded only on its posterior margin by the clypeus. It is usually a narrow transverse piece which has been confounded by some writers, particularly by Fabricius, with the clypeus. In some families, *Scarabæidæ* and *Lucanidæ*, it is very minute, but, as remarked by Mr. Newman,* cannot be considered to be in any case entirely wanting, as was supposed by Olivier. In those cases in which it appears to be absent it is concealed beneath a largely developed clypeus. In many families it is large and projecting, and often notched, as in the *Carabidæ* and *Silphidæ*. It is also very distinct in the water-beetles. It forms the anterior boundary of the mouth.

The *corneæ* constitute a great portion of the fixed parts of the head. The principal of these (*c*), the corneæ of the true or compound eyes, are situated on the lateral external surface of the cranium, bounding the basilar piece below, and the epicranium above. They are two large convex surfaces, generally of a nearly circular, but sometimes of a kidney-shaped form, divided into a great number of very minute facets, perfectly distinct from each other, each of which is the proper cornea of a distinct eye. They are more or less numerous in different insects, amounting in some to no more than fifty in each compound eye, but in others to so many as thirty-six thousand. Thus Lyonet reckoned eleven thousand three hundred in the eye of the goat-moth, and Geoffroy more than thirty-six thousand six hundred in the eye of a butterfly. Each compound cornea is usually situated immediately behind the external angles of the triangular or epicranial suture, and is more or less protuberant in different species, as in Hydröus and its affinities. This is particularly the case in the ground-beetles, as noticed by Dalman,† especially in those which reside near water or in sandy situations, as the *Cicindelidæ*, &c.; and, as remarked by Mr. Westwood, these protuberant eyes occur mostly in insects of rapacious habits. But it must further be observed that they occur also in insects which are not of rapacious habits, but require for some other purpose an extended field of vision. This is the case with the males of many species, and most remarkably so in the male of *Lampyris noctiluca*, the common glow-worm, in which the corneæ cover almost the whole lateral and under surface of the head. This insect is well known to be attracted by the light of the female. The like occurs in the male of the hive-bee, and in that of some Diptera, as in the *Empidæ*, which seek their females, and are constantly found *in copulâ connexos* on the wing in the open air. Again, in the sun-beetles, *Cetoniidæ*,

* Newman, p. 9.

* Paper on the Nomenclature of the Parts of the Head in Insects, p. 18.

† Entomologist's Text-book, p. 236.

which live on the pollen of flowers, the eyes are very protuberant. From these circumstances it may be inferred that all those insects in which the eyes are either protuberant or very large are directed by sight alone to some particular object of their search, whether this be the female of the species, as with the glow-worm, &c. or the active living prey, as with the rapacious beetles; and consequently in these instances a more extended field of vision is required than in those whose object of search is more easily discovered, or whose means of subsistence is less precarious. In many Coleoptera each eye is divided anteriorly by a process of the epicranium, the *canthus*, as is particularly the case in the Lamellicornes (*fig.* 333). The extent to which this is developed in different insects varies considerably, and seems to be greatest in those species which are constantly engaged in burrowing. Thus, while it is extended only a little way into the eye in *Cetoniidæ*, it is carried half way across it in *Copris*, and in the female of *Lucanus cervus*, but less than half in the male; in the genera *Ateuchus* and *Dorcas* more than half way across; while, according to Kirby and Spence,* in another genus, *Ryssonatus*, it completely divides the eye into two. In other instances the canthus is not produced, but the eye is encroached upon anteriorly by a portion of the epicranium or by the base of the antenna, which sometimes, as in the *Cerambycidæ*, appears as if inserted into the eye itself. In other families, as in the *Gyrinidæ*, the middle of the eye is excavated across its whole surface by a deep furrow, which gives the appearance of two distinct eyes on each side of the head. In some insects the eyes are entirely absent, an instance of which occurs in one of the *Xylophagi*, *Annomatus terricola*, recently discovered by M. Robert, near Liege, and an account of which was read before the Royal Academy of Sciences of Brussels by M. Wesmael, in Oct. 1835. This insect, whose habits are believed to be entirely subterraneous, is without any external organs of vision.†

The *ocelli*, *stemmata*, or single eyes, are simple, convex, hemispheric lenses, varying in number from one to three. They are always situated, in those insects in which they exist, on the superior part of the epicranium, posteriorly to the triangular suture. They are entirely absent in Hydröus and all Coleoptera except the *Dermestidæ*, in which there is a single ocellus situated on the centre of the epicranium, a little posteriorly to the true eyes; in one of the *Paussidæ*, and in some of the smaller Brachelytra;‡ but they almost invariably exist in some of the other orders, as in the Hymenoptera, Neuroptera, &c.

The under surface of the head is formed chiefly by the posterior and lateral parts of the *gula* (*fig.* 369, *n*), which unite with the lateral parts of the epicranium and occiput. It is bounded anteriorly by an indistinct suture, and laterally by the inferior portions of the corneæ. In *Melolonthidæ* it is of great extent, and is the *pièce basilaire* of Straus Durckheim. In *Hydröus* it is excavated in the middle line, on each side of which are two elevated ridges, the remains of the basilar parts of the mandibles (*o*), the proper appendages of the fifth sub-segment, or basilar portion of the head, with which they have become consolidated. The *sub-mentum* (*m*), *pièce pre-basilaire* of Straus, is the most posterior of the parts that form the under lip. Straus Durckheim and others appear to have considered this part as a process of the immoveable structure of the head, with which at first it appears to be firmly united. Mr. Westwood remarks, that although it appears to be articulated in some beetles, it is immoveable, and forms part of the under surface of the head.* We have but little doubt that it is a distinct piece, and is part of the third sub-segment of the head, however it may become anchylosed to the *gula* by the obliteration of the fourth in some instances, or be itself entirely obliterated in others. In Melolontha it is exceedingly short, but of great width. In Hydröus it is very distinct, and the maxillæ are articulated to the skull on each side of its base, as is the case also in Melolontha and most other instances. It is a little narrower posteriorly than anteriorly, and its length is not more than one-half its breadth. It is articulated anteriorly with the *mentum* (*l*); this is a short transverse plate, in *Hydröus* somewhat lunated on its anterior margin, rather broader than long, but not so short as the sub-mentum. In *Dyticus* it is excavated at its anterior margin, the sides being carried forward like separate lobes. In this genus it forms with the sub-mentum, from which it is separated only by a slight transverse articulation, a broad plate, rounded on its edges, and covering nearly the whole of the under surface of the mouth; in some of the *Staphylinidæ* it is exceedingly short and broad, in *Melolonthæ* it is nearly of a square form, but its anterior margin is acute; in *Cetonia aurata*, on the contrary, its anterior margin is much wider than its posterior, or articulation with the sub-mentum. In *Amphimalla* it is quadrate as in Melolontha, and forms with the *palpiger* a nearly square plate. The *palpiger*, first described by Mr. Newman,† is not developed in the lip of *Hydröus*. In those genera in which it is found, as in *Dyticus*, it is an articulation which, as its name implies, bears the labial palpi, and is situated between the mentum and ligula, of which it seems to be only a portion. It is subject to great diversity in size and shape, and in consequence is often confounded with the ligula itself. It is said to be very distinct in most of the *Carabidæ*, and in *Cychrus rostratus*, as remarked by Mr. Newman, it seems at first to have entirely taken the place of the ligula. In the *Staphylinidæ*, *Göerius*, it is much narrower and longer than the mentum, with which it forms as it were a cone. In one of the *Endomychidæ*, *Lycoperdina*

* Introduction to Entomology, vol. iii. p. 502.
† Fr. Ent. Soc. vol. ii. Proceeding, p. xii.
‡ Entomologist's Text-book, p. 238.

* Op. cit. 1838, p. 256.
† Entomol. Magazine, vol. ii. p. 82 et seq. Also a Paper on the Nomenclature of the Parts of the Head in Insects, p. 19.

bovistæ, according to the figure by Mr. Curtis,* it is a broad oval plate, much larger than either of the other parts of the labium. This irregularity in its size is very perplexing in examining the parts of the mouth, since in those cases in which it is developed to a great extent the ligula is often so much reduced in size as to appear entirely absent, and to render it a matter of consideration whether it would not be better to consider the palpiger in all cases as only the inferior portion of the true ligula, since, in a great number of instances in which the palpiger is large, the ligula is very small; and, as in the instance of *Cychrus*, is formed only of minute linear lobes, situated upon and almost hidden by the palpiger. The *ligula* (*i*) is the most anterior portion of the under lip. It varies as much in shape and size as the palpiger. In Hydröus it is divided into two lobes by a slight fissure in its anterior margin, which is membranous, and covered, as well as its internal surface, with short smooth hairs. It is the part which properly represents the true lip, its internal surface being continuous with the soft membrane of the mouth. In most of the Geodephagæ it is divided into three linear lobes, not very unlike in their appearance to the true palpi. This division into lobes occurs in most of the predaceous land-beetles. In *Cicindelidæ* the ligula is very minute, and this is the case also in some of the *Staphylinidæ*. In the predatory water-beetles, as Mr. Newman has observed, the ligula is of considerable size, and this is particularly the case in Hydröus.

The *mandibles* (*fig.* 369, *f*, *fig.* 370, A), the true organs of manducation, are two exceedingly large and strong arched jaws opposed to each other, and sometimes decussating like the blades of a pair of scissors. This is the case in the most rapacious insects, *Cicindelidæ*, *Staphylinidæ*, *&c.* In the Hydröus they do not decussate. They are situated immediately beneath the clypeus and labrum on each side, and are connected by a ginglymoid articulation with the upper and under surface of the head. The *superior external condyle* moves in the articulating surface of the small bone (*fig.* 372, *q*), a little anterior to the bone of the antennæ (*r*) and the *inferior external condyle* (*fig.* 370, *f.* 3) in the articulating surface (*fig.* 372, *y*) of the *os transversum*. In this insect their form is somewhat like that of a sickle or garden knife. They are thick and strong at their base, and hooked at their apex, and are armed with three projecting, notched, or double-pointed teeth. The internal margin of the apex of the mandible is excavated or grooved, as also are the teeth along their posterior surface. The object of this has reference, probably, to the habit of the insect, the structure of the jaws being somewhat similar in this respect to that of the jaws of the more rapacious Dyticus, which is said to prey upon small fishes and water-insects. The under surface of the internal margin of each mandible is covered with soft villi, and there are four condyles to each mandible. Those just described perform the

* British Entomology.

Fig. 370.

A, mandible; 1, process for 2, extensor tendon; 3, process to articulate with the inferior surface of the cranium; 4 & 5, flexor tendon; 6, internal margin of jaw; 7, bifid teeth.

B, under surface of the maxilla.

C, internal or upper surface; 1, cardo; 2, stipes; 3 & 4, palpifer; 5, lacinia; 6, galea; 7, lobus inferior; 8, unguis; 9, retractor maxillæ; 10 & 11, levator cardo.

chief motions; the others are the middle external condyle (1), which gives attachment to the tendon of the great extensor muscle, and is situated between the superior and inferior condyles; and the *internal condyle* (*b*) is situated on the internal posterior margin of the mandible, and gives attachment to the flexor muscles of the jaw. The internal margin of the mandible is also rendered concave, and forms part of the lateral boundary of the epipharynx. From the general structure of the mandible we at first are lead to suppose that the habits of the insect are entirely carnivorous, but it is said to subsist chiefly upon aquatic plants, although it feeds with avidity on dead larvæ and aquatic mollusca.* In the truly carnivorous Coleoptera, the *Cicindelidæ*, *Carabidæ*, and others, the mandibles are acutely pointed; but in those which feed upon vegetable matter, leaves of trees, &c., they are thick and obtusely dentated, as in *Melolonthidæ*. In the generality of species the mandibles are always strong dentated organs, but a few exceptions occur in the *Cetoniidæ*, which feed on the pollen of flowers, and in the *Aphodiadæ*, which subsist on the recent excrement of cattle, in which their margins are soft and flexible. They are always the most conspicuous parts of the mouth, and differ from

* Westwood, Introduct. Entomology, vol. i. p. 127.

the lesser jaws, *maxillæ*, in being articulated both with the upper and under surface of the head.

The *maxillæ*, or lesser jaws (*fig.* 370, B,C), are of very compound structure. They are situated between the mandibles and labium, and are employed by the insect to hold its food, and to convey it to the posterior part of the mouth. They are each formed of four primary and three or more accessory parts, when most completely developed. The primary parts are the *cardo* or hinge, the *stipes* or footstalk, the *palpifer*, and the *lacinia* or blade. The accessory parts are the *galea* or *lobus superior*, the *lobus inferior*, and *unguis*. The *cardo* (*fig.* 370, B, C, 1) is the joint upon which nearly all the motions of the maxilla depend. In Hydröus it is a minute trapezoid or irregularly triangular corneous plate, with an elongated curved process by which it is articulated with the *os transversum* on the under surface of the cranium, and over which the cardo is articulated like a hinge. In some genera, as in *Staphylinus*, it is more elongated, and this is particularly the case in *Melolontha*, whence it was called *branche transversale*. In most instances it is as it were wedged in between the sub-mentum and mandible. It is articulated at its anterior margin with the second piece of the maxilla, the *stipes* (2), which forms the outer surface of the organ, being considered its primary part. It is an elongated corneous plate, broadest at its articulation with the *cardo*. It is approximated along its anterior margin to the *squama palpifer* (3), a broad plate which covers the superior external surface of the maxilla. Immediately beneath the anterior margin or apex of the *squama* is inserted the palpifer (4), a short cylindrical appendage, which is usually considered part of the squama, the whole being together called the *palpifer*. It supports the proper maxillary or true palpus, which is remarkable for its length in the Hydröus. The *lacinia* (5), sometimes improperly called *maxillo*, forms the internal portion of the organ, and, as we shall hereafter see, appears in its earliest condition in the embryo to constitute a separate organ or appendage, belonging to the mentum—as the stipes appear to belong to the sub-mentum—but which in the course of development becomes approximated to the stipes to form part of the maxilla of the perfect insect. Like the stipes, it is a broad corneous plate, which forms the greater portion of the under surface of the maxilla, and is articulated with the cardo only by a small portion of its base. On its upper surface, which forms a great part of the sides of the mouth, it is soft, membranous, and covered with fine hairs. It gives origin at its anterior truncated extremity to the accessory parts of the maxilla, the *lobus superior* and *inferior*. The *lobus superior*, or *galea*, is a thick, double-jointed organ (6), densely covered at its anterior margin with stiff reddish hairs. It is articulated with the external angle of the lacinia, and covers the lobus inferior, which is articulated with the internal angle, and on this account, more particularly in *Orthoptera*, is called the *galea* or helmet. It is used by this and other insects as a palpus, or feeler, to touch and convey food to the mouth. The *lobus inferior* is a short quadrate joint (7), articulated with the internal angle of the lacinia, of which it forms the proper continuation. At its superior extremity is a minute articulated claw (8), densely covered on its upper surface with long stiff hairs, as is also the whole of the internal margin of the lacinia itself, which forms the lateral boundary of the mouth, and is continuous with the soft lining of the pharynx. The *maxillary palpi* (*h*) are two very long flexible organs, composed each of four joints. The *palpifer*, upon which they are situated, is a short joint or tubercle, inserted at the anterior external angle of the maxilla, between the angle of the lacinia and the plate which covers the superior surface of the maxilla (3), and of which it forms a part, but from which in this insect it appears quite distinct. The first joint of the palpus is exceedingly short, so as to allow of extensive motion to the organ in every direction, while the second is much longer than in most other insects, and, when the palpus is retracted, forms with the third joint a distinct elbow or bend. The third and fourth joints are also of great length, so that the insect is enabled to protrude the organ to a great distance. The *labial palpi* (*fig.* 369, *k*) are much shorter than the maxillary. The first two joints are very minute, the second being partly hidden within the first, but the third and fourth are long and projecting, but not so long as those of the maxillary palpi.

From all we have been able to observe, the office of the maxilla appears to be of a two-fold kind, and of greater importance to the insect than that of the mandibles themselves. The chief office is that of seizing and retaining the food within the mouth; and the secondary that of assisting the mandibles in comminuting it before it is passed on to the pharynx. Consequently all the parts of the maxilla are subject to great variation of form; and in the different tribes of Coleoptera, as in the other orders of insects, each particular form is adapted to the kind of food on which the insect subsists. In *Melolontha*, in which the four primary parts, the *cardo*, *stipes*, *palpifer*, and *lacinia*, were first accurately distinguished by Straus Durckheim,* the maxilla is a thick obtuse organ, with the cardo, which is less completely developed in Hydröus than in most other insects, forming a broad transverse piece, the stipes a short and triangular one, the palpifer also nearly triangular, and the lacinia, which, as Straus has remarked, is always continuous with the pharynx, nearly also of a triangular form, and together constituting a thick compact organ, with its inner angle, the lobus inferior in other insects, forming a strong projecting inarticulated tooth, and its external, articulated with a short thick galea, armed with three obtuse points, which probably serve the office of teeth for masticating the parenchymatous food of this species. This form of

* Considerations Générales sur l'Anatomie Comparée des Animaux Articulés, par Hercule Straus-Durckheim, 1828, p. 68, pl. i. fig. 8.

the maxilla and galea seems more peculiarly adapted to the phytophagous feeders, since in the true carnivorous insects, *Cicindelidæ*, tiger-beetles, and the larger *Carabidæ*, ground-beetles, the maxilla is more elongated, the internal lobe, or apex of the lacinia, is more acute, and often armed with a sharp hook, and the galea assumes the form of a distinct palpus, shorter but similar in appearance to the true maxillary palpus. This is more manifestly the case in the tiger-beetles, in which the galea is a distinctly double-jointed palpus, placed on a feeler-bearer, and the lacinia is armed with a long sharp hook, evidently more adapted for seizing and piercing its living food, like the canine teeth of carnivorous quadrupeds, than for comminuting it like the strong tuberculated galea of the vegetable-feeding Melolontha, or the tuberculated teeth of herbivorous quadrupeds. The office then of the galea, in distinctly carnivorous insects, is simply that of a palpus or feeler, and in accordance with this view we find that in the tiger-beetles it is longer than the inferior lobe, or hooked portion of the lacinia. In the ground-beetles Mr. Newman has remarked that it is shorter than the lacinia, but, in the generality of the tribe, we have also found it longer, as in the rapacious Cicindelidæ, particularly in the larger *Carabidæ*, and this is also the case in some of the *Harpalidæ*, particularly in one species, *Zabrus gibbus*, which is known to be a vegetable feeder. This form of the galea, however, seems more peculiarly to belong to the carnivorous insects, as it is also found in the Dyticidæ, but not, as we have seen, in the nearly allied but far less rapacious *Hydrophylidæ*. On the other hand, in most insects which feed entirely on vegetable matter, the galea is of a more obtuse form, and is less distinct from the other parts of the maxilla than in the rapacious insects. Thus in the greater number of the true vegetable feeders the galea is short, thick, and densely covered with hair. This is the case not only with the maxillæ, but also with the mandibles in those insects whose food is the pollen and perhaps also the honey of flowers, as in the *Cetoniidæ*, and also in the *Geotrupidæ* and other *Scarabæidæ*, which feed upon soft decaying vegetable matter. In the *Cerambycidæ*, as in the rare insect *Monochamus sartor*,* in the *Lepturidæ*, which are found upon umbelliferous plants feeding on the pollen and honey; and in the stag-beetle, *Lucanus cervus*, which subsists on the sap that flows from the wounded bark or roots of trees, the galea is always densely covered with hair, and sometimes elongated to a considerable extent, as in the stag-beetle. In those species which are purely phytophagous, as many of the *Galerucidæ* and *Chrysomelidæ*, which feed on the parenchymatous structure of leaves, both the *galea* and *lobus inferior* are short, obtuse, and covered with stiff hairs, while in the *Coccinellidæ* that very much resemble the latter insects, but are carnivorous feeders, the galea is longer and distinctly jointed, and resembles the same part in Hydröus, being still covered with hair.

* Curtis's British Entomology, pl. 219.

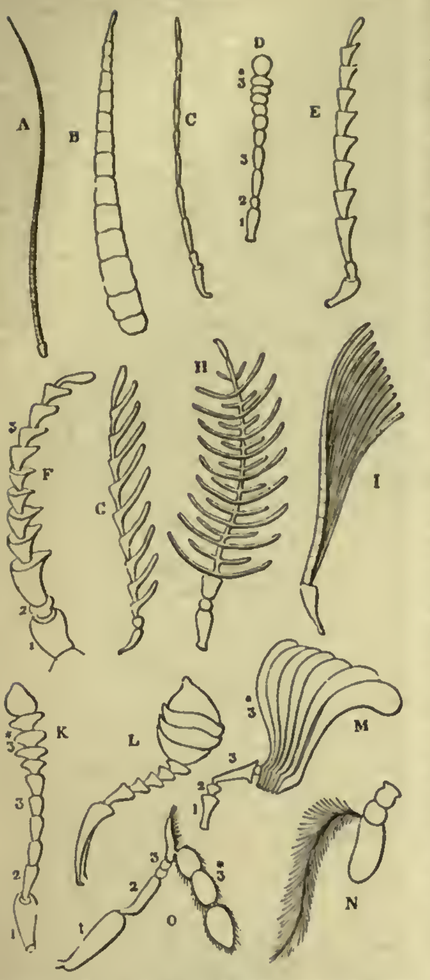
This is also the case in the common meal-beetle, *Tenebrio molitor*, which belongs to a family of less distinctly vegetable feeders. From these facts we are inclined to believe that the structure of the maxilla has much closer connexion with the kind of food and habits of the insect than that of either the labium or the palpi. The latter organs, however, are subject to great variation in the form of the terminal joint, which in some species is much dilated and shaped like a hatchet, as in the common lady-bird, *Coccinella*, while in others it is acute or obtuse. The number of joints is usually four, and it has been supposed that there are never more, either in the maxillary or the labial palpi, in any Coleopterous insect, but the Rev. Mr. Kirby* has mentioned an instance in which there appeared to be an anomalous condition of the maxillary palpi, in this respect, in one of the Geodephaga, *Sericoidia bembidioides*, K. In one of the palpi in this insect there was a fifth joint, retractile within the fourth. Mr. Kirby suggests that since the fifth joint was not apparent in the other palpus, it may perhaps have been a false joint, produced by an effort of nature to repair a mutilated organ, but at the same time observes that if this were the case it is the only instance he has met with in true insects of the reproduction of a lost organ.

The *antennæ* constitute the remaining moveable parts of the head (*fig.* 369, A). They are occasionally absent in the larva, but never in the perfect state in any insects. They are two jointed organs, attached to the head by a distinct and freely moveable articulation, in some insects near the middle of the front part of the head, but in Hydröus and most Coleoptera on each side immediately anterior to the corneæ, at the extremity of the epicranial suture, but never, so far as we are aware, in the epicranium itself. They are subject to much diversity of form, on which account they have been employed by naturalists as affording characteristic distinctions of different families. They have been divided into several parts, only three of which appear to be generally applicable. These are the *scapus*, (*fig.* 371, M 1), *pedicella* (2), and *clavola* (3).† The *scapus*, or basial joint, is usually very long, and often the most conspicuous part of the antenna. It is connected with the *torulus*, or part upon which it moves, by means of a ball and socket articulation, beneath the external margin of the clypeus. The second joint, *pedicella*, in Hydröus, as in almost every species, is a minute and nearly globular articulation, which allows of the freest motion, and supports the remaining portion of the antenna, the *clavola*, which forms the chief part of the organ, and is that which varies most in general structure. When each succeeding joint of the clavola is gradually diminished in size from the base to the apex of the organ, as in the *Gryllidæ*, *Achetidæ*, and *Blattidæ*, *fig.* 342 and 343, the antenna presents its simplest condition, and is

* Fauna Boreali-Americana, vol. iv. Insects, page 15. pl. i. fig. 2.

† Kirby and Spence, p. 515, et seq.

Fig. 371.



Antennæ, from Burmeister, Meigen, Paty, and Hope. M, antenna of *Melolontha fullo*; 1, scapus; 2, pedicella; 3, clavus; 3*, the laminæ.

called *setaceous* (*fig.* 371, A), but when, as in some of the *Locustidæ*, each joint is much smaller than the preceding and is angulated at its sides, the whole forming a sword-like organ, it is called *ensiform* (B). When all the joints of the clavola are of uniform thickness, as in the *Carabidæ*, (*fig.* 329,) the antenna is said to be *filiform* (*fig.* 371, C), but when the joints are of equal size, but are globular or rounded, as in the *Tenebrionidæ* (*fig.* 340), it is called *moniliform* (*fig.* 371, D). When the joints, as in some of the *Elateridæ*, (*fig.* 334,) appear like inverted triangles, with the inner margin more produced than the outer, they are said to be *serrated* (*fig.* 371, E), and when, as in the *Prionidæ*, the acute base of each joint is inserted into the middle of the broad apex of the joint behind it, *imbricated* (F). When every joint is developed on one side into a spine or process, the organ is said to be *pectinated* (G); and when a spine or process is developed on each side of the joints, *bipectinated* (H). In like manner it is called *plumose* (N) when each joint produces one or more rami which are themselves minutely pectinated, as in many of the *Bombycidæ*; and when, as in *Hemirrhipus flabellicornis* and other *Elateridæ*, each process from a joint is flattened, and is nearly as long as the whole of the succeeding joints taken together, and the whole form a fan-shaped organ, the antenna is called *flabellate* (I). But when, as in the true beetles, Pentamera, the clavola ends in a true *capitulum* or knob, it is said to be *clavate* (K), or *capitate* (L), according as the knob is gradually or suddenly formed at the extremity of the organ. In Hydröus the capitulum exists in that form which is designated *perfoliate*, in which the joints of the club are separated a little from each other by a minute foot-stalk. This form exists also in the *Necrophori*, and in a less degree in the clavated antennæ of other *Silphidæ*. It is in some of the *Lamellicornes*, the *Scarabæidæ*, *Geotrupidæ*, *Dynastidæ*, and *Melolonthidæ*, that the antennæ reach a degree of completeness which seems to indicate the real use of the organs. Thus in the *Melolonthidæ* (M), the capitulum is divided into seven laminæ, which may either be applied closely together, or be widely expanded at the pleasure of the insect. In the *Dynastidæ* and *Geotrupidæ* the capitulum is formed of only three laminæ, the two outer ones being convex externally, but flat on their internal surface, while the intermediate one is flat on both surfaces, the flat surfaces of each being more delicately organized than the hard corneous exterior. A similar structure exists also in the *Scarabæidæ*. When the insect is in motion the antennæ are stretched out, and the laminæ are expanded to their fullest extent, but by many species are immediately retracted on the occurrence of any loud or sudden noise.

These are the usual forms of the antennæ, but in some species they are subject to much greater variation. Thus, in the remarkable order *Strepsiptera* (*fig.* 347), each antenna has a distinct lobe at its base. This is also the case in some of the *Muscidæ* (N), in which the filamentous portion of the antenna represents the true *clavola*, and the club-shaped portion of the organ is simply an appendage. A similar deviation from the usual structure occurs in some Coleoptera, more particularly in the smaller water-beetles. Thus, in the *Gyrinidæ*, the true *pedicella* is developed into a large ear-shaped cup, which nearly covers the *clavola*. In another insect, *Globaria Leachii*, LATR. very beautifully figured in the recent work of the Rev. F. W. Hope,* the pedicella, (O, 2) instead of being a small rounded joint, is elongated like the scapus (1), while the clavola (3) ends in a large capitulum, attached laterally to the base of the fifth joint and directed backwards. These are a few of the variations which occur in the form of these

* The Coleopterist's Manual, part ii. tab. 3, fig. 6. 1838.

curious organs, the necessity of which it is difficult to understand.

The function of the antennæ has been a subject of much dispute amongst naturalists, some contending that it is simply that of *feeling*, others that of *smelling*, others again that of *hearing*, and lastly others that of a *sixth* sense unknown to vertebrata. Our own observations lead us most decidedly to the conclusion that the primary function of the antennæ is that of *hearing* or feeling the vibrations of the atmosphere, while an additional function possessed by the antennæ of many insects is that of common feeling or *touch*. We have endeavoured to support this opinion by facts and experiments detailed in a paper on the use of the antennæ, which was read before the Entomological Society of London in the beginning of 1838, but which has not yet been printed. First as regards the employment of the antennæ as olfactory organs, there seems in their anatomical structure the most decided evidence that they cannot be designed for such purpose. In every instance in vertebrata, the faculty of smelling is situated in a delicate mucous or soft surface, and in no animal that we are aware of has it ever been found to reside in a dry horny covering, or in a tense membranous structure, while, on the contrary, that of hearing is constantly dependent upon an elastic membrane, or other part sufficiently delicate to be affected by the vibrations of the atmosphere. If therefore the sense of smelling be dependent, as it appears to be, upon a moist or lubricated surface, it cannot reside in the antennæ, since the exterior surface of these organs is in every instance formed of a dry hardened covering. On the other hand, if the perception of sound be dependent upon the elasticity of a part, and its capability of being affected by the vibrations of the air, the structure of the antennæ is in no instance unadapted for the performance of this function. It seems improbable that the office of the antennæ is simply that of *touching* or feeling other objects, by direct contact, as supposed by some naturalists, from the circumstance that in certain insects these organs are much too short to be so employed, being in many species, as in the *Libellulidæ* and *Cicadiidæ* (*fig.* 353), shorter than the head itself. But that they are so employed by some insects is indisputable, particularly by the *Blattidæ*, *Gryllidæ*, and most of the Hymenoptera. The Gryllidæ, when sipping water from the channelled surface of a moistened leaf, constantly feel about with the antennæ; and the honey-bee, when constructing its cells, ascertains their proper direction and size by means of the extremities of these organs, while the same insect, when evidently affected by sounds, keeps them motionless in one direction, as if in the act of listening. Another circumstance which favours the opinion that they are auditory organs is their greater development in the males of some species than in the females, as in the bipectinated antennæ of many moths, and the lamellated ones of the *Melolonthidæ*. The structure well known to exist in the Crustacea,* the bony tubercle covered externally by a tense membrane, and communicating internally with a membranous vesicle, situated at the base of the antennæ, sufficiently proves that in those animals the antennæ are organs of hearing, and is not an inadequate reason for regarding them as ministering to the same function in insects. But the fact of the existence of a small circular space discovered by Treviranus, at the base of each antenna in the *Blattidæ*, (*fig.* 373, †) which are noted for extreme acuteness of hearing, and which space, as in Crustacea, is covered by a membrane, is an additional reason for considering the function of the antennæ in insects analogous to that of the corresponding organs in those animals. Thus then almost every circumstance connected with the antennæ leads us to the conclusion that these are the proper organs of hearing, while their occasional employment as tactors or cerebral feelers is not incompatible with the exercise of that function, hearing being in reality only a more exquisite sense of feeling.

Fig. 372.

Interior of the upper and under surface of the head of Hydrous.

d, clypeus; *e*, labrum; *g*, maxilla; *h*, its palpus; *i*, labium; *k*, labial palpus; *p*, sutura epicranii; *q*, cotyloid cavity; *r*, torulus; *s*, *v*, laminæ squamosæ; *t*, laminæ posteriores; *u*, tentorium; *w*, laminæ orbitales; *x*, os transversum; *y*, articulating cavity for the mandible; *z*, os hypopharyngeum.

Internal parts of the head.—On the interior surface of the superior portion of the cranium of *Hydrous piceus* (*fig.* 372), the insect we have selected for our purpose, is a thick horny ridge (*p*), extending along the middle line from the

* See vol. i. p. 768, art. CRUSTACEA.

occipital foramen to about midway between the corneæ, where it becomes much thickened and expanded, and then divides into two portions, which pass forwards and outwards in a diagonal direction, to the anterior margin of each cornea. These ridges on the internal surface exactly correspond to the faint indication of the epicranial suture on the external. They serve for the attachment of muscles, and divide the epicranium from the clypeus posterior. At the external angles of these ridges, immediately anterior to the corneæ, are two articulating apophyses, the most external of which, the *torulus* (*r*), is smooth and rounded on its anterior surface, and articulates with the broad concave extremity of the scapus] or basial joint of the antennæ, and the external one (*q*), (*cavité cotyloid*, STRAUS,) is smooth, rounded, and constricted in its middle, and articulates anteriorly with the superior external condyle of the mandible, and posteriorly with a process of the *laminæ squamosæ* (*s*), which support and protect the brain, and are united with other laminæ (*v*) (*lames laterales*, STRAUS,) which arise from the inferior surface of the cranium. The torulus (*r*) is attached externally to the most anterior portion of a thin broad lamina, the *orbital plate* (*w*), which extends backwards to the posterior angle of the cornea, in an arched direction, separating the cavity of the orbit from the interior of the cranium, with which it communicates only by means of a round foramen for the passage of the large optic nerve and its tracheæ. The superior half of this plate consequently belongs to the epicranial, and the inferior to the basilar portion of the skull. Immediately anterior to the epicranial suture is situated the clypeus (*d*), the middle portion of which is smooth and slightly concave, and forms the covering of the anterior part of the head. On either side it has a smooth broad inflected margin, which is not included within the interior region of the head. At the anterior margin of the clypeus is articulated the freely moveable labrum (*e*), the under surface of which is smooth and shining, and gives no attachment to muscles, excepting along its posterior margin. The ridge of the epicranial suture is developed to a greater extent in the head of *Hydröus* than in any other species we have yet examined. Its perfect correspondence with the faint indication of the suture on the exterior of the head clearly indicates the boundary of the epicranium, and is of very great importance, as we shall hereafter see, in enabling us to determine the number of segments of which the head is composed. This suture exists in every species we have examined, more or less developed in different individuals. Its existence appears to have been entirely overlooked by Straus-Durckheim in the head of *Melolontha*, in which, indeed, it is almost obliterated externally, but when the cranium is well cleansed, and then examined by means of transmitted light, a trace of it may still be observed, and its situation internally is indicated by a shallow triangular furrow, which extends backwards from the anterior portion of each orbital plate to within a short distance of the occipital foramen in the middle line, the longitudinal portion being exceedingly short. But in the larva of the same insect the suture is very distinct on the exterior of the epicranium, and the ridges corresponding to the suture are developed on the interior. Anterior to this suture in the same larva is a triangular piece, which is bounded in front by a freely articulating plate, the anterior clypeus. It is the part corresponding to this, and which is consolidated with the true clypeus in the head of Hydröus, as indicated by the diagonal depressions before noticed on the external surface of the head, which we shall distinguish in all insects as the *clypeus anterior*.

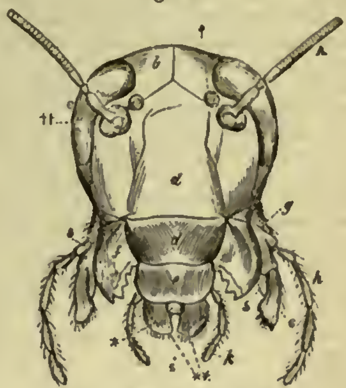
It will thus be found that in some insects the clypeus anterior and posterior have hitherto been confounded under one name, and in others the clypeus posterior and epicranium. We believe, however, that these are distinct parts in all insects, but are less readily distinguished in some than in others. The upper surface of the head is thus shewn to be formed of at least four clearly indicated portions, both in the larva and perfect insect. In the larva of melolontha there is also a slight indication of a *fifth* segment, of which the antennæ, or anterior prolongations of the spinal columns, are in reality the proper appendages. The indication of this segment exists in a triangular line, parallel with, but a little anterior to, the suture behind the clypeus posterior, and in the space included between it and the epicranial suture the antennæ seem to be inserted. But although we believe in the existence of the fifth segment in all insects, it must be acknowledged that it is not easily demonstrated. Four segments are, however, readily detected, yet in some species one of these has almost disappeared. Thus in *Geotrupes stercorarius*, the epicranial suture has become very indistinct on the upper surface of the head, and the ridges are entirely absent on the interior, as in melolontha, while the clypeus posterior exists only as a narrow triangular space, bounded by the suture posteriorly, and anteriorly by a ridge corresponding to the boundary of the proper anterior clypeus on the exterior of the head; the labrum also, as in all insects, being quite distinct. In *Lucanus cervus*, in which the head has reached its maximum of development, and is much broader than the pro-thorax, there is no indication whatever of the triangular suture in the male, all the parts of the head being firmly consolidated together. But in the female there is a faint depression internally, as in melolontha, and the trace of a corresponding line is apparent in some specimens externally. In some specimens of *Meloë cicatricosus* there is a distinct indication of the suture externally, extending from the occipital foramen to near the middle line between the eyes, while internally the ridge is distinctly elevated; but we have not been able to trace the clypeus posterior, which may be supposed to have merged in the largely developed epicranium. In *Blaps mortisaga* the epicranial suture is usually distinct on the upper surface of the head, posterior to the corneæ, but the ridge is absent, while the transverse ridges between the two portions of the clypeus are distinct, and also their corresponding sutures on the exterior. On the other hand, in the large *Buprestis chrysis*, the longitudinal portion of the epicranial suture is very distinctly marked on the upper surface, and extends as far forward as the middle between the corneæ, while internally the ridge is so largely developed that it extends downwards into the cavity of the head, like the ossified falx in the head of some Carnivorous Mammalia, partially dividing the posterior region of the head into two halves. But the clypeus anterior and posterior are so solidified together, and united with the epicranium, that they are not easily distinguished. This is also the case in the rapacious ground-beetles, *Cicindelidæ*, in which all the parts of the cranium are completely united, and the true clypeus is reduced to a narrow transverse plate, with which the labrum is freely articulated. But in the rapacious water-beetle, *Dyticus marginalis*, although the ridge of the epicranial suture is wanting, as in *Cicindelidæ*, the suture itself is remarkably distinct, and the anterior and posterior clypeus are well marked, and are very clearly seen owing to their thinness and translucency, when examined by transmitted light.

The inferior surface of the head affords us equal reason with the superior, for believing that this part of the insect is formed of an aggregation of several segments. We shall examine them more particularly when speaking of its development. On its interior surface are parts which tend much to confirm the opinion. In *Hydröus piceus* on each side of the occipital foramen there arises a strong bony plate, lamina posterior (t), which, bending a little towards the median line, extends across the basilar portion of the skull, as far as the *os transversum* (x), with which it is united. At a short distance from the occipital foramen the lamina of one side is connected with its fellow of the opposite by a narrow bony arch (u), which has been called by Straus *l'arcade*, and by Burmeister, who has described it in Dyticus, the *tentorium*. The two laminæ beyond this are expanded upwards and laterally, and uniting anteriorly by a thin process form a cradle, or bed, which, as Straus and Burmeister have remarked, supports the first subœsophageal ganglion, while the two *laminæ posteriores* inclose between them, as in a canal, the anterior portion of the spinal cord, which passes under the tentorium in its exit from the cranium through the occipital foramen. Each of these expanded portions of the laminæ are united by their superior angles with a narrow process (s), which articulates, as before noticed, with one of the apophyses of the upper surface or vault of the cranium. The orbital plates (w) above described are continued around the margin of the corneæ, and form the inferior lateral boundary of the basilar portion of the cranium. Between the anterior margins of the corneæ, extending across and dividing the basilar part of the skull from the sub-mentum, is a thick elevated ridge, the os *transversum* (x). On its anterior border the os transversum is connected with a minute bony ridge, which extends forwards on each side of the sub-mentum, and it has also two articulating surfaces. The first and most internal of these (x) is situated close to the base of the sub-mentum, and is that with which the hinge of the maxilla is articulated. The second is situated more externally, between this and the margin of the cornea. It is a deep smooth cotyloid cavity (y), which receives the external inferior angle of the mandible, and is separated from the articulation for the hinge of the maxilla by an elevated tubercle. Externally the base of the skull is connected only by an indistinct suture with a quadrate plate, the *sub-mentum*, which was supposed by Straus-Durckheim to form a process only of the basilar piece in melolontha, and was called by him the *pre-basilaire*. We have already seen that it is part of a distinct segment, and seems to correspond to the clypeus posterior of the upper surface. At the anterior margin of the sub-mentum, or rather extending backwards upon that segment from the mentum, are two broad diverging laminæ (z), which support the fleshy pharynx and tongue, in which respect they are similar in office to the proper hyoid bones of vertebrata. They serve as means of attachment for some of the muscles of the pharynx, and are connected with similar laminæ that cover the upper surface of the pharynx, and seem to be connected with the clypeus, as in the *Lucanus cervus*. The *mentum*, like the sub-mentum, to which it is attached, is broad, quadrate, and supports the diverging laminæ which form the floor of the mouth, and it also affords an attachment for some of the muscles of the tongue and labial palpi. The *ligula*, or most anterior portion of the labium, is densely covered on its upper surface with hairs. It is divided in the median line into two halves, which, when developed to a much greater extent, as in some other insects, take the name of *paraglossæ*.

The general structure of these parts is similar in most Coleoptera, but in some species there is considerable variation of form and relative size, owing to the greater development of one part than of another. Thus in *Lucanus cervus*, (*fig*.388,) in which the whole head is developed to its greatest extent, and the epicranial and basilar regions, with the mandibles (f'), have very far exceeded their usual proportions, the labrum is very minute, and soldered to the clypeus (d), and the maxillæ (g) are reduced to small palpiform organs. Internally, the posterior laminæ (t) do not extend forward to an *os transversum*, but are short, strong, triangular plates, which, instead of being connected, as in Hydröus and Melolontha, by an *arcade*, or tentorium (u), support a double ring, or *annulus*, like the ring of a vertebra, through which the nervous cord passes before it arrives at the occipital foramen. In *Geotrupes stercorarius* there is a like annular form of the same parts, but the *laminæ squamosæ*, which are absent in Lucanus, are thick and strong, and form a complete cradle for the supra-œsophageal ganglion. In like manner a similar change in the form and relative size of parts of the head occurs in the hog-beetles, *Curculionidæ* (*fig.* 337), in which the head is elongated forwards, and the mouth is situated at the extremity of a long rostrum or beak. This is occasioned by the narrowing and extension forwards of the clypei, and the parts corresponding to them, the mentum and sub-mentum. This change is carried to such an extent in some species, as in *Liparis Germanus*, that the antennæ are also carried forwards, and appear as if situated at the sides of the mouth. That this is the manner in which the change of form is effected is proved by the circumstance, that the basilar and epicranial regions in this insect do not exceed a fair proportion, as compared with other insects; while the triangular suture, which always divides the epicranium from the posterior clypeus, exists in its usual situation on the part between the eyes; and the labrum, which is very distinct, is freely articulated with the anterior margin of the clypeus. The effect of this elongation of some parts of the head and mouth is the necessarily small size of others, and consequently we find that the mandibles, which are so enormously large in *Lucanus*, are reduced almost to their minimum in the *Curculio*; because, although the elongated form of the head is admirably adapted to the habits of the insect, in boring deeply into hard substances, it is insufficient for the support of large and powerful organs, and its extent of surface is too limited to afford adequate room for the muscles necessary for their employment. Wherever large and powerful organs exist, the parts to which they are attached are enlarged in like manner. Thus we invariably find that in those insects in which the mandibles are large, the whole head is either short and wide, or its posterior portions, the basilar and epicranial regions, to which the muscles of the mandibles are attached, greatly exceed those of the anterior.

The parts observed in the head in Coleoptera are equally apparent in Orthoptera. In this order the head is placed vertically on the pro-thorax, without any constricted portion or neck, so that the extent of the occipital region is greatly reduced. The *epicranium* in some species, *Locustidæ*, *&c.* is broad behind, but narrowed in front, where it is bounded, as in other insects, by the *clypeus posterior*, and laterally by the corneæ and sides of the head, of which it forms a part. In this order the *ocelli*, or single corneæ, which are found only in a few solitary instances in Coleoptera, exist in most of the families. They are situated in the anterior portion of the epicranium, and form part of its surface, whether placed on the vertical portion of the head, or more anteriorly near the clypeus. In the osculant family, *Blattidæ*, the epicranium is exceedingly shortened, but retains along its vertex a trace of the epicranial suture, which is scarcely ever absent in the insects of this order. It is very distinct in the common house-cricket and mole-cricket, *Achetidæ* (*fig.* 342), in the *Gryllidæ* and *Locustidæ*. In the mole-cricket it sometimes appears as if wholly obliterated, but is always seen in the pupa if care be taken to remove the down with which it is sometimes covered. Its apex is situated in the middle line between the ocelli, and on each side it passes down to the insertion of the antennæ. It is in this order that the suture is particularly useful in indicating the boundary of the posterior clypeus, the extent of which in Orthoptera appears hitherto to have been overlooked.

Fig. 373.



Head of Blatta Americana.

A, antenna; †, tympanum; † †, socket for the antenna, covered with membrane; *dd*, clypeus, anterior and posterior; *, lingua; *i***, paraglossæ. (*Other letters and figures as in Hydrous.*)

In the epicranium of *Blatta* (*fig.* 373), the suture is almost obliterated, being only discoverable by aid of the microscope, but on careful inspection it is seen to end at a point opposite to the middle of the superior portion of the corneæ, where it forms the apex of the triangle, which enters, on each side, the anterior margin of a circular space covered with a tense membrane, the *tympanum* (†), which is situated, as observed by Treviranus, a little behind the insertion of the antennæ. These organs are also inserted in a rounded space covered by a membrane. From these points the suture becomes obliterated, but seems to pass in the direction of the anterior boundary of the corneæ to the base of the mandibles. The *clypeus posterior* (*d*) thus appears to form the greater portion of the front or *face* of the insect, and is united by a transverse freely articulating membrane, extending across from the base of each mandible with a short transverse plate, the *clypeus anterior* (*d*), which has hitherto been looked upon as the true clypeus. In the common green grasshopper, *Acrida viridissima*, the boundary of the posterior clypeus is at the most anterior part of the head immediately between the antennæ, the suture extending, as in other insects, to their base. The clypeus anterior is a short transverse moveable plate, and is articulated with the *labrum* (*e*), which is also short, transverse, and freely moveable upon the clypeus anterior. This moveable condition of the anterior clypeus and lip has not a little puzzled entomologists. Mr. Newman* has remarked that "the lip and *shield* move simultaneously

* Op. cit. p. 9.

with the mandibles in mastication," and that "this is a departure from a general law of nature, and its occurrence is well worth remarking; as the motion of the *shield* might induce an observer to suppose it the lip, which would consequently become a new and supernumerary elementary part." Thus, then, the motion of this part in Orthoptera is considered as an anomalous condition, but the same thing occurs in Coleoptera. In *Dyticidæ*, the clypeus is freely moveable, as well as the labrum, and probably this mobility has reference to the rapacious habits of the insects.

The inferior surface of the head in Orthoptera varies a little from the type of the Coleoptera, although it is formed, as in that order, of four distinct parts. The *gula*, or basilar region *(m)*, which includes part of the occipital foramen, is a broad transverse plate, rounded at its lateral, and concave at its anterior and posterior margins. In the mole-cricket, as in most of the beetles, the true gula is well developed between the occipital foramen and sub-mentum, and in that insect is of a triangular shape, with its apex directed backwards.

Fig. 374.

Under surface of mouth of Blatta. Figures as before.

But in the *Blattidæ (fig.* 374, *m)*, the sub-mentum and gula appear to have been closely united, without trace of their former distinction, and the mentum *(l)* is short, transverse, and articulated with the *palpiger* and *ligula (i)*. From the complexity of parts into which the ligula is divided, we consider it better, as before remarked, to omit any particular description of the palpiger, which, Mr. Newman states, is situated between the proper ligula and mentum. In Blatta the ligula is divided into six distinct parts. To two of these (*i*) are attached the labial palpi, and they appear to be the palpiger as described by Newman. From the upper anterior margin of these, nearest the median line, arise two short lobes, covered partly on their exterior margins by two larger ones, the *paraglossæ* (* *), which become of much importance in the mouth of Hymenoptera. In the mole-cricket the ligula is divided only into four lobes, all of which are exceedingly narrow, and very much resemble palpi. In some of the *Locustidæ*, the labium is simply divided in the median line as in Hydröus. The true *ligula* or tongue *(fig.* 374*) in most of the Orthoptera is a soft projecting fleshy body, like the tongue of other animals, and is situated above the mentum and sub-mentum, within the mouth of which it forms the floor and passage to the pharynx. In *Blatta* it is narrow and elongated, and projects as far as the middle of the ligula, and it is even more largely developed in the *Locustidæ* and *Achetidæ*. In the *maxillæ* we recognise the same parts as in Coleoptera, with but little variation of form except in the *galea* and *lacinia*. The *lacinia* (5) is usually elongated, and furnished with a sharp hook bipid at its apex. In *Achetidæ* and most of the vegetable feeders it is strong and much bent at its extremity, but in the omnivorous *Blattidæ* it is also sharpened to a cutting edge along its inner margin. It is in this order of insects that the secondary appendage of the maxilla, the *galea* (6), is most fully developed, and covers the lacinia so completely as to serve the office of a shield or helmet. In the vegetable-feeding *Locustidæ*, this part is sometimes three-jointed, as observed by Newman* in *Acrydium*, but usually it is simply an obtuse double-jointed organ, hollowed on its inner side; but in the *Blattidæ* it is expanded at its extremity into a thick oval bulb, or soft cushion, encircled with fine hairs, evidently well adapted for *touching* or *feeling*. In all the Orthoptera, but more particularly in the *Blattidæ*, the articulation of the maxilla with the sub-mentum is less compact than in the Coleoptera; and this appears to be referable to the same circumstance as before noticed with regard to the mobility of the anterior clypeus, the voracious habits of the insect. Thus, to allow of very extensive motion to the parts, the stipes (2) is articulated at an angle with the *cardo* (1), and a broad muscular structure, attached along the inner border of the lacinia, as far as the base of its sharp articulated apex, upon which it acts, is interposed between the maxilla and sub-mentum, and forms part of the inferior boundary of the mouth. The *mandibles* in this order of insects, as remarked by Marcel de Serres,† are more perfectly constructed than in any other. In those which masticate their food, and devour large quantities of vegetable matter, as the *Locustidæ*, the mandibles are furnished both with cutting and grinding surfaces. The anterior or apical margin is developed into acute cutting teeth, somewhat like the canine teeth of vertebrata, while the inner and posterior part of the mandible is broad, flattened, and covered with elevated irregular ridges, like the teeth of some Herbivora, and is admirably adapted for grinding or chewing. This complicated structure does not exist in the more carnivorous species, the *Blattidæ*, in which the mandibles are arched, and indented with sharp triangular teeth *(fig.* 373, *f)*, very closely resembling the cutting teeth of Carnivora, and are articulated by strong condyles at the side of the head, on a line with the articulation of the clypeus anterior, and not so far back as that of the maxilla. The eyes in Orthoptera are usually exceedingly prominent and round, but not large, except in *Blatta*, in which they

* P. 32.

† Annales des Muséums, No. xvi. p. 56.

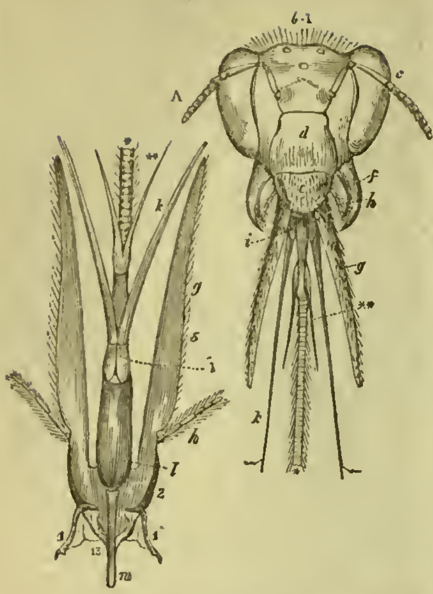
are kidney-shaped, and are spread over a great part of the sides of the head. The *ocelli*, which are found in most of this order, do not exist in *Blatta*. They are very distinct in the *Gryllidæ* and *Locustidæ*, and also in the mole-cricket; but it is remarkable, as Mr. Kirby formerly observed, that they are not met with in the pupa or larva state of these insects. In the pupa of the mole-cricket there are simply two slightly elevated tubercles, in the situation in which the ocelli are afterwards developed. They thus appear to have reference to some particular condition of the perfect insect, although the habits of the three states appear to be similar. The *antennæ* are organs of much importance, and are usually of considerable length, except in the carnivorous *Mantidæ*, or praying insects, in which they are very short. These insects, which take their living food by sight alone, have the shortness of their antennæ, the supposed organs of. hearing, compensated for by the immense size of their large globular corneæ, situated at the superior angles of the head, so as to enable the insect to see in every direction. But in those which reside in the dark, or which seek their food by the aid of other senses, the antennæ are exceedingly long, and formed of an immense number of joints, especially in the *Gryllidæ*, *Achetidæ*, and *Blattidæ*, which are noted for acuteness of hearing. In the interior of the head the *laminæ squamosæ* are thick and strong, and are articulated, as in Hydröus, with the angles of the epicranial suture superiorly, and inferiorly with the *laminæ posteriores*, and the *tentorium* forms a distinct ring, as in *Lucanus*.

In the Neuroptera we recognise the same elementary parts in the head and mouth as in the preceding Orders, but in this they are developed into new forms. The *epicranium*, so conspicuous in the former, is reduced to its minimum in this Order, owing to the immense development of the organs of vision, which, attaining their greatest extent in *Œshna grandis*, are expanded over the whole of the upper and lateral surfaces of the head, and are approximated together in the median line, leaving only the epicranial suture between them. A small portion only of the epicranium exists anterior to these great corneæ, but in that portion, as usual, are situated the *ocelli;* while the minute antennæ, reduced also to their minimum of size in these *Libellulidæ*, the most rapacious and insatiable of all insects, are still situated, as in Coleoptera, at the external angles of the suture. In the dilated anterior portion of the head we distinctly recognize the *clypeus posterior* and *anterior*, and below these the transverse cordiform *labrum*, separated by sutures, but freely articulated together as in Orthoptera. At the lower concave margin of the clypeus anterior in *Œshna grandis* is a short triangular plate intervening between the clypeus and labrum, and articulating with both like a distinct segment; it is probably only part of the labrum. On the under surface of the head the *gula* and *sub-mentum* are indistinct, and merged as it were in the construction of three immensely dilated, doubly articulated plates, which cover the whole lateral and under surface of the mouth. The anterior portion of the middle plate, which in *Œshna* is rounded at its anterior margin, is the true *ligula*, while the articulation behind it, from which arise the lateral plates, is the analogue of the *mentum*. The two lateral plates, composed each of two articulations, and in some species also of a third very minute one in the form of a short spine at the apex, we regard, with Brullé,* as the proper labial palpi immensely dilated. The *mandibles* concealed within the mouth are short, strong, and, in *Libellula quadrimaculata*, arched. At the apex they are bifid, and armed with two sharp triangular teeth, and at their base with four sharp-pointed ones, excavated, and placed in different directions, adapted for crushing and cutting rather than for masticating the food. Within the head they are articulated with portions of the epicranial and basilar regions, as in Coleoptera. The *maxillæ* are long and prehensile. The true palpi are entirely absent, but the *galea* exists as an oblong articulated lobe, and the *lacinia*, which is articulated at its base and sharpened along its inner margin, as in the *Blattidæ*, is armed at its apex with four crooked sharp-pointed teeth, while the *cardo* is long, and articulated with the base of the maxilla at an angle, to allow of extensive motion, as in the maxilla of Orthoptera. In other families of the Neuroptera, as in the *Panorpidæ*, the organs of manducation are small, but the anterior part of the head is elongated into a rostrum, occasioned by the narrowing and extension of the clypei, as we have before noticed in the *Curculionidæ*, while in the *Phryganidæ*, which take no food in their perfect state, the parts of the mouth are almost atrophied.

In Hymenoptera the mouth assumes an entirely new form, but the changes in it are confined to the maxillæ and labrum, which are soon to become its chief organs. The head, placed vertically on the thorax, is still well developed. The *epicranial* region is large, and extends very nearly to the insertion of the antennæ on the front. In most species it is densely covered with hairs, and the *ocelli (fig.* 375, *b*,) which are constant in this class, are usually arranged in a triangle on its most vertical part. The *corneæ* (*c*) are large and kidney-shaped, and cover part of the lateral surface of the head, leaving between them a broad front, occupied by the clypei (*d*) and part of the epicranium. But in the males of the hive-bee, which come abroad only in the brightest sun-light in quest of the female, this space is diminished, and the corneæ are expanded over part of the front, and the whole of the epicranial region, as in the *Libellula;* the most extensive vision being required by these insects, to enable them to discover the object of their solicitude, as by the other in the pursuit of its prey. In some of the pollenivorous and pre-

* Annal. Soc. Entom. de France, tom. ii. p. 343.

Fig. 375.



Anterior and inferior views of the mouth and head of Anthophora retusa.

A, antenna; *b*, epicranium and ocelli; *c*, cornea; *d*, clypeus anterior; *e*, labrum; *f*, mandible; *g*, the maxilla; *h*, its palpus; *i*, feeler-bearer or part of the ligula; *k*, labial palpus; *l*, mentum; *m*, sub-mentum; 1, cardo of the maxilla; 2, stipes; 5, the *lacinia* or blade; *, *ligula*; **, *paraglossæ*, its lateral lobes.

daceous genera, the *Tenthredinidæ* and *Vespidæ*, the clypeus posterior seems to have become entirely obliterated, unless we regard the broad clypeus in these insects, as in the Hornet, the posterior one, and the plate concealed beneath it, within the mouth, to which the labrum is attached, as the anterior. But we are not inclined to do this, because in some of the *Ichneumonidæ* and *Sphecidæ* a trace of the clypeus posterior remains a little anterior to the antennæ. In *Ichneumon Atropos* the clypeus is narrowed and depressed in its middle, as if originally formed of two parts, while in *Ammophila vulgaris* the clypeus posterior is clearly indicated as a minute triangular plate situated in the middle line, immediately beneath the insertion of the antennæ, and it exists in a similar form in some of the *Apidæ*, as in the large female *Bombus lapidarius*, and in some specimens of *Anthophora*, the clypeus posterior being in all instances bounded by a trace of the triangular suture. The *labrum* (*c*) is always distinct, but variously formed. In *Vespidæ* it is narrow, acute, and hidden beneath the anterior clypeus; in the leaf-cutting bees, *Megachile*, it is narrow and quadrate; but in the hive and humble-bees it is large, and rounded at its anterior margin. The *mandibles* are subject to considerable variation of form.* In some, as in *Ammophila*, which burrows in the sand, they are long, hooked, and furnished with but a single tooth at the apex, without cutting edges; and they are of somewhat the same form in *Anthophora* (*fig.* 375, *f*), whose habits of life in this respect are similar. In the *Vespidæ*, which gather the materials for their nests by rasping off little packets of fibres from decaying wood, they are broad, triangular, and armed along their edges with strong teeth; and such is also their structure in *Anthidium manicatum*, which scrapes off the down from the woolly stems and leaves of plants for the same purpose; while, in the hive-bee, which employs them in moulding the soft wax in the construction of the combs, they are shaped at the apex like a spoon, without indentations; their form in each instance being thus distinctly referable to the habits of the insects. In the gregarious species there is also a difference in their form in the two sexes, those of the males being often smaller and less curved than of the females, or workers, and they are always, particularly in the *Bombi*, more densely covered with hairs.

In the whole of the Terebrantia, Pupophaga, and some of the Aculeata the mandibles are still the chief cibarian organs; the *Athalia* employs them in masticating the pollen of flowers, and the maxillæ and labium in sipping the honey; while the omnivorous *Formicidæ* and *Vespidæ* employ them in tearing and masticating their food, whether it be the pulpy substance of fruits, or the muscles and hard coverings of other insects. In the *Apidæ* the chief use of the mandibles is in constructing the nest, while the maxillæ and labium are the only organs employed in taking food. In the strictly carnivorous families the *maxillæ* are not longer than in the preceding Orders. In most of these, as well also as in the *Terebrantia* and *Chrysididæ*, the extremity of each maxilla is obtuse, and divided into a distinct lacinia and galea, and the palpi are long and six-jointed. In the *Formicidæ* and *Vespidæ*, which subsist upon fluid as well as solid aliment, their length is increased; but in the true *Apidæ*, which subsist entirely upon honey, they are drawn out to a great length, and, with the labium beneath, form a tube through which the aliment is conveyed to the mouth, as in the hive and humble-bees. In these species the *cardo* (1) is long, slender, and formed of two parts, which conjointly articulate with the stipes (2). The longest of these, the basilar portion, has two apophyses at its extremity, and is articulated with the anterior part of the base of the cranium, at the inner side of the articulation for the mandibles, exactly as in Coleoptera; and its muscles in like manner are attached to the lateral and inferior parts of the head and orbital plates. It is the *lora*, or lever of Kirby, which enables the insect, by the additional articulation of its second part with the sub-mentum, to thrust out the maxillæ and labrum together to a great distance. The part that articulates with the sub-mentum, the proper *cardo* of Kirby, is very short in *Bombus lapidarius*, but of consi-

* See Essay on Fossorial Hymenoptera, by W. E. Shuckard, p. 12, et seq.

Fig. 376.

Lateral view of the mouth of Anthophora. Letters and figures as before. 12, the lingua, or tongue.

derable length in *Anthophora.* In each instance it is broadest at its articulation with the stipes, and, passing backwards diagonally, unites at its extremity with a corresponding part of the opposite side, and the two thus joined articulate with the narrow sub-mentum, the *fulcrum* of Kirby. The *stipes* forms the lateral basilar part of the maxilla, and is shorter in Anthophora than in Bombus, in which it is about one-third of the length of the maxilla. The *palpifer* is also distinct (3). The lacinia (5) is of great length, and gradually tapers to its extremity. Internally it is slightly concave, and externally is covered with a few scattered hairs. It is articulated freely with the stipes and palpifer, upon which it is inflected in a state of rest to form a sheath for the labium, when the parts of the mouth are folded. When the maxillæ are extended to form the sucking tube with the labium, they are a little separated at their base, and inclose between them the cavity of the mouth, within which is a soft fleshy body, the *lingua* (12) or true tongue, situated anterior to and serving as a valve to the pharynx. The *sub-mentum* (*m*) is articulated by a single joint with the united extremities of the two cardines (13). It is long and narrow in *Anthophora*, but short and triangular in *Bombus*. It is attached at its sides by a fine membrane to the under surface of the head and throat. The *mentum* (*l*) articulates with the sub-mentum, and is an elongated rounded plate, which forms internally a channelled passage to the pharynx. Within it are inserted the muscles of the labial palpi (*k*). These organs are long and styliform, and arise from a space at the base of the ligula, the part described as the palpiger by Newman. Their great length is occasioned by an excessive elongation of the second basial joint, which is sometimes as long as the whole maxilla itself, and is furnished at its distal extremity with a minute brush of hairs, and also articulates with the remaining short joint of the organ. The remaining portion of the labium is divided into three parts. The two lateral ones are short styliform processes, the *paraglossæ* (**), and the central one, commonly called the *tongue* of the bee, is the part employed by the insect in gathering honey. In *Apis, Bombus*, and *Anthophora* it is a long tapering muscular organ, formed of an immense number of short annular divisions, and densely covered throughout its whole length with long erectile hairs. It is not tubular but solid, and when actively employed is extended to a great distance beyond the other parts of the mouth, but when at rest is closely packed up and concealed between the maxillæ. The manner in which the honey is obtained when the organ is plunged into it at the bottom of a flower, is by lapping, or a constant succession of short and quick extensions and contractions of the organ, which occasion the fluid to be accumulated upon it, and ascend along its upper surface, until it reaches the orifice of the tube formed by the approximation of the maxillæ above, and the labial palpi and this part of the ligula below. At each contraction a part of the extended ligula is drawn within the orifice of the tube, and the honey with which it is covered ascends into the cavity of the mouth, assisted in its removal from the surface of the ligula by the little brush of hairs with which the elongated second joint of each labial palpus is furnished. From the mouth the honey is passed on through the pharynx into the œsophagus by the simple act of deglutition, as in other animals. In *Anthidium* the ligula is not longer than the labial palpi; while in the *Andrenidæ* all the parts of the mouth are much shortened, and resemble similar parts in the *Vespidæ* in being divided into four lobes.* In the latter insects the ligula is quadrifid, and is dilated at its apex, and each lobe is terminated by a minute gland.† The two lateral lobes, *paraglossæ*, are shorter than the middle ones. In *Tenthredinidæ* the ligula is also short, but is divided only into three lobes.

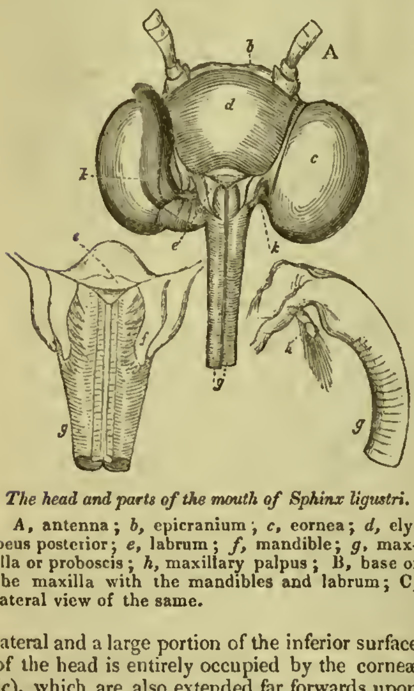
We have thus seen that the head and its appendages are most perfectly developed as a whole in the Coleoptera, and that in passing through the succeeding Orders of Mandibulata certain parts are more or less developed in each Order, in accordance with the general habits and mode of life of the insects; that in the carnivorous and omnivorous families, and in those whose habits of life require a great amount of strength, either in procuring their food or in the construction of their nests, the mandibles are the most important of the oral organs, and are most largely developed. But as we pass from insects with these habits to the Haustellata, whose food and modes of life are of an entirely different description, the mandibles lose their importance, and become atrophied, and their office, now altered in its character, is performed by the maxillæ and labium,

* Newman. Paper on the Head of Insects, p. 22.

† Curtis. Westwood.

the development of which, in the higher forms of insects, is only of secondary importance, compared with that of the mandibles, but is now carried to so great an extent that these organs become almost or entirely the sole means of taking food. Not only do these changes take place in the parts of the mouth, but the whole head undergoes a similar alteration in the relative form and size of its parts, occasioned by the excessive development of the organs of vision. Thus in the Lepidoptera, (*fig.* 377,) the

Fig. 377.



The head and parts of the mouth of Sphinx ligustri.

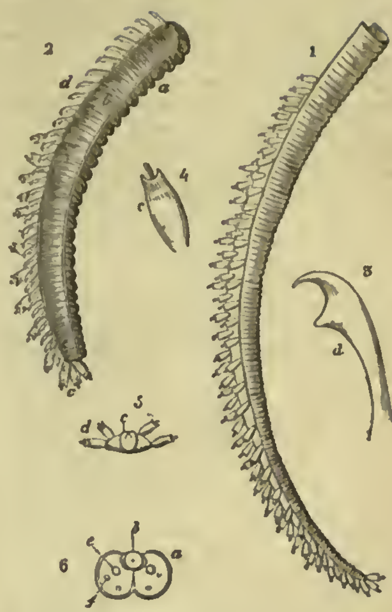
A, antenna; *b*, epicranium; *c*, cornea; *d*, clypeus posterior; *e*, labrum; *f*, mandible; *g*, maxilla or proboscis; *h*, maxillary palpus; B, base of the maxilla with the mandibles and labrum; C, lateral view of the same.

lateral and a large portion of the inferior surface of the head is entirely occupied by the corneæ (*c*), which are also extended far forwards upon the anterior. The occipital region is confined to the flat surface that is approximated to the prothorax. The epicranium (*b*) is distinct, and, as in the preceding Orders, extends as far anteriorly on each side as the base of the antennæ between the corneæ, but the suture that separates it from the clypeus posterior (*d*) is almost transverse. The *clypeus posterior* is very large, and occupies the whole of the space between the corneæ, on the front of the head. It is convex as in Neuroptera, and is narrowest at its inferior part. The *clypeus anterior* appears to exist in the form of a minute transverse plate, a little elongated in its middle on the hinder part, and separated by a transverse groove on its anterior from a much smaller plate, the *labrum* (*e*), with which it is consolidated. This part, which was first detected in Lepidoptera by the accurate Savigny,* is also a small convex transverse plate with a little triangular scale at its anterior margin, fitted closely to the front of the maxillæ. In *Sphinx ligustri*, (*fig.* 377,) the separation of the labrum by suture from the part which we regard as the clypeus anterior, is distinct, but it appears to have been overlooked by Savigny and others. On each side of the labrum are the rudiments of the mandibles (*f*). They are two minute, triangular plates, attached in part to the labrum and margin of the clypeus, to which, as Savigny has remarked, they appear to be soldered. They are applied to the base of the maxillæ, and in *Sphinx* appear each to be formed of two parts, and are covered along their inner margin with stiff hairs. They are the remains of the large corneous mandibles of the larva. We are indebted for their discovery to the indefatigable researches of Savigny, who first traced their identity. The *labium*, which forms so conspicuous a part of the mouth in the preceding Orders, like the mandibles, is reduced to insignificance in this. It is a small triangular plate, closely attached to the under surface of the head, at the base of the maxillæ, and its division into parts, so distinct in other insects, is now scarcely perceptible. The *labial palpi* (*k*) arise one on each side of the labium. They are usually long, hairy, and three-jointed, and are reflected on the front of the head. Next to the maxillæ they are the most conspicuous parts of the mouth, particularly in *Pyralidæ* and *Tortricidæ*, in which they are long and pointed. The *lingua* has been supposed to be entirely absent in Lepidoptera. It was not detected by Savigny. Latreille believed it to exist in the suture at the floor of the mouth, but Mr. Newman has observed a small mammiform protuberance in *Sphinx ligustri* which he regards as the analogue of the tongue in this Order. The labrum, mandibles, and labium are entirely concealed by the reflected labial palpi and a dense clothing of scales, and are only observed when the anterior part of the head is completely denuded of these coverings. Their atrophied condition affords a beautiful illustration of the law that in proportion as the functions of an organ become suspended, or are rendered unnecessary by the employment of other parts, the organ itself becomes wasted and utterly useless, and perhaps entirely disappears. Thus in those Lepidoptera whose food is liquid honey produced in the deep chalices of flowers, the short mandibles of the voracious herbivorous larva would be entirely useless to the perfect insect, and its food would be inaccessible to it. Accordingly we find that the mandibles are now unimportant organs, and the office of conveying food to the mouth is performed solely by the maxillæ (*g*), which are extended in the shape of a long sucking tube. Each maxilla is composed of an immense number of short, transverse, muscular rings. It is convex on its outer surface, but concave on its inner, and the tube is formed by the approximation of the two organs. When at rest they are rolled up like a watch-spring, between the large labial palpi, but are capable of being darted forth in an instant. They are the so-called tongue, or proboscis of the butterfly and moth. Each maxilla has usually

* Mémoires sur les Animaux sans Vertèbres.

been described as being hollow in its interior, or forming " in itself a tube,"* which appears to have arisen from the circumstance of there existing in each, one or more large tracheal vessels, (*fig.* 378, 6, *e*,) connected with the tracheæ of the head, and which are divided, as they approach the extremity of the organ, into a great number of minute ramifications, but which have no communication with the external surface, their distribution being precisely similar to that of the tracheæ in other parts of the body. The maxilla is composed of elementary parts, as in the preceding Orders, but they are not easily distinguished. The long extensile portion is the proper *lacinia*, which is constricted at its base, immediately beyond which is situated, in *Sphinx ligustri*, a minute three-jointed hairy palpus (*h*). Mr. Newman could not detect this maxillary palpus in Sphinx,† and hence concluded that it was obsolete in this family. It is indeed exceedingly minute and easily overlooked, but is distinctly three-jointed, and densely covered with long hairs. The structure of the maxillæ in different genera and species is particularly interesting, and their length is exceedingly various. Thus in the *Sphingidæ*, in *Smerinthus ocellatus*, which takes no food, they scarcely exceed one-eighth of an inch, while in *Sphinx ligustri*, which continues hovering on the wing while extracting the sweets from a flower, they are nearly two inches in length, and this is also the case in the humming-bird moth, *Macroglossa stellatarum*. In the butterflies, and in many of the *Noctuidæ*, they are often about equal to the length of the body. The inner or concave surface which forms the tube is lined with a very smooth membrane, and extends along the anterior margin throughout the whole length of the organ, as in the transverse section, (*fig.* 378, 6, *b*.) At its commencement at the apex it occupies nearly the whole breadth of the organ, and is rather smaller than at its termination near the mouth, where the concavity or groove does not occupy more than about one-third of the breadth. In some species the extremity of each maxilla is furnished along its anterior and lateral margin with a great number of minute papillæ, but in others these parts are entirely absent. They are extensively developed in some of the butterflies, as in *Vanessa atalanta*, (*fig.* 378, 1, 2, *c*,) in which they are little elongated barrel-shaped bodies, (4, *c*,) terminated by three smaller papillæ, arranged around their anterior extremity, with a fourth one a little larger than the others placed in their centre. These papillæ are arranged in two rows along the lateral and anterior surface of each maxilla, near its extremity, for about one-sixth part of its whole length, as at 1, and 5, *c*, *d*. There are seventy-four in each maxilla, or half of the proboscis. To judge from their structure, and from the circumstance that they are always plunged deeply into any fluid when the insect is taking food, they may probably be regarded as organs of taste. They are largely developed in this genus of insects, but in *Pontia*, the common white butterflies, and in *Sphinx ligustri* they are scarcely perceptible. There are also some curious appendages arranged along the inner anterior margin of each maxilla, in the shape of minute hooks, which, when the proboscis is extended, serve to unite the two halves together. They were first noticed by Reaumur,* and subsequently by Mr. Kirby.† In many insects, as in *Sphinx* and *Pontia*, they have more the appearance of cilia, like the barbs of a feather, than of hooks, but in *Vanessa* they are falcated, and furnished with an additional tooth (3, *d*) a little beyond the apex. They are so exceedingly minute, and arranged so closely together, that their true form is with difficulty distinguished. They lock across each other like the teeth in the jaws of some fishes, and we are inclined to believe that the points of the hooks in one-half of the proboscis are inserted, when the organ is extended, into little depressions between the teeth of the opposite side, so that they form the anterior surface of the canal, but of this we are not con-

Fig. 378.



Parts of the maxillæ or proboscis of Vanessa atalanta.

1, external surface of the apex with the double row of papillæ; 2, internal or concave surface; *a*, transverse muscles; *b*, tube; *c*, papillæ; *d*, hooks which join the maxillæ; 3, one of the hooks; 4, one of the papillæ; 5, section of the tip of the maxillæ, showing the position of the papillæ on each side of the tube; 6, section of maxillæ near their base, showing the position of the tube, *b*; the large trachea, *e*, and the smaller one and nerve, *f*.

* Newman on the Head of Insects, p. 28.
† Op. cit. p. 28.

* Memoires, &c. tom. i. p. 125.
‡ Introduction, vol. i. p. 394.

fident. That they really form the anterior surface of the canal or tube seems evident from the distinctness with which coloured substances are observed to pass along the tube when the insect is taking food.

There are various opinions with regard to the manner in which the food ascends the tube to the mouth. Some have imagined that it is simply by capillary attraction, and others, the chief of whom was Lamarck, that it is forced along by successive undulations and contractions of the sides of the tube, occasioned by the action of the transverse muscles. Kirby and Spence* believe that these undulatory motions, which certainly do exist to a considerable extent, are not sufficiently powerful to carry along the food with the rapidity with which it usually ascends, but that the lateral canals, which, as we have just shewn, are the proper tracheæ of the organs, assist in producing the phenomenon by occasioning a vacuum in the mouth and tube which facilitates the conveyance of the food more rapidly along it. That something of this kind does in reality occur is proved by the following observation. We gave sugared water, coloured with indigo, to two specimens of *Pontia napi*, and on attentively examining the front of the organ with a microscope while the insects were busily employed in partaking of the fluid, observed the particles of indigo disseminated in it ascend along the tube, not in a gradual and regular succession, as must have been the case had the ascent of the fluid been occasioned simply by capillary attraction, but pumped up, as it were, sometimes in a full stream in quick succession for one or two seconds, as if the insect was then sipping a full draught, while at others a few particles only ascended quickly, followed by still fewer with a much slower motion; thus indicating distinct intervals between each draught or ascent of fluid. From these circumstances we are led to offer the following explanation of the manner in which the food ascends the tube to the mouth. The instant an insect alights upon a flower, it makes a forcible expiratory effort, by which the air is removed both from the tracheæ that extend through the proboscis, and from those with which they are connected in the head and body, some of which we shall hereafter see are distributed over the œsophagus and alimentary canal, and at the moment of applying its proboscis to the food makes an inspiratory effort, by which the tube is dilated, and the food ascends it at the instant to supply the vacuum produced, and is carried onward by the same act to the mouth, and from thence by the action of the muscles of the pharynx into the œsophagus and stomach, without any interruption of the function of respiration, the constant ascent of the fluid into the mouth being assisted by the action of the muscles of the proboscis, which continue in action during the whole time the insect is feeding. By this combined agency of the acts of respiration and the muscles of the proboscis, we are enabled to understand the manner in which the humming-bird sphinx extracts in an instant the honey from a flower while hovering over it without alighting, and which it certainly would be unable to do so rapidly were the ascent of the fluid dependent only upon the action of the muscles of the organ.

In Diptera there is the same irregularity in the development of certain parts of the head as in Neuroptera and Hymenoptera. The shape of the head is usually that of a flattened hemisphere, with its base or occipital region concave, and approximated to the prothorax, as in the common house-flies, *Muscidæ*, the blood-suckers, *Tabanidæ*, and the gad-flies, *Œstridæ*. But in others, as in the gnats, *Culicidæ*, the long-legs, *Tipulidæ*, and the *Asilidæ*, (*fig.* 349,) it is either convex at its occipital surface or extended in the form of a short neck. In the latter instances the *occipital* and *epicranial* regions are large and distinct, and the *corneæ* are protuberant, and situated a little anteriorly at the sides of the head, but do not much encroach upon the epicranium. This is not the case in the *Tabanidæ*, &c. in which they occupy nearly the whole of the epicranial region. But in most of the genera in which the eyes are thus expanded, there is usually, as in Neuroptera, some portion of the epicranial region still existing in the form of a small triangular space anterior to the inner margin of the corneæ. On this space the longitudinal portion of the triangular suture is often distinctly marked, and extends backwards between the corneæ to the occiput, as is well seen in *Tabanus bovinus*. Anteriorly it extends as far as the middle line behind the antennæ, where it terminates, thus distinctly indicating the proper boundary of the *clypeus posterior* in this order. The whole front of the head or face is formed of the two clypei, which are so united together as to be scarcely distinguished as originally separate parts. They together form a broad and somewhat lozenge-shaped plate, at the upper portion of which are situated the antennæ, and at the lower or anterior, which is notched, the labrum, freely articulated with it, and which is usually concealed beneath it. In some genera, as in the *Tabanidæ*, the antennæ are inserted on each side of the middle line, into little fossæ close to the triangular suture; while in others, as in *Chrysotoxum* and *Conops*, the place of these fossæ is occupied by little elevations, upon which those organs are seated, sometimes nearly close together, as in *Sargus*. The face thus formed of the two clypei is developed laterally on each side of the corneæ, and is gradually narrowed from its upper part to its lower, where it is articulated with the labrum. In *Rhingia rostrata* the posterior clypeus is elongated, and forms the long projecting front: it is deeply notched at its interior margin, where, as also in *Volucella*, is a very minute plate, apparently the analogue of the clypeus anterior. The *corneæ*, as above stated, are usually the most conspicuous parts of the head in Diptera, and form

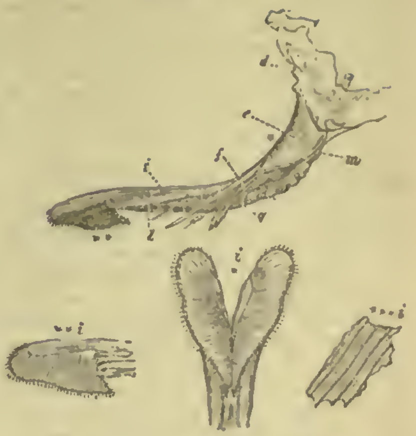
* Introduction, vol. iv. p. 470.

its lateral regions. They are always largest, as in Neuroptera, in those species which are most constantly abroad in the brightest light, and are expanded over nearly the whole of the epicranial region, as in *Tabanus*, *Chrysotoxum*, and *Doros*. But although the corneæ of the compound eyes are so largely developed, the *ocelli* also are almost invariably present in this order. They are generally three in number, placed on the most vertical part of the epicranium, immediately behind the proper corneæ. This is their situation in *Musca*, *Helophilus*, and *Stratiomys*, and also in the gnat, *Culex annulatus*, but we have not observed them in a neighbouring genus, *Pedicia*. Professor Muller* believes that the *ocelli* are designed chiefly for observing near objects, and the fact of their existing, as just stated, in many insects in which the corneæ of the proper eyes are exceedingly large, seems to favour this opinion. Their presence, as in Hymenoptera, is most remarkable in the males, as in the male *Empidæ*, in which, although the proper corneæ cover the whole surface of the head, yet there are also three large ocelli situated in the triangular space immediately behind the corneæ, and even elevated upon a pedicle. In *Tabanus* there appears at first to be only a single ocellus, situated in the median line between the corneæ at the anterior part of the head; but on close inspection it is found to be divided into two by the longitudinal suture which passes through it, so that the two ocelli from their close approximation appear but as one.

In the organization of the mouth the same parts exist in Diptera as in the preceding orders, but modified in form to adapt them to a different mode of use. Thus we have seen that in Hymenoptera and Lepidoptera it was simply necessary that the parts should be elongated, to enable the insects to obtain the liquid food already prepared for them; but in Diptera not merely was it necessary that this should be the case, but also that their form should be materially altered, to adapt them to a mode of employment different from that of analogous parts in other insects. Thus in *Tabanidæ*, the labrum and mandibles are used like lancets, to pierce the integuments of other animals, before these parasitic blood-suckers can obtain the living fluid they are in quest of; while in other species, as in *Eristalis floreus*, (*fig.* 379,) which subsists both on the pollen and honey of flowers, the mandibles and maxillæ are employed to scrape off the pollen from the anthers, before it is conveyed along the tube formed by the united parts of the mouth to the pharynx. In other Diptera, of which the food is entirely fluid and easily accessible, as in the common house-flies, *Muscidæ*, all the parts of the mouth are soft and fleshy, and simply adapted to form a sucking tube, which in a state of rest is closely folded up in a deep fissure, on the under surface of the head, formed by the two sides of the clypeus.

* Elements of Physiology, by J. Muller, M.D., (translated by W. Baly, M.D., part v. p. 1116.

Fig. 379.



Mouth or proboscis of Eristalis floreus.

d, front beneath the clypeus; *e*, labrum; *f*, mandible; *g*, maxilla and palpus; *i*, labium; *i**, labium dilated; ***i*, inner surface of paraglossa; ****i*, the rows of hairs on the inner surface; *l*, ligula; *m*, cardo and submentum.

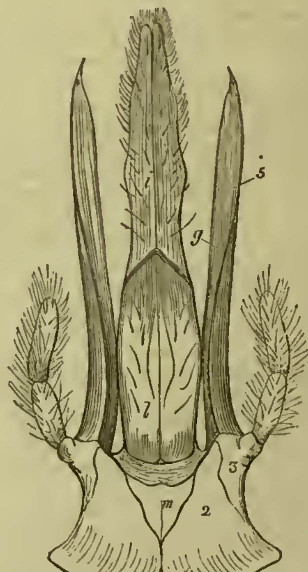
On the other hand, in the *Œstridæ*, which, as we have seen in the *Phryganidæ*, *Bombycidæ*, and others that take no food in their perfect state, all the parts of the mouth have entirely disappeared. It is in *Tabanidæ* that the oral organs of Diptera are most perfectly developed, and approach nearest to those of Hymenoptera, and are easily distinguished; while in the soft fleshy proboscis of *Muscidæ* their identification is a matter of considerable difficulty. According to Savigny* the proboscis of Diptera is formed solely by the labium, or under-lip, divided into its primary parts as in other insects; while Desvoidsy† on the contrary believes that it is *not* formed by the labium, but, as in Lepidoptera, solely by the maxillæ. Now we have seen, that although in Lepidoptera the maxillæ alone form the tubular mouth or proboscis, yet that in Hymenoptera the labium is the part chiefly employed in gathering the honey, which is conveyed to the cavity of the mouth and pharynx only by the maxillæ assisting to form a tube of which the labium constitutes the inferior portion. Analogy therefore would lead us to expect a somewhat similar conformation of the mouth in Diptera, and that since these insects have either to pierce the coverings of other animals before they can obtain their food, or to gather their nourishment by employing the proboscis as a prehensile organ, the maxillæ may fairly be supposed to enter into its formation, and accordingly we find, on a careful examination, that such is actually the case, and that the proboscis is formed of the maxillæ and labium united. We have been led to this conclusion by a care-

* Mém. sur les Anim. sans vertèbres.

† Essai sur les Myodaires, par le Docteur J. B. Robineau Desvoidsy, 4to, 1830, tom. x. Mémoires de l'Institut de France.

ful examination and comparison of the parts of the mouth in *Volucella*, *Echinomyia*, and *Musca*, with those in *Tabanidæ* and *Asilidæ*. To commence our observations with the most perfect form of mouth, we find in *Tabanidæ* that the *labrum* is an elongated, acute, corneous plate, freely articulated to the margin of the clypeus, and marked along its middle line with a raphé. It is concave on its under surface, and is as long as the mandibles and maxillæ, which it partially covers, and somewhat resembles in appearance. In *Culex* it is longer than these parts, and is more sharp-pointed. In *Asilus crabroniformis* it is much shorter than either the mandibles or maxillæ. It is narrow, triangular, and rounded at its apex, with a slight indentation, and is not used by the insect as a lancet, as in the preceding instances, but merely forms the anterior covering of the mouth. In *Eristalis floreus* (*e*) it is a short mitre-shaped plate, which covers the base of the mandibles and maxillæ, and articulates freely with the clypeus. In *Volucella bombylans* it is reduced to a very narrow short plate, articulated with, and, in a state of rest, inflected beneath a small triangular one, which is inserted into a deep cleft of the clypeus, and which appears to be the proper analogue of the clypeus anterior. In *Rhingia rostrata* it has almost entirely disappeared, so likewise has the part that we are inclined to regard as the clypeus anterior, which is inserted into the cleft at the extremity of the elongated rostriform anterior part of the head. In *Echinomyia* it still exists as a very narrow corneous plate articulated with the clypeus, inflected beneath the head when the proboscis is retracted, but forming the anterior portion of its base when the organ is extended. In *Musca* it has entirely disappeared as a distinct piece, but seems to have become the union of two corneous plates, which together form an arch on the front of the mouth, or base of the proboscis, and represent the mandibles, the intervening space being covered by a strong membrane. The *mandibles*, which had almost disappeared in Lepidoptera, still exist in the rapacious Diptera, and in those which pierce the skin of other animals. In *Tabanus* they are long, and somewhat lancet-shaped plates, situated immediately beneath the labrum. They are slightly curved, like a cutlass, and sharp-pointed. They are not employed in crushing or cutting solid food, as in proper mandibulated insects, but in puncturing or piercing with a horizontal motion from behind forwards, and not from side to side. In this genus, however, their motion appears to be not simply that of thrusting or piercing, but also that of cutting vertically with a sweeping stroke, like the lancets of a cupping instrument, for which motion they are well adapted by their cotyloid form of articulation. In the common gnat, *Culex*, they are very slender, and sharp-pointed. The pain occasioned by the piercing, or supposed biting of the insect, arises from the act of thrusting these instruments through the skin. In these instances the mandibles are equal in length to the other parts of the mouth, but in *Eristalis*, in which they have still the same acute form, they are somewhat shorter. In the rapacious *Asilus crabroniformis* the mandibles of the two sides are united to form a single, strong, sharp-pointed barb, very acute, and ciliated at the apex on its upper surface, and projecting beyond the other parts of the mouth. In *Rhingia rostrata* they still exist as delicate elongated setæ, approximated at their apex; but in the neighbouring genus, *Volucella*, we have been unable to detect them, except as two flat plates, approximated to the anterior part of what we regard the proper *cardines* of the maxillæ and labrum, and by which the parts of the mouth are thrust forwards. In *Echinomyia* the mandibles have also disappeared as distinct organs, and seem to be united to the base of the cardines within the mouth, as in *Volucella*, and there is a similar condition of these parts in *Musca*, in each instance the anterior part of the mouth being covered by a strong membrane, which supplies the place of the horny labrum. The *lingua* exists in most Diptera. It is largely developed in *Tabanus*, in which it is a single horny seta situated between the mandibles in the centre of the mouth. It was distinctly pointed out by Savigny, and subsequently by Latreille. It was called by the former the *hypopharynx*. The *maxillæ*, like the mandibles, undergo a gradual diminution of size. In *Tabanus* they are straight, and as long as the mandibles, but narrower and less acute. In *Asilus*, (*fig.* 380, *g*) they are very acute and

Fig. 380.



Under surface of the mouth of Asilus crabroniformis.

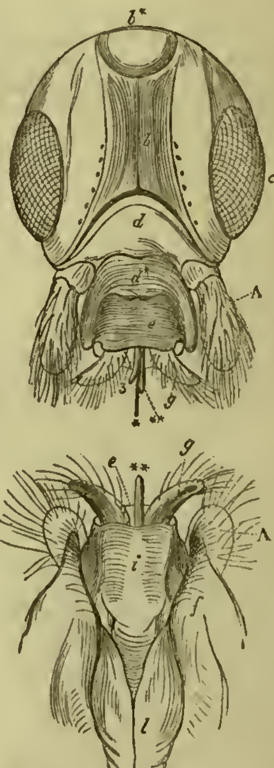
m, submentum; 1, cardo; 2, stipes; 3, palpifer; 5, lacinia: *h*, maxillary palpus; *l*, mentum; *i*, ligula.

strong, with sharp cutting edges. They are shorter and narrower than the mandibles, and are usually inclosed within the sheath or proboscis formed by the labium. In this family some of their primary parts are easily distinguished. Thus the blades (5) that lie within the sheath of the labium, are the true laciniæ in other insects. These are articulated at their base with the palpifer (3), a small triangular plate, which bears the maxillary palpus and is situated most externally,—and also with a broad squamous plate (2), which is united at its base to its fellow of the opposite side, and appears to be analogous to the *stipes* and *cardo* (1) united. This plate, with its fellow, forms the anterior boundary of the throat, and is closely united to the proper *gula* that bounds the anterior margin of the occipital foramen. The muscles attached to the posterior margin of the mentum and submentum pass over this plate to be attached, one set to the anterior margin of the gula, and the other to the posterior. In *Volucella bombylans* the maxillæ have lost much of their importance, but are still easily distinguished, and, with the other parts of the mouth, are beginning to be merged in the united fleshy proboscis. The *cardines*, upon which all the motions of flexion and extension in this kind of mouth depend, are very largely developed. They are two elongated plates, approximated to each other along their inner margins, and to two triangular plates, the remains of the mandibles, at their anterior and lateral. The cardines thus form the posterior, or basilar part of the proboscis, and the plates which, from being articulated within the margin of the clypeus posterior, we regard as analogous to the mandibles, the lateral. At their inferior portion, which forms the joint or elbow of the proboscis, the cardines are freely articulated with the *stipes*, which is a short plate not easily distinguished from a part of the mandible with which it is also in apposition. Between the stipes and cardo is a short triangular plate, the *palpiger*, rounded at its most inferior part, and, with its fellow of the opposite side, assisting to form the elbow or joint of the proboscis. The maxillary palpus, which aises from its external border, is long and slender, and appears to be formed of three short joints and one very long one. At the inner and anterior margin of the palpifer and stipes is articulated the *lacinia*, which, as in *Asilus*, is of considerable length. It is interesting to remark, that in this insect, which is parasitic in its habits, insinuating itself into the nests of humble-bees to deposit its eggs, the mandibles, as just shewn, are atrophied, and the two laciniæ of the maxillæ, although distinct from each other, are approximated in the middle line to form the anterior or upper surface of the tube to the mouth, as in Hymenoptera, the sides and lower portion of the tube being formed by the labium, and all the motions of extension and flexion in the proboscis being dependent upon the cardines, as we have before seen in Hymenoptera. In this genus therefore we discover one of the transitionary forms of mouth from that of the blood-sucking insects to those of the more omnivorous feeders, all the parts of the mouth being less and less distinct in proportion as the act of taking food is less complicated. Thus we have seen that in *Tabanus* distinct mandibles are required to pierce the skin of an animal, before the food is accessible; but in the *Muscidæ*, whose fluid aliment is every where present, a complicated form of mouth is unnecessary, and accordingly we find it reduced to a simple sucking tube. In *Eristalis* the *maxillæ* are present, as in *Asilus* and *Volucella*, as also are their palpi, which are nearly equal to them in length. In *Echinomyia* they are less distinct than in *Volucella*. The anterior part of the proboscis at its base is formed simply by a broad membrane united to the anterior margin of the atrophied mandibles, while the laciniæ, which were distinct in the preceding genera, are united in this genus to form the front of a lower portion of the organ. That this union has taken place is shewn in the presence of the maxillary palpi, which invariably exist in Dipterous insects. In all the *Muscidæ* the palpi arise from a distinct *palpifer*, which appears to be connected with a proper *stipes*, but the remaining parts are not easily distinguished. It seems evident, however, that at least the basilar portion of the proboscis is formed by the union of the laciniæ above and the labium below, as in Hymenoptera, and that the labium forms the chief portion of the organ, contrary to the opinion of Desvoidsy, who believed that the proboscis of Diptera was formed of the maxillæ alone, and to that of Savigny, who regarded the proboscis as formed only of the labium. The principle therefore upon which the proboscis of Diptera is constructed, is precisely analogous to that of Hymenoptera, but there are important differences in the form of similar parts in the two orders. The *labium* includes the same primary parts as in Hymenoptera, but the labial palpi are almost invariably absent. The *submentum* is usually indistinct. In *Asilus* the part we regard as such is a small triangular plate, (*m*,) distinguished only when the parts are examined by transmitted light. It is situated between the anterior portions of the two cardines. In *Volucella* it is that part of the proboscis which is nearest to the cardines, close to the articulation. In *Culex*, in which the cardines are short, it is situated very close to the under surface of the head; in other Diptera it is frequently very indistinct. The *mentum* on the contrary is always a conspicuous part. In *Asilus* it is the broadest part of the proboscis (*l*). It is a strong horny plate, deeply channelled on its upper surface to form a canal to the mouth, and receive within it the mandibles and maxillæ. It is articulated with the ligula, or extremity of the proboscis (*i*), which is distinctly formed of two halves approximated together, and narrowest at the apex, with three slight lateral dilatations. In *Volucella* the mentum in like manner is a strong deeply channelled plate, covered above by the laciniæ. There is a similar structure of the proboscis in *Eristalis*. The submentum is the part in which the flexion of the organ takes place; the mentum, as in the preceding instances, is a strong horny plate, almost closed on its upper as well as its under surface, and the ligula is horny, but terminated by soft dilatable lips. The *ligula* is always articulated by a distinct joint with the mentum, and appears to be constantly present in this order. In *Asilus*, as we have just remarked, it is strong and corneous, but in the less rapacious insects, as in *Eristalis*, and the *Muscidæ*, it is terminated by two dilated fleshy lips, which we regard as the analogues of the *paraglossæ (fig.* 379, * *i.*) In *Tabanus* these are exceedingly large and broad, and are widely expanded to encompass the wound made by the insect with its lancet-like mandibles in the skin of the animal it attacks. The structure of these paraglossæ is curious. On their outer surface they are fleshy and muscular, to fit them to be employed as prehensile organs, while on their inner they are more soft and delicate, but thickly covered with rows of very minute stiff hairs (*** *i*) directed a little backwards, and arranged closely together like the teeth of a comb. There are very many rows of these hairs on each of the paraglossæ, and from their being all arranged in a similar direction are easily employed by the insect in scraping or tearing delicate surfaces. It is by means of this curious structure that the busy house-fly often occasions much mischief to the covers of our books by scraping off the albuminous polish, and leaving traces of its depredations in the soiled and spotted appearance which it occasions on them. It is by means of these also that it teases us in the heat of summer when it alights on the hand or face to sip the perspiration as it exudes from and is condensed upon the skin. The manner in which the fluid ascends the proboscis is similar to that of its ascent in other Haustellata, it being dependent partly upon the sucking action exerted by the application of the proboscis, assisted by the muscular action of the paraglossæ, as any one may readily convince himself on watching the motion of the parts in the common house-fly, when sipping a drop of fluid, or moistening the stolen grain of chrystallized sugar between its paraglossæ.

The *palpi* yet remain to be noticed. Those of the maxillæ appear to be constant throughout the whole order. In *Culex* they are very conspicuous parts, covered with hairs and as long as the proboscis; they are formed of three short basial joints and three very long ones, the fourth joint being more than twice the length of either of the others. In *Tipula* and *Empis* they are also six-jointed, but of moderate length. In *Tabanus* also they are very conspicuous, and appear to be formed of two short and one very long joint densely covered with hairs, and serve as a cover to the base of the proboscis. In *Asilus* they are short, three-jointed, and slightly hairy (*fig.* 380, *h*), and they are equally conspicuous in most of the *Muscidæ* and *Syrphidæ*, in which they are formed in general of two short joints and one very long one. In the common *Musca* they are long and club-shaped, but in *Eristalis (fig.* 379, *g*, *h*) and *Volucella* they are long, slender, and sometimes covered with hairs. The *labial palpi* do not appear to exist in Diptera. Savigny believed that he had observed at the base of the ligula in *Tabanus* a pilose excrescence which he considered the analogue of the labial palpi; but although, as Mr. Newman has remarked, the spot which Savigny pointed out is exactly that at which they ought to be situated if they really did exist, we have been unable to detect them or to confirm his opinion.

In Homaloptera the head resembles that of Diptera. It is rounded but flattened on its upper surface, and is so closely approximated to the anterior margin of the prothorax into a notch in which it is inserted, as to appear as if separated from it only by a suture. All the primary parts found in the head in other insects appear to be developed in some species of this order. Thus the *epicranium* in *Oxypterum* is broad, distinct, and channelled along the median line into a deep groove (*fig.* 381, *b*),

Fig. 381.



The upper and under surface of the head in Oxypterum.

b, epicranium; *c*, cornea; *d*, clypeus posterior; *d**, clypeus anterior; *e*, labrum; *f*, undeveloped mandibles; *g*, maxilla; *i*, labium; *, lingua.

and the triangular suture, particularly the anterior portion, which divides the epicranium from the clypeus posterior (*d*), is very distinct. At the anterior external angle of this part of the clypeus, as in Coleoptera, are situated the *antennæ* (A), two short and thick porrected organs, covered with a few long hairs, and which, although apparently composed each of two joints, appear to be rigid and motionless. Immediately anterior to the clypeus posterior, and divided from it by a distinct suture, is a short lunated plate (*d**), the *clypeus anterior*. The cornua of this part are extended laterally at the sides of the mouth, and are continuous with a portion of the under surface of the head (*f*) that bounds the labium. Between the two cornua of the upper surface is extended a strong and somewhat horny membrane (*e*), the proper *labrum*, which is continuous with a similar membrane on the under surface (*i*), the labium, which thus forms the orifice of the mouth, the parts of which do not appear to have been sufficiently examined in this order. Thus, although the entrance to the mouth is indicated by a distinctly marked labrum and labium, scarcely more developed than in Coleoptera, the habits of the insect require that it should also be furnished with a strong sucking tube. Accordingly we find that within this membranous mouth are situated two curved horny plates, a little convex on their external, but concave on their internal surface, and capable of being protruded to some distance. They are directed downwards, and when approximated form a tube analogous to that of Lepidoptera. These parts have been described by Curtis as the *maxillæ* (*g*), of which they seem to be the proper analogues, so that in the Homaloptera the maxillæ form the sheath or outer part of the sucking tube. At the base of these parts, within the cavity of the mouth, are two horny margins fringed with dark hairs, which are probably rudimental maxillary palpi. In the centre of the mouth is situated an elongated slender organ (*), which is folded at an angle like the proboscis of Diptera, but is retractile within the mouth, and extends backwards to the entrance to the œsophagus. It consists of three parts, an inferior one which is strong, horny, and forms a groove or canal, the upper surface of which is covered by another smaller piece, and the two inclose between them a third setiform organ. Upon the precise nature of these parts we do not offer a positive opinion; the inferior one, which is continuous with the inflected portion of the labium, seems to represent an elongated portion of that organ, and the middle one probably is the lingua, in which case the upper one would answer to a similarly elongated portion of the labrum.

The under surface of the head is divided by a deep incisure anteriorly, the margins of which are covered with stiff hairs and form the lateral boundary of the mouth. The *mentum* (*l*), described as such by Curtis, is a strong convex plate, divided also at its anterior part by a continuation of the incisure just noticed. The *corneæ* (*c*), of an oval convex shape, are situated more on the upper than on the lateral part of the head, but the ocelli in this insect are entirely wanting, unless we regard as a large ocellus a convex plate situated in the middle of the most posterior part of the epicranium (*b**). In the other genera of this order, as in *Hæmobora*, the head is more orbicular and less flattened; the epicranium is broad and distinct, and the suture between this part and the clypeus posterior is strongly marked. In *Melophagus*, the tick or sheep-louse, the maxillæ are of considerable length, and the retractile portion of the labium inclosing the lingua is of considerable strength. The ocelli are present, inserted in little excavations in *Hæmobora*, but absent in *Melophagus*. In *Nycteribidæ* the head offers a most anomalous condition of parts, its form being, as described by Latreille, that of a reversed cone. We have had no opportunities of examining for ourselves either the head or parts of the mouth, which, according to Messrs. Curtis* and Westwood,† are styliform, and analogous to those of *Hippoboscæ*.

In Aphaniptera the head is compressed from side to side, but we have not yet identified its primary parts. Its chief characteristics are its extreme narrowness, the situation of its antennæ, and the peculiarity of its organs of vision, the corneæ of the proper eyes being each simple and not compound as in other insects. The mouth is formed upon the same general principles as in the blood-sucking Diptera, being composed of six primary parts adapted for piercing the skin, and occasioning the pain which distinguishes the puncturing of these troublesome insects.

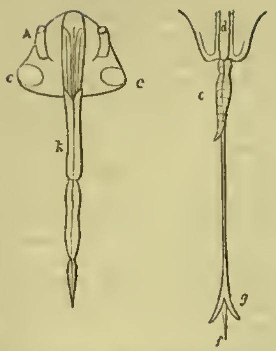
In Aptera, all of which, like the insects of the two preceding orders, are parasitic upon the bodies of other animals, the mouth in one family, the true *Pediculidæ*, is formed for sucking, but in the other, the *Nirmidæ*, it is distinctly mandibulated, and approaches the usual type of mandibulated insects.

In Hemiptera the head is often flattened and somewhat triangular, and the mouth is rostriform as in some of the Diptera, but the sheath of the organ is formed entirely by the labium (*fig.* 382, *k*). The corneæ are usually very prominent, and are placed at the posterior angles of the head. The epicranium is distinct, but its occipital portion is sunk into a notch in the prothorax. The ocelli are usually two in number, placed on the most posterior part of the epicranium, and are constant throughout the order in the perfect state, but are not developed in the larva or pupa. The division of the head into its primary parts is very distinct in some genera. In *Coreus marginatus* the epicranial suture is strongly marked along the middle line as far as the space between the corneæ, where it joins the triangular suture which passes outwards immediately behind the insertion of the antennæ, bounding the clypeus posterior. In some specimens, but more particularly in the pupa, a faint longitudinal suture extends forwards over the clypeus as far as the

* British Entomology, pl. 277.

† On *Nycteribia*, in Transactions of the Zoological Society of London, vol. i. p. 279.

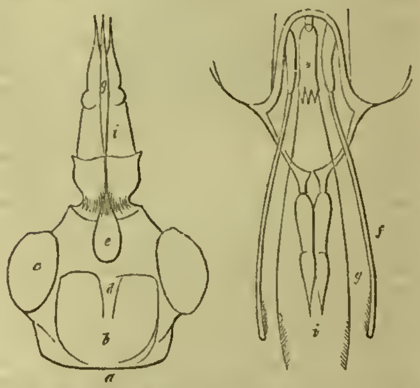
Fig. 382.



Head of Pentatoma rufipes (Savigny).

most anterior portion of the front of the head, where it joins with a second triangular suture which passes outwards on each side anterior to the insertion of the antennæ, and thus divides the clypeus anterior from the posterior. The proper triangular suture between the epicranium and clypeus passes backwards from behind the insertion of the antennæ along the sides of the head as far as the margin of the cornea, thus clearly indicating the extent of the epicranial region, as in Coleoptera. The *clypeus anterior* is distinctly marked at the front of the head (*d*) as a narrow elongated plate, a little widened at its lower portion, where it is articulated with the *labrum* (*e*), which is narrow, lengthened, and ends in a point, and covers the front of the proboscis (*k*), which is formed of four joints or articulations, and is believed by Savigny to represent the true *labrum.* This part, which, in a state of rest, is concealed beneath the under surface of the head and prothorax, forms a cylindrical tube throughout nearly its whole length, from its apex to its base, where it is covered by the labrum. It incloses four distinct setæ, which have been shewn by Savigny to be the proper mandibles and maxillæ. We are satisfied of the correctness of this opinion from our own examination of these parts, the insertion of the muscles belonging to them being in the basilar portion of the head, as in all the preceding orders. But it is in *Reduvius* that the parts of the head are most distinctly marked. The occipital portion is so much elongated backwards as to form a very distinct neck, narrower considerably than the other parts of the head, and the corneæ are large and protuberant and stand out from its broadest part, while the *ocelli,* two in number, are also exceedingly large and are placed on short pedicles almost on the constricted neck-like part of the epicranium, far behind the *corneæ,* and with their axis directed posteriorly. Between this portion of the head and that which contains the true corneæ is a deep transverse impression, which seems to indicate that the corneæ and ocelli are derived from distinct segments. But one of the most marked characteristics of the epicranium in this insect is the existence of a triangular elevation or ridge, which commences in the usual situation of the suture in the middle line between the corneæ, and extending outwards marks the course of the antennæ. The posterior margin of this ridge is in the usual direction of the triangular suture, posterior to the insertion of the antennæ. Anterior to this is a lozenge-shaped plate, the clypeus posterior, which is elevated along its middle line, and which is continuous with a similar elevation on the clypeus anterior. The labrum is short, and terminates in a triangular process, that covers the base of the proboscis as in the preceding species. We have thus five clearly indicated segments in the head of a perfect insect,—the occipito-basilar segment bearing the ocelli, the proper epicranial with the corneæ and antennæ, the two clypeal, and the labial. The proboscis consists, as in *Coreus,* of four distinct articulations, which form the labium, and correspond to the segments of the upper surface of the head, but which are extended forwards and form a sheath for the setiform mandibles and maxillæ. In the *Hydrometridæ,* which connect the terrestrial with the aquatic Hemiptera, the head is elongated forwards, and the corneæ, which are large and kidney-shaped, are very protuberant. In *Gerris paludum* the epicranial region is short, but the suture is still very distinct. It divides as usual at a point opposite to the middle of the corneæ, and passes outwards to their anterior margin. The clypeus posterior is broad and lengthened, and seems to have become united with the anterior, and the antennæ are moved forwards to the base of the proboscis. The *Nepidæ* have a form of head similar to that of the Hydrometridæ, but the epicranial region (*fig.* 383, *d*) is of greater extent. In

Fig. 383.



Upper and under surface of the head of Nepa cinerea (Savigny.)

a, occiput; *b,* epicranium; *c,* cornea; *d,* clypeus posterior; *e,* labrum; *f,* mandibles; *g,* maxillæ; *i,* labium; *, lingua.

the figure which we have copied from Savigny the parts of the head are not distinguished, but they are distinct in the insect. The epicranial suture, the proper guide to a correct determination of the primary parts of the head in every species, bounds the corneæ anteriorly and the clypeus posteriorly, which is reduced to a small triangular plate (*d*) with its apex directed backwards. It is divided by a transverse suture from the clypeus anterior, which forms a chief part of the front of the head. The labrum (*e*), as in the preceding species, is short and pointed, the mandibles (*f*) are long and setiform, but larger than the maxillæ (*g*), and the lingua (*), according to Savigny's observations, forms a short trifid process within the cavity of the mouth, at the base of the maxillæ, the covering or sheath to the parts being formed, as in the other species, by the labium.

In Homoptera, which are considered by many naturalists as constituting only a division of the Hemiptera, the general form of the head is that of a triangle, the lateral and basilar angles of which are occupied by the protuberant corneæ. In the *Cicadiidæ* the epicranium is short but exceedingly wide, bearing at its sides on distinct pedicles the large projecting corneæ similar to the pedunculated eyes of *Diopsis*, one of the Diptera. The epicranial suture is most distinctly marked. It passes outwards from the middle line on each side behind a large, convex, transversely striated protuberance on the front, which is the proper *clypeus posterior*, as far as the base of the pedunculated corneæ, where the antennæ are inserted immediately in front of it. The *ocelli*, three in number, arranged in a triangle, are placed on the most vertical part of the epicranium, and the suture passes through the anterior one. The clypeus anterior is a short triangular plate, united by suture to the anterior margin of the clypeus posterior. It has usually been described as the labrum. The proper *labrum* is a small pointed corneous plate, which covers the base of the proboscis in front, and is freely articulated to the margin of the clypeus. It has been figured by Messrs. Kirby and Spence* as an appendage to the labrum *(appendicula)*, which, as just shown, is the clypeus anterior. It is often partially concealed beneath the clypeus. The mandibles and maxillæ are usually strong corneous setæ, contained within the sheath formed by the labium. At the base of the maxillæ, concealed by the labium, are two short membranaceous appendages, which are probably the rudimentary maxillary palpi. They are attached to the external under surface of the maxillæ, and are entirely concealed by the labium. In the *Fulgoridæ*, as in *Fulgora candelaria*, the epicranial region constitutes the greater portion of the head. The large curved process or horn on the front is derived entirely from the epicranium. The *corneæ*, which are remarkably protuberant, are included within the same region at the sides of the head, as also are the two *ocelli*, which are placed one on each side immediately before the corneæ. The *antennæ* present a remarkable character, being formed of three short thick joints, terminated by a minute setaceous one. The third joint, which is nearly globular, is covered with minute protuberances, somewhat resembling the structure of the corneæ, or rather that of the antennæ in the males of *Eucera longicornis*. These organs are situated in deep fossæ, into which the triangular suture enters. The clypeus posterior forms the chief portion of the front, as in the preceding family, the clypeus anterior a narrow plate united to the latter by suture, and the labrum a small triangular appendage.

* Introduct. vol. iii. pl. 6, fig. 7, *a*.

We have entered thus minutely into an examination of the parts of the head and mouth in the different orders of insects, in consequence of the uncertainty which has hitherto existed among naturalists with regard to the number of segments of which the head is normally composed, and also because it was necessary that we should first show the analogous parts of the head in the different orders before stating our opinions with regard to the manner in which they are developed; and further, because from the minuteness of the subjects and consequent difficulty of investigation, the most ample elucidation was necessary upon which to base our opinions.

In our examination of the remaining parts of the skeleton the same minuteness will be of less consequence, because the parts are more easily examined, and have already been identified through the excellent and elaborate investigations of Audouin, Macleay, and others.

Developement of the head.—We have seen in our examination of the perfect insect, that the head is normally composed of four, and apparently even of five sub-segments, as is proved by the existence of the parts we have described, which correspond to the superior and inferior arches of that number. The first, or most anterior of these sub-segments, is formed by the labrum above and the ligula below; the second, by the clypeus anterior and the mentum; the third, by the clypeus posterior and submentum. But the fourth, which has become entirely atrophied, is represented above only by the little bones of the antennæ, within the cranium, and perhaps also the corneæ; and below by that reduplicature of tegument which forms in some insects, as in Hydrous, the large transverse bone, or ridge between the submentum and anterior margin of the gula; while the fifth is formed by the epicranial region above, and the gula and broad basilar region below, the greater size of this sub-segment being the result of its confluence with the preceding one, the fourth, which has disappeared. The number and position of these parts are precisely similar in the larva and the perfect insect, as seen in Coleoptera, Hymenoptera, and the vermiform larvæ of Diptera. In each of these instances the greater or less distinctness of the parts is in an inverse ratio to the more or less perfect organization of the individual. Thus, if we take, for example, the head of the larva of the common Chaffer-beetle, *Melolontha*, the first, second, third, and fifth sub-segments are very distinct, and the antennæ, inserted at the angles of a strongly marked triangular suture, indicate the situation of the fourth atrophied sub-segment. But in the perfect beetle, as we have formerly seen, not only have all these separate parts of the larva become confluent, but their previous existence as distinct pieces is scarcely to be detected. A similar condition of parts exists in the heads of other Coleoptera. The disappearance of one segment of the head thus early in the larva state is in perfect accordance with that progressive developement which we know takes place in every part of the body, and hence it was to be expected, that those parts in which the changes first occur are those which first entirely disappear. Hence the disappearance of the fourth subsegment, which we believe exists in the earliest stages of the larva, and of which the antennæ are the superior appendages. If we turn from this transitory larva state of the insect to the permanent vermiform condition of the Annelida, the lower Articulata, we find in the common *Nereis* a condition of the head apparently analogous to that of the vermiform larva. It is elongated forwards, and formed of distinct segments, of which the posterior ones, as in insects, support the organs of vision. But these remarks on the relations of the different parts of the head are offered with much hesitation, because, in Myriapods, which have usually been compared with the larvæ of insects, the form of the head seems to be opposed to this mode of viewing its development in Articulata, since the antennæ and organs of vision are situated on the most anterior part of a large and broad shield, which has been considered the first segment. But if this be correct, it will be difficult to explain the circumstance of the antennæ and corneæ of hexapodous insects being constantly situated posteriorly to the first three sub-segments of the head, the labrum and clypei.

The appendages of the head, which form part of the organs of manducation, correspond in number to the number of sub-segments. These parts are analogous to those which constitute the organs of locomotion, when attached to other segments of the body, as in Myriapoda, and Crustacea. In the head of an insect the mandibles are the proper appendages of the fifth or basilar sub-segment, while a small but freely articulated lobe, which sometimes exists, as in some of the *Brachelytra*, at the inner side of the mandible, appears to represent that of the fourth. The stipes, or external portion of the maxilla, which at its base articulates with the cardo, and at its distal extremity is connected with the palpus, seems to be the proper appendage of the submentum, while the inner portion of the maxilla, which originally appears to be a distinct part, and which at its distal extremity supports the galea, seems to be the proper appendage of the second sub-segment, and the labial palpi in like manner represent those of the ligula or first. It has been shewn by Savigny and others, that these analogues of the organs of locomotion undergo a very gradual change of form and use in the different classes. In Myriapoda the appendages that belong to the basilar segment of the head, which constitute the mandibles, are greatly enlarged, and are directed forwards as organs of prehension, like the chelate organs of Crustacea and Arachnida, but are jointed and retain the exact form of true legs. In insects the mandibles are in like manner directed forwards, and are placed above those of the preceding segments, but are compressed, and materially altered in size and shape, their terminal portions, the tarsal joints, being undeveloped, and the tibia alone enormously enlarged, constituting the whole jaw or manducatory organ, while the basilar joints, the femur and coxa, are lost in the under surface of the segment, with which they have become confluent. That this is really the case is proved by the fact that all the muscles that belong to these powerful organs are attached to the basilar and postero-lateral parts of the head, in the very situations which they must have occupied had the organs remained free for the purposes of locomotion or prehension, as in Crustacea, Arachnida, or Myriapoda. That this confluence of parts has in reality taken place is further proved by the circumstance, that the outlines of the portions that become united with the skull are distinctly marked in *Lucanus cervus*, and still more clearly in that of the great Hydröus (*fig.* 369, o). There is a remarkable illustration of the principle upon which the change of form in the adaptation of these organs to a new function depends, in that curious instance of monstrosity in an individual of *Geotrupes stercorarius*, described in a former page (860), in which the tibiæ of the pro-thoracic legs have been arrested in their development, and are lunated like the proper mandibles, the tarsi being entirely absent. In a remarkable insect, *Onitis aygulus*, to which our attention was directed by Mr. Shuckard, there is a further illustration of this principle, in the permanent condition of the pro-thoracic legs of that species, in which the tarsi are entirely absent, and the tibiæ are lunated and terminated each by a sharp hook. There is also a similar condition of the same parts in other species, *O. Olivierii*, *O. serripes*, and *O. chinensis* and *Apelles*, while in a species of a neighbouring genus, *Bubos bison*, the tibiæ are considerably narrower than in the preceding, and approach much nearer in shape to the instance of monstrosity in *Geotrupes*, thus distinctly indicating, not only that the form of parts depends either upon excessive or deficient developement, but also that the abnormal conditions occasionally met with in some species are permanent normal conditions in others.

From the manner in which the appendages of the cranial sub-segments are arranged to form the parts of the mouth, it necessarily follows that the most posterior pair, the mandibles, are carried upwards, and become the superior lateral organs; while the maxillæ obtain the next place beneath them, and the whole are covered in by the inferior arches of their respective sub-segments, which constitute the labium.

In all insects, the whole of the parts of the head in the perfect individual exist in the head of the larva, the changes which take place being only those of size and relative position. When the head of the larva is smaller than that of the future imago, as in the Hymenoptera, its increase of size just before the insect changes into a nymph, and when a great portion of the head is found beneath the skin of the second segment, does not depend upon its having become confluent or united with a portion of that segment, but upon the development of those parts which already existed in it in the larva, so that the diminution which the second or prothoracic segment undergoes is simply an atrophied condition, which results from the developement of the adjoining parts, and not from an actual union or coalescence with them; since in every instance in which a part becomes confluent with an adjoining one, it loses its distinctness of form and character, and does not remain free as when simply atrophied, or arrested in its developement. But when the head of the perfect insect is smaller than that of the larva, as in the Lepidoptera, the extent of the pro-thoracic segment is not diminished, unless encroached upon from behind by the enlargement of the meso-thorax.

The thorax is that region of the body which immediately follows the head, and bears all the organs of locomotion in the perfect insect. It is always composed of three very distinct segments, first, the *pro-thorax*, which bears the first pair of legs; second, the *meso-thorax*, which bears the first pair of wings and second pair of legs; and third, the *meta-thorax*, which bears the second pair of wings and third pair of legs. Besides these segments, which are analogous to the second, third, and fourth in the larva state, there is also another, the fifth segment of the larva, which enters in part into the composition of the thorax of the perfect insect, and forms its connexion with the abdominal region. We have already alluded to this in our account of the changes of the larva, (p. 877, 8,) during which we have shewn that at least one segment of the body always becomes atrophied, and very frequently almost disappears, and that this segment is the fifth. But we have not there sufficiently explained that this segment belongs partly to the thoracic and to the abdominal regions, on which account we propose to designate it the *thoracico-abdominal* segment, and consequently the number of segments of which the abdomen is composed will depend upon whether or not we include this in that region. For our own parts we prefer to consider it as forming a most distinct part, for reasons which we shall presently explain. Now it has been shewn by M. Audouin, in an admirable and elaborate series of investigations, that each segment of the thorax is normally composed of four sub-segments, which sub-segments or annuli are each formed of distinct parts, one upper or dorsal, one lower or pectoral, and two lateral. The four annuli thus formed are easily demonstrable on the upper surface of each thoracic segment, but are less readily detected on the pectoral or under surface, in consequence of the parts having there become confluent, in order to afford a greater degree of solidity to the skeleton; and in consequence also of the diminished extent of the pectoral as compared with the dorsal surface, which, as before explained, (page 877,) is dependent upon the greater extent of change that takes place on the pectoral than on the dorsal surface during the metamorphoses of the insect. The parts capable of demonstration in each segment, according to the views of Audouin, are, on the upper or dorsal surface, the *præscutum*, *scutum*, *scutellum*, and *post-scutellum*; on the inferior or pectoral surface a single piece, the *sternum*, and on the lateral two pieces, the *episternum* and *epimeron* on each side; in addition to which there are also two evanescent pieces, which are of considerable size in some species, but scarcely distinguishable in others. These are the *paraptera*, portions of the thorax not articulating with the sternum, but with the episternum, anterior to each wing, and the *trochantin*, articulating with the epimeron and coxa of the leg, the paraptera of the pro-thorax being, according to Audouin, absent. Hence the number of pieces he describes as forming the external thorax are ten for the pro-thorax, twelve for the meso-thorax, and a like number for the meta-thorax, making in all thirty-four pieces. These are parts capable of being demonstrated, if we regard each sternum as formed of two transverse pieces united, and corresponding to the episterna and epimera. But as remarked by Mr. Macleay,* each sternum at the maximum of development ought to be regarded, like the dorsal surface of each segment, as composed of four transverse sub-segments united longitudinally, and the sides of the same number. If then the four portions on the dorsal surface of each segment, and the sternum on the under, be also divided in the median line, the number of pieces in the thorax will amount to seventy-two. But this number, as Mr. Macleay has well remarked, can never appear together in any insect, owing to the great extent to which some parts are developed, and the consequent atrophy of others. At the same time it must be observed, that if we adopt this, which appears to be the correct theoretical mode of considering the subject, the number of pieces which enter into the composition of the thorax is in reality greater than that given by M. Audouin, who has not described any parts belonging to the pro-thorax as analogues of the paraptera of the meso- and meta-thorax, but which we think may be found in a pair of those little detached plates that exist in the articulating membrane between the head and pro-thorax in Coleoptera, and which have been described by Straus Durckheim† as *pièces jugulaires*, and conceived by him to represent the remains of two distinct segments, situated originally between the head and pro-thorax, but which have disappeared during the transformations. But we are more inclined to consider them as detached portions of the pro-thorax than as remains of distinct segments, since we are totally unaware that any such disappearance of segments ever takes place between the head and pro-thorax; the head or first segment of every Coleopterous larva being the proper representative of the head of the perfect insect; and the second segment of the larva being in

* Zoological Journ. vol. i. p. 177.

† Considerations Gén. &c. p. 75.

like manner that of the pro-thorax, the change which takes place between these two segments during the metamorphoses being chiefly a shortening of the sternal surface of the pro-thorax, or second segment, occasioned by a reflexion inwards of a portion of the external tegument, to form the articulation as in other insects. If, therefore, we include the jugular pieces of Straus as the analogues of the paraptera, the external surface of each of the three thoracic segments will be found to consist of twelve primary and readily demonstrable pieces, making in all thirty-six, the number which we believe always enters into the composition of the thorax, as formerly stated by M. Jurine. But it is probable that the parts described by M. Audouin, and recognised by ourselves, are not identical with those of that author, since the scutum of the meso-thorax in Hymenoptera, as will presently be seen, and as formerly pointed out by Mr. Macleay,* is not only divided in the median line, but its two sides are also separated by a deep longitudinal fissure each into two parts, the outermost of which Mr. Macleay designates *parapsides.* This division of the scutum of the meso-thorax, if constant in the other orders, would raise the number of distinct pieces to thirty-eight. M. Audouin, who adopts the name given to these parts by Mr. Macleay, states that although he was previously well acquainted with this division of the scutum in Hymenoptera, he did not assign names to the pieces because he considered them rather as mere divisions of the scutum itself than as distinct parts of the skeleton. The existence of these pieces, therefore, in Hymenoptera, is a circumstance connected with the number and identification of the normal parts of the skeleton, which, it must be acknowledged, offers not a little difficulty, because if it be ultimately found that these, which are so distinct in some genera, the *Chrysididæ*, be in reality normal parts of the mesothorax which are thus shown to exist as such only by this segment being developed to its maximum extent in this Order, it must be admitted that they also exist primarily in all other insects, not merely in the mesothorax, but in the pro- and metathorax, so that the dorsal surface of each thoracic segment must be regarded as formed not of four but of sixteen parts, the præscutum, scutellum, and post-scutellum being each divided in the same manner as the scutum into four pieces, first by a median line into two halves, and these again divided laterally into two others. The two middle pieces would then constitute the *notum*, or dorsal surface of each segment, and the two lateral the *parapsides.* An equal number of parts must then be recognised as entering into the formation of the ventral arch of each segment. Each middle or sternal piece, formed of four consecutive pieces, analogous to those of the dorsal arch, and divided in the median line, would correspond to the middle series of dorsal pieces, the proper *notum*, and a like number on each side of the sternum would correspond to the lateral portions of the dorsal arch, the parapsides. Of these lateral pieces of the ventral arch, three are already known in each segment, as we shall presently find, the *parapteron*, *episternum*, and *epimeron.* But since there has never yet been actually found even an approximation to this multitude of pieces in the dorsal surface or arch of the thorax, we prefer for the present to follow the views of M. Audouin, and with him to regard the parapsides as only detached portions of the scutum in Hymenoptera, in which the development of the mesothorax is carried to its greatest extent. It must be acknowledged, however, that in admitting the parapsides to be only detached portions of the scutum, and not primary parts, the same thing may be urged with regard to some of those which, according to M. Audouin's views, are believed to be normal structures. But this objection seems to be replied to by the fact that the pieces described by M. Audouin are almost always found to exist most distinctly marked, whether developed to a greater or less extent, in the generality of insects. Thirty-six, therefore, we regard as the number of the distinct external parts of the thorax. Yet even this is more than has been recognized by others who have attended to this subject. Thus Knoch describes only twelve, Chabrier and Burmeister, eighteen; Kirby and Spence, twenty; Straus Durckheim, twenty-two; and Macleay, fifty-four. But whatever be considered the exact number, they are never all distinctly developed in every insect, owing to the causes before explained with reference to the greater developement of some parts than of others, although some trace of the existence of the atrophied pieces usually remains. It is owing, also, to the same causes, that the actual position of the parts becomes altered in different insects, although their relative position continues the same.

Very much confusion has arisen in the descriptions of the parts of the thorax, in consequence of various authors applying different names to the same parts in different insects, and also from the uncertainty which, as above shewn, exists in the opinions of authors with regard to the exact number of pieces that enter into the composition of the thorax. In order, therefore, to obviate as much as possible this serious inconvenience and difficulty in recognizing the parts, we shall add a table of the names given to them by Audouin, with references to the delineations of them by that author, and also the synonyms used by other writers. In doing this we shall also adopt Burmeister's very convenient names for the upper and under surface of each thoracic segment, which are equally simple, and distinctive of the parts to which they are applied.

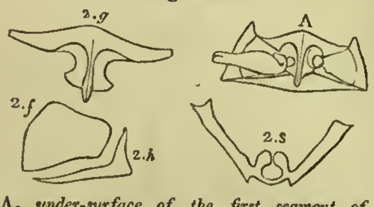
* Zoological Journ. vol. i.

TABLE OF PARTS OF THE THORAX.

Thorax	2d segment Prothorax.	Prothorax, *Nitzsch, Chabrier, Aud. Macleay, Burmeister* Manitrunk, *Kirby & Spence* Corslet, *Straus Durckheim*	composed of 4 sub-segments	Dorsal surface	Pronotum, *Burm.* Prothorax, *Kirby* Tergum, *Macleay*	Præscutum Scutum Scutellum Post-scutellum	*Audouin*
				Pectoral surface	Prosternum, *Burm.* Ante-pectus, *Kirby* Pectus, *Macleay*	Paraptera ?	Pièces jugulaires, *Straus*
						Sternum Episternum Epimera	*Audouin*
						Ante-furca, *Kirby*; Entothorax, *Aud.*; Apophyse episterne, *Straus* Stigma primum, *Burmeister*; Peritreme, *Aud.* cadres premiere, *Straus*	
	3d segment Meso-thorax	Meso-thorax, *Chabrier, Kirby, Audouin, Macleay, Burm.* Prothorax, *Straus Durckheim*	composed of 4 sub-segments	Dorsal surface	Mesonotum, *Burm.* Meso-thorax, *Kirby* Tergum, *Macleay*	Præscutum, (3. a) Scutum, (3. b) Scutellum, (3. c) Post-scutellum, (3. d)	*Audouin*
				Pectoral surface	Meso-sternum, *Burm.* Medi-pectus, *Kirby* Pectus, *Macleay*	Paraptera, (3. e) Sternum, (3. g) Episternum (3. f) Epimera, (3. h)	*Audouin*
						Medifurca, *Macleay*; Ento-thorax, *Aud.* Apophyse episterne moyenne, *Straus* Stigma secund. *Burm.* Peritreme secund. *Aud.* cadres, *Straus.*	
	4th segment Meta-thorax	*Chabrier, Kirby, Aud. Macleay, Straus, Burmeister*	composed of 4 sub-segments	Dorsal surface	Meta-notum, *Burm.* Meta-thorax, *Kirby* Tergum, *Macleay*	Præscutum, (4. a) Scutum, (4. b) Scutellum, (4. e) Post-scutellum (4. d)	*Audouin*
				Pectoral surface	Meta-sternum, *Burm.* Post-pectus, *Kirby* Pectus, *Macleay*	Paraptera, (4. e) Sternum, (4 g) Episternum (4. f) Epimera, (4. h)	*Audouin*
						Post-furca, *Macleay*; Ento-thorax, *Audouin*; Apophyse epistern post, *Straus*	

The *pro-thorax*, as we have stated, is composed of four sub-segments, which on its upper surface, or *pro-notum*, are generally confluent, more particularly in Coleoptera, and form a smooth, uniform, and often very broad surface. In shape, the pro-notum is usually more or less quadrate and convex, with its sides arched and dilated. In many species, as in some families of Coleoptera, Orthoptera, and Homoptera, the pro-notum is larger than the corresponding part of any segment of the body, being considerably broader and longer than the head. This is the case more especially in those insects which are much employed in burrowing, as in *Gryllotalpa*, *Geotrupidæ*, *Copridæ*, and *Silphidæ*. Sometimes, as in the *Cercopidæ*, it is enormously enlarged. In *Membracis foliata* it is developed in the median line into an elevated crest like that of a helmet, which is not only extended forwards so as completely to conceal the head, but also laterally and backwards over the whole body. In others of the same family, as in *Ledra*, it resembles an acute triangle, its sides being developed into two obtuse processes, while it is elongated backwards like an acute spine, which completely covers the abdomen. In other instances, as in *Dynastidæ*, (*fig.* 333,) it is developed into a strong horn or process, which is as long as the whole body. In each of these instances, the abnormal form and size depend either upon the excessive development of the whole of the sub-segments, as in *Gryllotalpa*, or upon one or more of them, as in *Dynastes*, since in those species in which the parts of the pro-notum are all nearly equally developed, and are of moderate size, their lines of separation are very distinctly marked, as in the common green grasshopper, *Acrida viridissima*. The *pro-sternum*, or under surface of the pro-thorax, is considerably shorter than the pro-notum. In *Dyticus circumflexus* (*fig.* 384 A), the species selected by Audouin

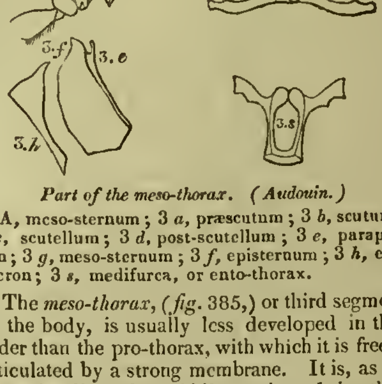
Fig. 384.



A, under-surface of the first segment of the thorax or pro-sternum of Dyticus circumflexus, (Audouin); 2 *g*, pro-sternum; 2 *f*, episternum; 2 *h*, epimeron; 2 *s*, ante-furca or ento-thorax.

for the purpose of illustrating the anatomy of the thorax in Coleoptera, it is divided into three distinct pieces. The *sternum*, or largest piece, (2 *g*,) is situated in the middle line, and is of a triangular form. It is extended on each side, at the anterior part of the segment, into two processes, which articulate at their extremities by a distinct suture with the produced margins of the pro-notum. Posteriorly to these it is developed in the median line into a spine or crest, on each side of which it is hollowed out to form part of the *acetabula*, into which the coxæ of the anterior legs are inserted. External to each acetabulum is a broad and somewhat triangular-shaped plate, the *episternum* (2 *f*). This part is united by suture at its anterior margin to the extended part of the sternum, by its superior border to the dilated margin of the pro-notum, and by its posterior to the *epimeron*. It is a very distinct piece, and does not enter at all into the formation of the acetabulum, as it appears to do on a cursory examination. The third piece, the *epimeron* (2 *h*), is that which is always connected with the *coxa*, or basial joint of the leg. In this species it is a narrow plate, situated posteriorly to the episternum, and forms the posterior margin of the sternal surface of the pro-thorax. At its sternal end it has a short process, that forms the outer margin of the acetabulum, and articulates both with the sternum and episternum. It is probable that a portion of this process is the proper *trochantin* of the leg on each side, since the part, which has been described by Audouin as the trochantin in the meso- and meta-thoracic segments, has not been delineated in his drawing of the pro-thoracic. In *Dyticus marginalis* there is a mark upon the process which resembles a suture, and which still further induces us to believe that this part is the analogue of the trochantin. Within the cavity of the pro-thorax, extending upwards from their attachment to the pro-sternum, are two bony rami, which at their inferior extremity are developed into two rounded plates (2 *s*), that form a collar, or leave a circular hole between them for the passage of the spinal cord. They constitute the *ante-furca*, the *ento-thorax* of Audouin. These are the parts that enter into the formation of the pro-thorax, exclusive of the anterior pair of legs, the only appendages of this segment.

Fig. 385.

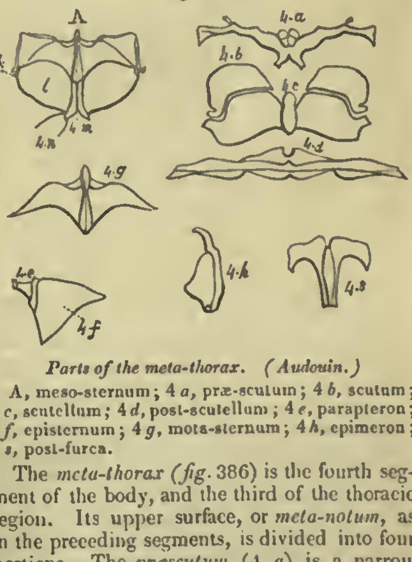


Part of the meso-thorax. (Audouin.)

A, meso-sternum; 3 *a*, præscutum; 3 *b*, scutum; 3 *c*, scutellum; 3 *d*, post-scutellum; 3 *e*, parapteron; 3 *g*, meso-sternum; 3 *f*, episternum; 3 *h*, epimeron; 3 *s*, medifurca, or ento-thorax.

The *meso-thorax*, (*fig.* 385,) or third segment of the body, is usually less developed in this order than the pro-thorax, with which it is freely articulated by a strong membrane. It is, as its name implies, the middle portion of the thorax, and in most instances its division into four sub-segments is distinctly marked on its dorsal surface, or *meso-notum*. It is the segment that bears the elytra and middle pair of legs. The first piece, the *præscutum* (3 *a*), is in general narrow and transverse; it is very readily overlooked, being in most cases bent downwards to form the *meso-phragma*, the anterior boundary of the segment. The second piece, the *scutum* (3 *b*), is a much broader and very distinct corneous plate, and may be regarded, perhaps, as the most important division of the meso-notum, since it is to this that the anterior pair of wings, the elytra, are articulated. It is followed by the *scutellum* (3 *c*), which also is a very important division. Like the scutum it is a broad piece, that covers the posterior part of the meso-notum, and extends on each side to the base of the elytra, the *alulæ*, which are continuous with them, being attached to its margin. It is developed in the middle line into a remarkable elevated plate, that is shaped like an armorial shield, and is so exceedingly large in some species, that it covers nearly the whole of the body. In *Dyticus*, and most of the Coleoptera, it is the small triangular plate which is situated between the elytra, at their base, and is supposed to be of use in keeping these organs steady during flight. The fourth and last piece of the meso-notum, the *post-scutellum* (3 *d*), like the præ-scutum, is narrow and inconspicuous. It is situated immediately behind the scutellum, and is the posterior boundary of the meso-notum. These parts together form the dorsal surface of the first wing-bearing segment, which is developed to as great an extent on its under as on its upper surface. The meso-notum is most fully developed in those insects in which the anterior pair of wings are the largest, as in the Lepidoptera, Hymenoptera, and Diptera, while in those in which the chief organs of flight are the posterior wings, as in the Coleoptera, it is the smallest of the three thoracic segments. The *meso-sternum (fig.* 385, A), like the pro-sternum, is formed by a strong middle piece, the proper sternum of the segment, (3 *g*,) which is developed laterally into two processes, behind which the coxæ of the middle pair of legs are articulated, and anteriorly and laterally the episterna (3 *f*) and epimera (3 *h*). Each *episternal* piece is a broad elongated plate, which forms the anterior part of the meso-sternum. It is attached to the anterior margin of the lateral sternal process, so that its actual position is a little altered, the corresponding part of the pro-thoracic segment being situated behind the process of the sternal piece. This is a circumstance which occasionally takes place in the development of every part of the skeleton, the actual position of one part being altered by the greater or less developement of another, while the relative position of each part always continues the same. Thus, although the episternum is situated more anteriorly in the meso- than in the pro-sternal surface, it still continues to be articulated with the sternum. The epimeron (3 *h*) is situated behind the episternum. It is a narrow elongated plate, that forms the posterior portion of the meso-thorax, and is united to the anterior of the meta-thorax. At its superior extremity it is much broader than at its inferior, which is articulated with the extremity of the sternal process, and also with the coxæ of the middle legs. At the anterior border of the episternum there is a very narrow but distinct plate, the *parapteron* (3 *e*). This piece, which is connected especially with the wings, undergoes a great change of form and size in the different orders. In the Coleoptera it is narrow and evanescent, but as we shall hereafter see, is largely developed in the Lepidoptera. It is evidently a normal portion of the skeleton, but has only been described by Audouin as found in the meso- and meta-thoracic segments. We have before alluded to the existence of two detached pieces in the connecting membrane of the pro-thorax and head, which we regard as the analogues of these pieces of the meso- and meta-thorax. If this be correct, the relative position of these to the other parts of the pro-sternum is precisely similar to that of the same parts of the meso-sternum. The *medifurca*, (3 *s*,) or ento-thorax of this segment, is attached to the internal surface of the sternal piece, as in the pro-thorax. It is formed by two ascending rami, which are larger and longer than those of the pro-thorax, but like them are developed into two expanded portions, which are approximated together and form an arch, under which the nervous cord passes in its course to the meta-thorax.

Fig. 386.

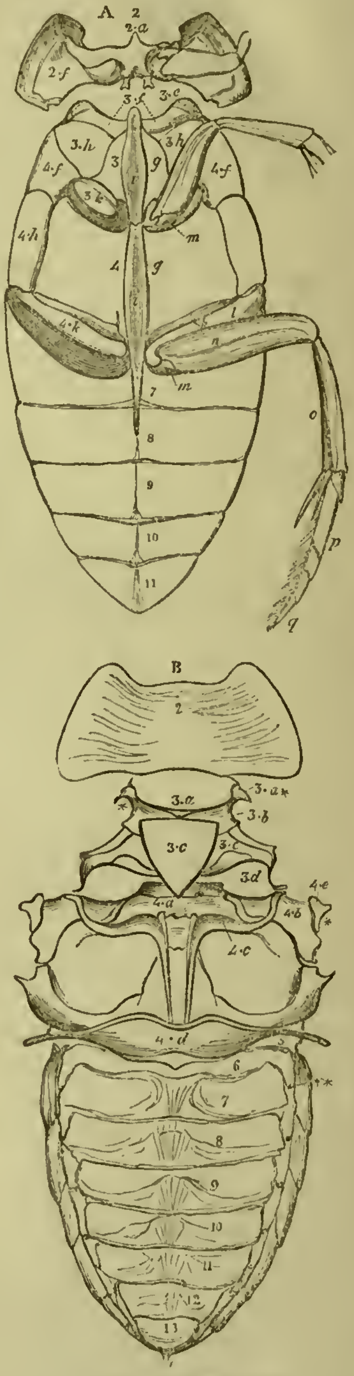


Parts of the meta-thorax. (*Audouin.*)

A, meso-sternum; 4 *a*, præ-scutum; 4 *b*, scutum; 4 *c*, scutellum; 4 *d*, post-scutellum; 4 *e*, parapteron; 4 *f*, episternum; 4 *g*, meta-sternum; 4 *h*, epimeron; 4 *s*, post-furca.

The *meta-thorax (fig.* 386) is the fourth segment of the body, and the third of the thoracic region. Its upper surface, or *meta-notum*, as in the preceding segments, is divided into four portions. The *præscutum* (4 *a*) is a narrow transverse plate, which is bent down at its anterior margin like the præscutum of the meso-notum, to form the meta-phragma, and is extended on each side as far as the paraptera, bounding the insertion of the wings. In the middle line it is extended backwards upon the dorsal surface as far as the scutellum, thus dividing into two parts the second piece, the *scutum*, (4 *b*,) which, like the corresponding part of the meso-notum, is connected with the wings of the segment. This connexion is the great characteristic of the scutum in all insects. The next piece, the *scutellum*, (4 *c*,) is a much broader plate, and is extended across the whole surface of the meta-notum. Like the corresponding piece of the meso-notum, it bears on the middle line an excavated shield-shaped plate, and is connected at its external margin with the borders of the wings. The last piece, the *post-scutellum*, (4 *d*,) which, although narrow like the præscutum, is a strong horny plate that extends on each side, and like the scutellum, is connected with the wings. Its posterior margin is bent down to assist in forming the division between the thorax and abdomen, and is connected with the remains of the atrophied fifth segment. The *meta-sternum* (A) is frequently the most developed portion of the meta-thorax, particularly in those insects which, as Audouin has observed, are especially walkers. In *Dyticus*, the middle piece, the proper *sternum* (4 *g*), is a smooth expanded plate, which is produced at its anterior part into a spine, that articulates with the emarginated extremity of the crest of the meso-sternum. On each side of the spine it is developed into a broad, smooth, triangular plate, to the anterior border of which is articulated the episternum, (4 *f*,) also of a triangular form. This piece occupies the anterior lateral region of the meta-sternum, and the *parapteron*, (4 *e*,) which is situated immediately beneath the insertion of the wing, is articulated with its superior border. The *epimeron* (4 *h*) of this segment is exceedingly small, and appears at first to be removed from its proper situation, being carried upwards to the side of the body by the enormously expanded *coxa* (*l*). But although removed from its usual situation, and reduced in size, it still retains its characteristic distinction, that of articulating with the coxa, and also with the *trochantin* (?), (*k*,) which, although minute, is in connexion both with the coxa and epimeron. The *meta-furca*, or ento-thorax of this segment, (4 *s*,) is an exceedingly large and important piece, shaped like the letter Y. It is attached at its posterior extremity to a thin vertical plate, which is situated between the united coxæ of the legs of this segment, and it is also articulated with the posterior part of the internal surface of the meta-sternum. From this attachment it is extended upwards and forwards into the middle of the meta-thorax, where it is expanded on each side into two broad curved plates, to which the muscles of the posterior legs are attached. In the middle line it is grooved, and at its anterior part forms a partially covered canal, along which the nervous cord is transmitted in its course to the abdomen. Besides the parts now described, there are also two curved plates reflected inwards from the posterior margin of the meta-sternum, where it is articulated with the coxæ, and also one central vertical one, which arises in the median line from the interior surface of the sternum, and which appears to be the proper interior sternal ridge. Each of the posterior coxæ is also furnished with a broad plate, which is situated within the meta-thorax, on each side of the attachment of the post-furca. These parts afford attachments for the muscles of the legs.

Fig. 387.



Skeleton of Hydrous piceus.

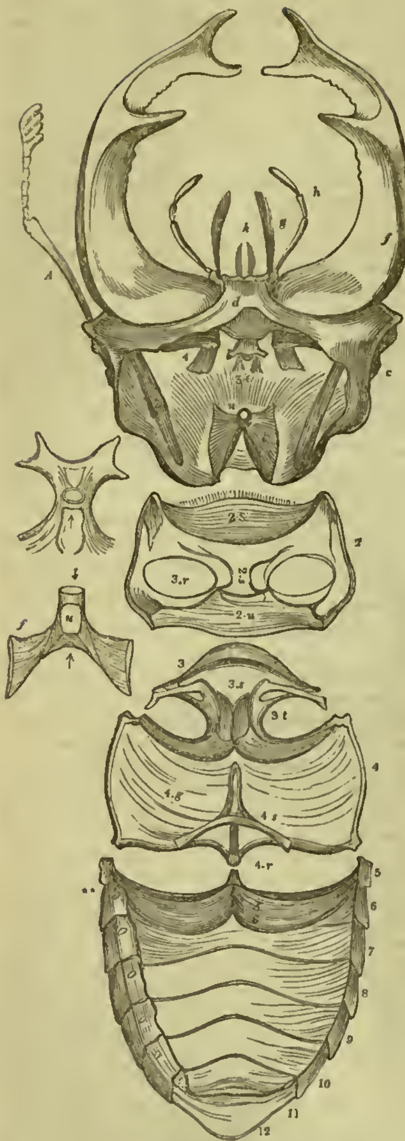
A, pectoral surface; B, dorsal surface; 2, *pronotum*; 2 *a*, prosternum; 2 *f*, episternum; *meso-*

notum; 3 *a*, præscutum; 3 *b*, scutum; 3 *c*, scutellum; 3 *d*, post-scutellum; *meso-sternum*; 3 *g*, sternum; 3 *h*, episternum; 3 *f*, epimeron; 3 *i*, crest of the meso-sternum; 3 *e*, parapteron; 3 *k*, trochantin; 4, *meta-notum*; 4 *a*, præscutum; 4 *b*, scutum; 4 *c*, scutellum; 4 *d*, post-scutellum; 4 *e*, parapteron; *meta-sternum*; 4 *f*, episternum; 4 *g*, meta-sternum; 4 *h*, epimeron; 4 *i*, crest of meta-sternum; 4 *k*, trochantin (?); 4 *l*, coxa; 4*m*, trochanter; 4 *n*, femur; *o*, tibia; *p*, tarsus; *q*, unguis.

These segments constitute the proper thorax of the insect, and the parts we have described are found in nearly all the Coleoptera, the most perfect species; although, as before stated, they are sometimes greatly modified in shape, and varied in size and position, in order that the body of the insect may be adapted to its peculiar habits. Thus in the great water-beetle, *Hydröus piceus*, (*fig.* 387,) which in its general appearance and mode of life very nearly resembles the *Dyticus*, and not only burrows deeper into the mud at the bottom of stagnant waters, but is also accustomed to float among the weeds on the surface to bask in the sun, the form of the sternum is admirably adapted to its habits. The sterna of the meso-thorax and meta-thorax are not only both armed with a strong keel like a boat, but the two are firmly articulated together, which enables the insect more securely to float on the surface of the water, and thus afford additional strength to its whole body for the accomplishment of its object. But in the *Dyticus*, to which it is of the utmost consequence to be able to swim with the greatest rapidity, and turn with facility in the water, in the pursuit of its living prey, the pro-sternum and meso-sternum only are slightly keeled, while the meta-sternum is smooth, and the sides of the body are acute, and offer the least possible resistance to its movements. In addition to this, to afford sufficient strength to the body, together with facility of motion, the sternum of the meta-thorax is produced in front into a short spine, which is inserted into a notch in the posterior part of the meso-sternum; while the coxæ of the posterior pair of legs upon which the chief efforts in swimming depend, although enormously enlarged to afford sufficient space for the insertion of the muscles, are flat and smooth like the rest of the under surface of the body, in order that they may not oppose the slightest impediment to the motions of the insect. The different forms of the coxæ (*l*) and of the acetabula (4 *k*), into which they are inserted, have also a reference to the habits of the species. The large posterior coxæ of the *Dyticus* are immoveably united by suture to the posterior margin of the meta-sternum, because, in this insect, the posterior pair of legs being especially designed for swimming, and their motions consequently being almost wholly in one direction, additional strength is afforded to these organs by the immobility of the coxæ. In the Hydröus, in which all the legs are employed in walking, as well as in swimming, the coxæ are freely articulated in their respective acetabula, and each one is supported in part by the *trochantin* (?), (*k*), which is more developed than in the other insect.

The strength of the body depends much upon the size of the thoracic segments, and the firmness of union which exists between them. Thus in those species which are more especially employed in walking, in flying, or in swimming, the meso- and meta-thoracic segments are the largest. If the insect be aquatic, the largest parts, as we have seen, are the sternal surface of the meta-thorax, and its coxæ; but if, on the contrary, the habits of the insect be aerial, then the dorsal surface of the segment is larger than the sternal. In those insects which are mostly employed on the ground in running or walking, as the *Carabidæ*, *Geotrupidæ*, *Copridæ*, and *Lucanidæ*, the meso- and meta-thoracic segments are often anchylosed together, to give greater strength to the whole body. This is particularly the case in *Lucanus cervus* (*fig.* 388), in which the small sternum of the meso-thorax (3 *g*) is firmly anchyclosed to the enormously enlarged sternum of the meta-thorax. The reason for this is not merely to afford greater stability to the meta-thorax and its wings, upon which entirely devolves the labour of supporting this unwieldy insect during flight, but also to give greater strength to the whole body, during the efforts of the insect to strip off the bark from the smaller roots and branches of trees, to obtain a flow of the juices upon which it subsists. That such is the reason for this anchyclosed condition of its segments is evident from the circumstance, that it occurs not only in those insects which require great muscular power during flight, but also in those which are much accustomed to laborious efforts in tearing, in burrowing, or in running. In these, also, the acetabula (2 *r*, 3 *r*), are exceedingly deep, and almost entirely enclose the coxæ within them, so that while the limb can be rotated freely in almost every direction, a dislocation of it is utterly impossible. The acetabula are situated on each side of the posterior part of the sternum, in each of the three thoracic segments, and in general are formed by an approximation of the sternum and epimeron, and sometimes, also, of the episternum, as in the *Dyticus* (*fig.* 384, A). When, as in this instance, the episternum enters largely into the formation of the acetabulum, the epimeron is carried backwards, and forms the postero-lateral boundary, the episternum the antero-lateral, and the sternum the anterior boundary, so that the acetabulum is formed by the junction of three articulating sutures, and completely surrounds the coxa. This consolidation of parts gives an amazing increase of strength to the segment in which it occurs, and is one of the circumstances which enables the insect to exert a degree of muscular power which is sometimes truly astonishing. It occurs in general in the pro-thoracic segment, as in *Lucanus*, (388, 2,) *Geotrupes*, *Ateuchus*, and other *Lamellicornes*. A similar condition of the acetabula of the meso-thorax exists also in the same insect (3 *r*). But instead of the posterior wall of the cavity being formed by the epi-

Fig. 388.



Internal skeleton of Lucanus cervus.

meron, it is formed by a reflection inwards of part of the anterior margin of the meta-sternum, (4 *q*,) with which the meso-sternum has become anchylosed, and the episternum and epimeron form the lateral boundary of the cavity. The great strength of limb required by insects for other purposes than those of locomotion, belongs especially to the first and second pair of legs, and consequently the articulations of these with the body are required to be most secure. We have seen that in the aquatic insects the posterior pair are almost solely employed in swimming, and in the terrestrial insects they are in like manner employed chiefly in locomotion. The necessity, therefore, for a consolidation of the walls of the acetabula, into which they are inserted, is not so great as in the preceding instances, and consequently we find that those for the posterior pair (4 *r*) are formed by the posterior margin of the expanded meta-sternum in front, and the consolidated margin of the inferior surface of the fifth or thoracico-abdominal segment behind, reflected inwards and upwards, and loosely articulated in the median line with the sternum, thus allowing of the freest motion to the coxæ, the sides of each being formed by the epimeron. But in insects which move with a sudden effort, as in jumping, and in those that employ the hinder legs as prehensile organs, like the *Copridæ, Ateuchi*, and others, these legs, like the anterior ones, are inserted into deep acetabula.

The *abdomen*, or third division of the body, is entirely destitute of organs of locomotion. It contains the chief part of the digestive, respiratory, circulatory, and generative systems, and, like the thorax, is composed of distinct segments. These are nine in number, if the fifth segment of the body, which almost disappears during the change to the perfect state, be included. This segment, however, we prefer to consider as a distinct part, so that the abdomen consists certainly of eight segments, besides the anal appendages. Each segment is formed of one dorsal and one ventral plate, connected at the sides by a distinct membrane. Only five of these plates are in general to be observed on the under surface, but some trace of the whole number is always seen on the upper, and also at the sides (*fig*. 388). This arises from the circumstance that a portion of the ventral surface of the first three segments of the larva is employed in forming the under surface of the anterior part of the abdomen of the perfect insect, the change in Coleoptera, as in other insects, being carried to a greater extent on the under than on the upper surface of the body. One segment, also, the anal one, becomes partly removed from the others at the posterior part, and is retractile within the abdomen, so that there are only five connected segments to the ventral surface, but nine on the upper. The form of the abdomen is in general somewhat triangular or oval in Coleoptera, its basial part being of the same width as the thorax. Each segment is freely moveable, the anterior part of one being retractile within the posterior of another. At the external margin of each dorsal plate, in the membrane that connects those of the upper with the under surface, there is an oval corneous ring, the *spiraculum*, or breathing orifice, which communicates internally with the organs of respiration. In most of the Coleoptera the abdomen is covered by the elytra, but in some species it is exposed, as in the oil-beetles, rove-beetles, and ear-wigs. In the latter instances it is furnished at its extremity with strong forceps, which appear to be analogous to parts which we are about to consider more particularly in other insects.

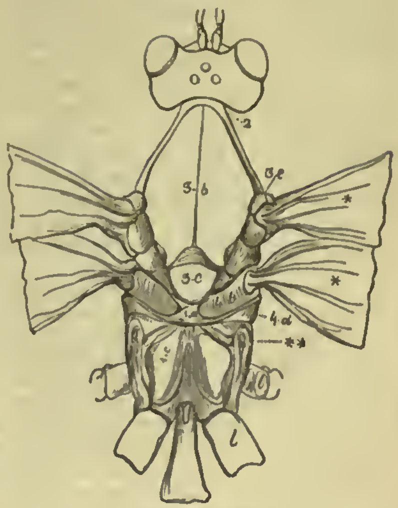
In Orthoptera the structure of the thorax is similar to that of the Coleoptera, but it is unnecessary to describe it more minutely at present, a greater interest being attached to the whole skeleton of those insects which undergo metamorphoses, more particularly the Hymenoptera and Lepidoptera, than to those in which these interesting changes do not take place.

The structure of the thorax in Hymenoptera merits considerable attention, from the circumstance that it is scarcely yet decided whether it be composed only of three distinct segments of the larva, or whether a fourth one enters in part into the composition of it. We have seen that in the larva state in this order there are fourteen distinct segments, besides an anal tubercle, and that during the transformations the body is constricted in the fifth segment, which seems to form the connexion between the thorax and abdomen. According to the usually received opinions, the true thorax is always composed of but three segments, but M. Audouin believes that this is not strictly the case in Hymenoptera, and has endeavoured to shew that in this order the posterior portion of the thoracic region is part of a segment that belongs to the abdomen. Mr. Macleay, on the contrary, contends* that this is not an additional segment, but is in reality part of the fourth or meta-thoracic segment of the larva. In this opinion he is supported by Burmeister and Westwood, while the views of Audouin are advocated by Latreille and Kirby and Spence.

The *pro-thorax*, which is a large segment in the larva state, is greatly reduced in size in the perfect insect, owing to the operation of causes which take place during the metamorphoses. But it is not so much reduced as in the Lepidoptera and Diptera. The boundaries of this segment in Hymenoptera, like those of the meta-thorax, are a subject of dispute among naturalists, owing to the segment in the perfect state being divided into two distinct parts, the first of which is articulated with the head, and freely moveable upon the other, which is attached firmly to the meso-thorax. The piece articulated with the head is believed by Kirby and Spence to represent the entire pro-thorax, or second segment of the larva. It bears the first pair of legs, and in the winged species is readily detached from the other, which is the *collare* of those authors, who, on account of its being attached to the great meso-thorax, believe it forms a part of that segment. This, as Mr. Macleay has shewn, is not the fact, as is proved by the circumstance that in the Ants and other walking Hymenoptera it is readily removed from the meso-thorax, and is united to the anterior piece, which bears the first pair of legs; while he suggests that the reason for its being attached to the meso-thorax in the flying species, is to give strength to that segment, and support the wings.† We have convinced ourselves of the correctness of this view of the subject by an examination of the parts in *Ichneumon atropos*, (*fig.* 389, 390,) in which the

* Zoological Journal, vol. i. p. 145, et seq.
† Op. cit. p. 168.

Fig. 389.



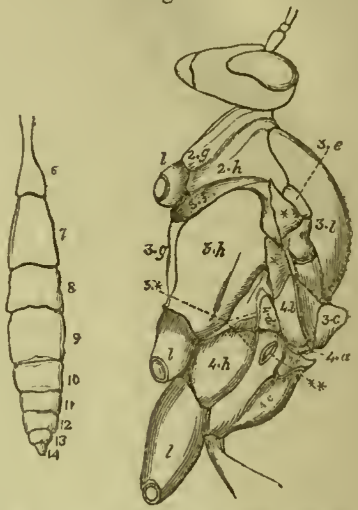
Ichneumon Atropos.

2, pronotum; 3 *b*, scutum of meso-thorax; 3 *c*, scutellum; 3 *e*, parspteron; *, wing; 4 *b*, scutum of meta-thorax; 4 *d*, frenum; 4 *c*, scutellum; **, spiracle; *l*, coxa.

two pieces are freely separable. The *præ-scutum* and *scutum* of the *pro-notum* are exceedingly short and evanescent, as described by Mr. Macleay in *Polistes*, the præ-scutum being merely a ligamentous membrane that unites this segment to the head. The scutum is a short plate that forms the upper surface of the anterior portion of the segment, the sides being formed, as we shall see, by the epimera and episterna (2 *g*). The posterior piece, the *scutellum*, is of considerable size laterally (2 *h*), but it is short on the upper surface (2), and is deeply notched to fit it to the anterior part of the meso-notum, its two sides being produced into a somewhat triangular shape, and wedged in between the scutum of the meso-thorax and the episternum on each side. The *post-scutellum* exists only as a rudimentary membrane, which assists to mark the proper boundary of the pro-thorax, this being, as Mr. Macleay has observed, one of the proofs that the scutellum now described does not belong to the meso-thorax, while the non-existence of a similar membrane, or *phragma*, between the two portions of the pro-thorax itself, affords an additional reason for considering these but as parts only of one segment.

The *meso-notum* is the most largely developed portion of the thorax in this order, as in Diptera and Lepidoptera. It is a convex elongated plate that covers nearly the whole of the dorsal surface of the thorax. The præ-scutum is a vertical piece, developed inwards to assist in the formation of the pro-phragma that divides the collar from the scutum. The *scutum* (3 *b*) is broad, convex, and lozenge-shaped. At its sides are developed the anterior pair of wings, and at its base, which is slightly truncated, is an elevated *scutellum*. It is marked on the median line by a longitudinal suture, and in some genera by two others, one on each side of this. In the *Chrysididæ*, these lateral markings completely divide the scutum into three distinct pieces, the two outermost of which are those to which Mr. Macleay has given the name of *parapsides*, and which he somewhat curiously suggests may probably be a third pair of paraptera,* those of the prothorax, pushed out of their proper place. But, as remarked by Audouin,† in his notes to Mr. Macleay's paper, were this the case, it would indeed be a most singular displacement; at the same time we are compelled to acknowledge that we hesitate to admit the explanation which M. Audouin has given of the nature of these pieces. He regards them as mere divisions of the scutum, and not as elementary parts. If this be the case, other parts that are considered as distinct pieces may with equal justice be regarded as only occasional divisions of more important ones. They seem rather to indicate the division of the skeleton into a much greater number of parts than are at present recognized in it. We are led to this opinion from the circumstance that these markings exist more or less distinct in very many species. We have found them very distinctly in the dried skeleton of *Bombus terrestris*. The *scutellum* (3 *c*) is of large dimensions in most of the Hymenoptera, and is usually considerably elevated above the level of the scutum. It is in general of a triangular figure, and in many species of this order, as well as in some Diptera, is a marked character of the thorax being often armed with spines. The post-scutellum is not developed externally, but its position is indicated by an elevated ridge, which is extended forwards on each side from the hinder part of the scutellum very nearly to the base of the anterior pair of wings, as in the Diptera and Lepidoptera, and indicates the boundary of the segment. It forms the *meso-phragma*, and as Mr. Macleay has remarked in *Polistes*, is connected with the scutum only at the sides, being deficient in the middle line. The pectoral surface of this segment, the *meso-sternum*, is larger in *Ichneumon Atropos* (*fig.* 390) than in many other species. In form it is nearly quadrate (3 *g*). It covers the whole under surface of the segment, and is divided by a deep fissure into two halves. At its anterior margin it is united by an indistinct suture to a thin plate, the *episternum*, (3 *f*,) that covers the front of this part of the segment, and is almost hidden behind the pro-thoracic legs, and it has sometimes been considered as forming part of that segment. Its lateral portion passes upwards posteriorly to the collar of the prothorax, and forms a process that projects beneath the anterior pair of wings, and above the *epimeron*, (3 *h*,) which is the chief portion of the side of this segment. At its inferior margin this piece is united by an indistinct suture to the sternum, at its anterior to the episternum, and at its posterior it is articulated with the coxa of one of the middle pair of legs.

Fig. 390.



Lateral view of thorax of Ichneumon Atropos.

2 *g*, episternum; 2 *h*, epimeron and scutellum of pro-thorax; meso-thorax; 3 *b*, scutum; 3 *c*, scutellum; 4 *d*, frenum; * *, stigma; 3 *h*, epimeron; 3 *g*, sternum; 3 *f*, episternum; 5, scutellum; 4 *b*, scutum of meta-thorax; 6 to 14, segments of the abdomen.

The next segment, the meta-thorax, is an exceedingly interesting portion of the body, owing to the varied extent to which it is developed in the different Orders of Insects; and on account more particularly of the question that has been started, as to whether this portion of the thorax in Hymenoptera is formed entirely by the fourth segment of the larva, or whether a portion of the fifth also enters into the composition of its posterior part, as believed by Audouin and Latreille. According to Mr. Macleay, the first piece of its dorsal surface or meta-notum, the *præ-scutum*, is very distinct in *Polistes*, while the scutum is concealed within the thorax, being developed inwards to form a phragma, only a part of it being visible laterally, but which, as usual, is connected with the posterior pair of wings, a circumstance that invariably characterises the scutum in all insects. In *Ichneumon Atropos*, the *præ-scutum* exists immediately behind the scutellum of the meta-thorax, and covers part of the *scutum*, (4 *b*,) which, although much encroached upon in the median line by the developement backwards of this part and the scutellum of the preceding segments, is a distinct region on each side of the meta-notum, and gives origin to the posterior pair of wings. This sufficiently identifies the part as the proper scutum, otherwise it might be mistaken for the præ-scutum of *Polistes*, which is considerably more developed than in *Ichneumon Atropos*. But the greater part of the scutum is developed inwards, and forms a deep cleft or incision, that divides the segment into two parts transversely, the poste-

* Op. cit. p. 169.

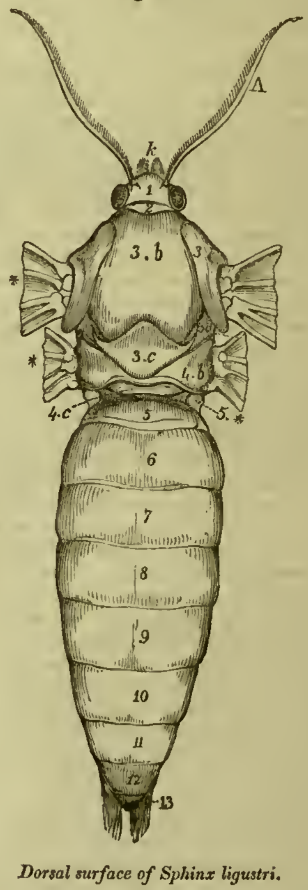
† Annales de Sciences Naturales. 1831.

rior portion of which, according to Mr. Macleay, is the proper scutellum (5) enormously enlarged, while Audouin regards it as being the dorsal surface of the fifth segment of the larva, so that, if the latter opinion be correct, the thorax of Hymenoptera must be composed of four instead of three segments. We must confess that at first we were inclined to Audouin's opinion, more especially on account of what we shall presently find in Lepidoptera, in which the fifth segment, in its atrophied condition, is as much connected with the thorax as with the abdomen. On further examination, however, we are satisfied that that portion of the meta-thorax which is posterior to the incisure belongs to the third segment of the thorax; but we differ from Macleay in regarding it rather as the scutellum and post-scutellum united, than as the scutellum alone. Its proper boundary is marked on each side of the segment by an elevated ridge or frænum, (4 *d*,) which is extended across the incisure from a little behind the insertion of the wings,—where it is continuous with a ridge of the meta-notum,—as far as the posterior margin of the acetabulum for the insertion of the coxa of the leg. The post-scutellum, therefore, may be regarded as having coalesced with the scutellum, and assisted in the enlargement of that part. It is distinct, but of small size in *Polistes*, and is connected at its upper part with a short ligament, or *funiculus*, that is attached to the anterior margin of the sixth segment (6), the first segment of the abdomen, which it assists to support. But we have yet to trace the fifth segment of the larva, which at first appears to be entirely lost. On carefully separating or removing the meta-thoracic coxæ of *Ichneumon Atropos*, we find a very short plate, reduced almost to a ligament, but still distinct as the remains of a separate segment. It is the connecting medium between the under surface of the thorax and abdomen. We regard it as the remains of the ventral plate of the fifth segment, of which the upper or dorsal plate has entirely disappeared, or exists perhaps in an altered form, as the funiculus just alluded to. We are strengthened in this opinion by an examination of several species of *Ichneumonidæ*, although in the generality of Hymenoptera the fifth segment appears to have coalesced with the sixth, to form the petiole or peduncle of the abdomen. The meta-sternum is formed of the same parts as in the preceding segments. The *paraptera* are situated immediately beneath the posterior wings, in the triangular space bounded in front by the epimeron of the preceding segment, and above and behind by the incisure and frænum, (4 *d*,) that connect the scutellum with the scutum. The episternum is concealed by the preceding segments, and the sternum is reduced to a small triangular piece, situated between the coxæ. The *epimeron* (4 *h*) is large, to give attachment to the large coxæ, but the *trochantin* does not exist as a piece distinct from the coxa (*l*), with which it appears to have become united. The meta-thoracic or second pair of *spiracles* (* *) are situated in the anterior lateral parts of the scutellum. The situation of the spiracles has sometimes been considered as indicatory of the different segments, but, as remarked by Mr. Macleay, these parts are unsafe guides, since they exist in certain segments in some species, but not in others, and their situation is often changed during the metamorphoses from the larva to the perfect state. We have seen that the meta-thoracic spiracles of the larva are placed at the most posterior part of the fourth segment, (*fig.* 356,) but in the perfect insect, as we now find, this is not the case. If the situation of these parts were alike in the two states of the insect, there would be no difficulty in identifying the segments of the imago with those of the larva. We believe, however, that the true thorax is formed of the second, third, and fourth segments in all insects, and that the fifth segment, always greatly reduced in size, and sometimes, as in this order, almost entirely atrophied, is not in reality a part of the true thorax, but is sometimes connected more or less with that region, or with the abdomen, being intermediate between the two. Hence we have ventured to designate it the *thoracico-abdominal* segment.

The number of segments in the *abdomen* of perfect Hymenoptera appears on a cursory examination to vary considerably; those in which the abdomen is supported on a pedicle or foot-stalk having fewer than others in which the abdomen is of the same width as the thorax, and the sting or borer of the female is not concealed, as in *Sirex juvencus*. This insect on a cursory inspection seems to have nine segments in the abdomen, besides a very large terminal joint, more than twice as large as any of the others, which is pointed at its extremity, and on the under surface of which is situated the anal aperture. In reality, however, there are but nine segments in this most developed form of abdomen, the tenth being only a large meta-thoracic post-scutellum, which is extended over the base of the abdomen, while the thirteenth and fourteenth segments of the larva, instead of becoming atrophied, as is usually the case in other insects, during the metamorphoses, have coalesced and become enormously enlarged in order to afford sufficient space for the muscles required for the employment of the strong *terebra* or borer with which the insect penetrates the solid timber of living trees to deposit her eggs. In the *Tenthredinidæ*, as in *Allantus scrophulariæ*, there are nine distinct segments besides the post-scutellum, and this is probably the case in *Atholia centifoliæ*, although we can discover but eight distinct ones in that species. We suspect that the last three segments in this insect become united to form the parts connected with the female organs. In the males there is the same number of segments as in the females. This is also the case in *Ichneumon Atropos* (*fig.* 390), in which there are nine distinct segments to the abdomen besides the minute plate at the base of the sixth, the remains of the thoracico-abdominal segment before noticed. In the wasp, hornet, and bee, only six segments are at first evident in the abdomen, which arises from the circumstance that the anal segments, which form part of the organs of generation, are retractile within the abdomen. The sixth segment is concealed, and the seventh and eighth segments, particularly the latter, which is greatly enlarged, form the chief portion of the abdomen. In the common honey-bee there appear at first to be but five segments; but one segment, the sixth, which forms the base of the abdomen, is almost concealed, and the others constitute the sting and retractile organs of generation. In the male or drone two segments are lost in the termination of the male organs of generation. Thus, then, the actual number of the segments is the same in all Hymenoptera, the apparent difference being occasioned by the retraction of one or more segments within those which precede them. To so great an extent is this carried in some species, as in the *Chrysididæ*, that the abdomen at first sight appears to be formed of only four segments, the margin of the posterior being armed with several spines. But even in this family the number of segments is exactly the same as in the Ichneumon above noticed, in which all the segments are apparent. The five last segments are retractile within the abdomen, and when extended form a long jointed tube, which is employed by the insect for the purposes of oviposition. Thus then the ovipositor of the Tubulifera, the sheath of the sting in the Aculeata, and that of the terebra or borer in the Terebrantia, are all derived from the terminal segments of the body. But we have already seen that in the hymenopterous larva there is an additional segment to the body, which from the existence of an *apparently* additional organ in the perfect insect, may reasonably be supposed to be especially connected with the developement of that part. On examination, however, it is discovered that it is not from the fourteenth or terminal segment that the ovipositor, or sting, is entirely derived, but from at least the *two* last segments, the sheath being developed from elongated portions of the thirteenth or penultimate segment, while the fourteenth forms only a short valve at its base, like the extremity of the abdomen in *Sirex*. From these circumstances it is evident that the defensive organs of the aculeate Hymenoptera are simply developments of certain parts only of the sides of the abdominal segments, while the tubulated joints of the ovipositor of the *Chrysididæ*, with which there are many analogies among the Lepidoptera, are the entire segments. It is evident also that although the fourteenth segment is certainly connected with the sting or borer, it does not become its chief part, the sheath of the organ being always formed by parts of the thirteenth and sometimes also of the twelfth segment, so that these organs are simply developements of parts which already exist in all insects. The analogues of the ovipositor are found in the *Panorpidæ* among the Neuroptera, and in the *Bombycidæ* among the Lepidoptera; while those of the other forms of the same part, the terebra and sting, exist in the exserted ovipositors of the female *Gryllidæ* in the Orthoptera, and in the prehensile ones of some of the *Arctiidæ* and other species, in almost every instance the parts being derived from similar segments.

In Lepidoptera the size of the three segments of the thorax is more unequal than in Hymenoptera. The prothorax is reduced to a very thin plate or ring, more especially on its upper surface or pronotum. On the prosternal surface the primary parts, although greatly reduced in size, are still distinguishable. The *prosternum* is a small square piece, which is articulated in front by suture with a part of the anterior of the basal joint of the first pair of legs, and which we are inclined to regard as the *trochantinus* (*fig.* 392, 2 *k*). Immediately above this is a short semicircular piece, which is perhaps the analogue of the epimeron, and which is united by suture to a large broad lunated piece, that forms the greater part of the lateral surface of the prothorax, and is continuous with the narrow ring on the upper surface (*figs.* 391, 392, 2). The meso-notum is enormously developed. The *præscutum* (*fig.* 391)

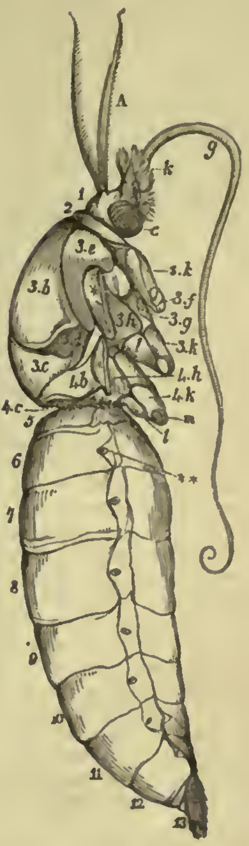
Fig. 391.



Dorsal surface of Sphinx ligustri.

is hidden within the segment and forms the *prophragma*, the anterior boundary of the segment. Laterally it is extended on each side beneath the scutum as far as the anterior boundary of the wings, where it is developed on each side into a little inflated eminence, which we regard as simply an extended portion of the præscutum unto which the *parapteron* is attached (3 *c*). The *scutum* (3 *b*) forms a broad convex plate, marked in the middle line by a raphé. It extends from immediately behind the narrow ring of the pronotum on each side to the insertion of the anterior pair of wings, and from thence backwards to a point opposite to the margin of the posterior pair, thus forming the greater portion of the proper thorax of the insect. It gives attachment on its internal surface to some of the most powerful muscles of the wings, and consequently requires to be more developed than any other part of the thorax. It is separated by a deep triangular suture from the *scutellum* of the mesothorax (3 *c*), which as in Hymenoptera is a large and important part. It forms the lozenge-shaped posterior part of the mesothorax, and if carefully examined its angles are seen to pass under the sides of the scutum, by the enlargement of which it has been carried backwards. The *post-scutellum* (3 *d*) has almost disappeared; a portion only of it is seen on each side at the base of the anterior pair of wings, bounded by an elevated margin, which extends outwards to join a frœnum that is connected with the posterior margin of the anterior pair of wings. Besides these parts, which form the mesonotum, there are also two broad moveable plates, the *paraptera* (3 *e*), that cover the base of the anterior pair of wings. They are called by Kirby and Spence *putagia*, or tippets, and are loosely attached by a part of their concave surface to the little eminences which we have before noticed at the sides of the præscutum. They are broad arched plates, which in form resemble scapulæ, and extend from the anterior part of the scutum, the sides of which they entirely cover as well as the insertion of the first pair of wings. They are always covered with long hairs, and are more developed in Lepidoptera than in any other order. In Coleoptera we saw them placed beneath the wings on the anterior part of the sides of the mesothorax. They were then unimportant organs; in Hymenoptera they were removed to a position above the wing, but in this order they have arrived at their maximum of development, and appear to be of great importance to the insect. The *meso-sternum* in Lepidoptera is a part of very difficult examination, and we are not confident that we have rightly made out the analogies of its different parts with those in other insects. The meso-sternum is greatly reduced in size, while the base of each leg is considerably enlarged. It appears to be formed by an union of the *trochantinus* (*fig.* 392, 3 *k*), and of the *coxa* (*l*), these parts in each limb appearing to be united, and distinguished laterally by a very marked suture. The base of the limbs thus occupies the greater part of the meso-sternal region. The part which we thus regard as the trochantinus is articulated in front with the sternum (3 *g*), and the coxa with the *epimeron* (3 *h*). The *sternum* extends upwards on each side of the segment

Fig. 392.



Lateral surface of Sphinx ligustri.

as far as the upper portion of the epimeron, a little below the insertion of the wings. It is marked transversely by a depression which has the appearance of a suture. At its anterior margin, on the front of the meso-sternum there is a very distinct plate which is united to it by suture, and which appears to be the proper episternal piece (3 *f*). The *spiracle* or *meso-thoracic* stigma is situated in a little fossa immediately beneath the *patagia* on each side before the anterior pair of wings, and communicates with the tracheæ between the pro- and meso-thoracic segments. The *metathorax*, which bears the posterior pair of wings, is considerably reduced in size by the developement backwards of the scutellum of the meso-thorax, which encroaches upon this segment posteriorly, as the scutum anteriorly does upon the prothorax, but not to so great an extent. The præscutum, as in the preceding segment, is concealed within the thorax, being developed inwards to assist with the post-scutellum of the preceding segment in forming the meso-phragma, while only a portion of the *scutum* is visible on each side of the scutellum of the meso-thorax (4 *b*), where it forms a triangular space, from the sides of which originate the second pair of wings (*). It is bounded posteriorly by a short thick ridge, the remains of the scutellum (4 *c*), the extremities of which pass outwards and are connected with the base of the wings. The *post-scutellum* (4 *d*) is also a very short fold, that forms the most posterior part of the true thorax. It is developed inwards and becomes continuous with the remains of the upper portion of the fifth or thoracico-abdominal segment (5). At each side it is connected with the lateral portions of the scutellum, and with it is connected to the base of the posterior wings, and also with a membrane or frænum (5*) that passes from the base of the posterior wings to the posterior margin of the thoracico-abdominal segment, thus clearly indicating the relation which this segment bears to the last segment of the thorax. The *metaphragma* or septum that exists between the thorax and abdomen is formed during the metamorphoses by a constriction in the middle of the fifth segment, and as the changes proceed, a portion of the fourth segment, the post-scutellum, is included in the fold or constriction, and assists to form the *metaphragma*, so that the fifth segment, at least in Lepidoptera, is common both to the thorax and abdomen, and cannot properly be said to belong more especially to one than to the other. Only a short portion of the fifth segment exists on the dorsal surface of the abdomen, posterior to the thorax, while the inferior portion, which was more reduced in extent during the changes than the upper, is reduced to a very short piece, which has entirely coalesced with the under surface of the sixth segment, the first true segment of the abdomen. In the meta-sternal surface there are the same parts developed as in the meso-sternal, the arrangement of all the parts being precisely similar to those of the meso-thorax. The *trochantinus* (4 *k*) is united with the *coxa* (*l*), from which it is distinguished, as in the limbs of the preceding segments, by a lateral suture. The first is articulated anteriorly with the *sternum* (4 *g*), and the second posteriorly with the *epimeron* (4 *h*). The second or meta-thoracic *spiracle* is situated in a deep cavity behind the wings.

The abdomen in Lepidoptera consists of nine distinct segments, or the remnants of that number of the larva if we include the segment which we have thus seen is connected with the thorax. We prefer, however, to consider the fifth as a distinct segment, although a portion of it covers the base of the abdomen. Each segment is formed, as in other insects, of two arches, a superior and an inferior one. The superior one is a strong corneous plate, and is equal to nearly a complete semicircle. The inferior plate is similar in its form, but does not include so large a portion of an arch, and is not so completely solidified. The lateral margins of the inferior arches are nearly straight, but those of the superior ones are emarginated or notched, each notch or incisure being near the middle of the edge. It is occupied by an oval corneous ring, the *stigma* or spiracle which exists in the soft membrane or *conjunctiva* that connects the margins of the superior and inferior arches of the segments. A similar membrane connects the different segments together longitudinally in such a manner that the anterior margin of one segment is drawn beneath the posterior of the one that immediately precedes it. By this arrangement of the parts of the segments the abdomen can be elongated or shortened at the will of the insect, and expanded or contracted during respiration, which takes place in the abdominal as well as in the thoracic region. There are nine *stigmata* or spiracles on each side of the body. Two of these we have seen are situated in the thorax, and the remaining ones in the abdomen, from the sixth to the twelfth segment; but the twelfth is apparently closed, and probably does not take part in the function of respiration, which is carried on chiefly through the thoracic spiracles. It is worthy of note also that there appears to be a change in the situation of one of the spiracles during the transformation of the larva and pupa state. In the larva a spiracle exists in the fifth segment, but this does not seem to be the case in the perfect insect, in which the spiracle is removed forward to the base of the wing in the fourth, a circumstance which is highly interesting from the fact that the wings are directly connected with the organs and function of respiration.

We will not enter further upon an examination of the thorax and abdomen in the different orders, sufficient illustrations having been given of the parts of which they are composed, and of the manner in which they are developed from the almost uniform body of the larva.

3. *Organs of locomotion.—The wings*, the organs of flight in Insects, differ from those of Birds in being supernumerary parts adapted especially for aerial motion, as the legs, the proper organs of progression, are for terrestrial. The wings of Birds are simply modifications of the anterior pair of extremities, which are employed in most other Vertebrata either as organs of prehension or of terrestrial or aquatic locomotion, and form parts of the normal type of the skeleton.* But the wings of Insects have no more analogy with the legs, the proper organs of locomotion, in the invertebrated than in the vertebrated classes. They are derived entirely from the respiratory structures, and have sometimes been aptly designated *aerial gills*. They are expanded portions of the common tegument of the sides of the meso- and meta-thorax, occasioned by the enlargement and extension of numerous tracheæ and the accompanying passages for the circulatory fluids, and their motions are intimately connected with the function of respiration. These tracheæ ramify throughout every part of the wing, and immediately after the assumption by the insect of the imago state become solidified like the rest of the skeleton. They are hollow for the reception of air like the proper respiratory organs within the body,

* See the Article AVES.

They afford strength and lightness to the wings, with which they are in direct communication like the bones in the wings of birds, although the organs themselves in these different classes are not analogous. Dr. Leach formerly designated these solidified tracheæ in the wings of insects *Pterigostia*, or wing bones, a name that seems appropriate, both on account of its convenience and as being indicatory of their principal function, although it has sometimes been objected to as incorrect on account of their forming part of the respiratory system. But it may be remarked that the true bones in the wings of birds also communicate with the respiratory organs, and perform functions similar to these in insects, while the interesting fact noticed by Odier, that in their solidified condition they are composed of the same kind of earthy matter as that which enters into the composition of other parts of the skeleton, is sufficient to warrant us in retaining the designation. There appears to be no part of the body in vertebrata analogous to the wings of insects, except, perhaps, in the single instance of one of the Saurian reptiles, *Draco volans*, in which a pair of supernumerary organs to assist in locomotion are developed from the sides of the body, and which are formed by the ribs, directed horizontally outwards and covered only by the skin. We have thus in appearance the remains in one class of the vertebrata of a condition which is permanent in another class in the invertebrata, which resemble them in their general form and metamorphoses. In every instance, then, the wings of an insect, like these appendages of the thorax in the reptile, are perfectly distinct in their origin from the proper organs of locomotion; they have their normal condition in the lower invertebrata in the superior branchial tufts of the Annelides, and, consequently, are not more analogous to the wing of the Bat, as they have recently been supposed,* than to that of the Bird. We have already seen that the full developement of the wings takes place at the last change of the insect, but it is commenced in the earlier periods of the larva state, in which, with Oken and Carus, we have detected these organs in their most rudimentary condition. They are distinctly seen on the second or third day after the insect has assumed its last larva covering, before changing to the pupa. They are then scarcely so large as the head of a moderate sized pin, and appear like newly-formed folded portions of delicate tegument, extensively supplied with ramifications of minute air-vessels, derived directly from the principal tracheæ. They are at that time situated immediately beneath the external covering, at the inferior part of the sides of the meso- and meta-thoracic segments, and continue to increase in size during the growth of the larva. When the insect has discontinued to feed, about a day before changing into the pupa state, and the new skin of the future pupa is nearly completed beneath that of the larva, these rudiments of the wings have become so much enlarged that their existence is distinctly indicated by the swollen appearance of the segments. It is at this period of the larva state that they were formerly discovered by Swammerdam.* At the moment of fissuring the skin of the larva, they are suddenly somewhat enlarged, and when the skin has been cast off, and the delicate parts of the newly exposed naked pupa are beginning to be agglutinated together and folded upon each other previously to becoming solidified to form the strong pupa case, they again acquire a considerable increase of size, owing to the extension and enlargement of the tracheal vessels within them, together with a corresponding increase in the quantity of the fluids in the circulatory canals, by which they are every where accompanied. The wings are then expanded so as to cover the whole under-surface of the thorax and limbs, and when the insect subsequently bursts from the pupa case and is assuming the perfect state, they are again suddenly enlarged, and acquire their full expansion through the recurrence of similar phenomena.

It is thus evident that the wings are formed from extensive ramifications of vessels inclosed between two membranes, which are continuous with, and are expanded portions of, the common tegument. In many instances, as in Neuroptera, they are perfectly naked, or are covered only with a few scattered hairs, as in Hymenoptera. But in others they are densely covered with peculiar cuticular developments in the form of flattened scales, closely imbricated upon each other, and inserted each by a little footstalk or quill into little spaces in the external membrane.† In other instances, as in the Coleoptera, the anterior pair become solidified and adapted to a new function, but are then entirely useless as organs of flight. They serve as covers to protect the posterior pair, which, in a state of rest, are carefully folded beneath them; and when these are entirely absent, as in some of the *Tenebrionidæ*, the anterior pair become united together and form a strong covering for the abdomen. Now we have seen that the solidification of the tracheæ alone affords sufficient strength to the membranous wings, which are always employed as organs of flight, and that the earthy matter by which they are consolidated is similar to that which is the means of consolidating other parts of the dermo-skeleton. It is by the deposition of a greater quantity of the same kind of earthy matter, not alone in the tracheæ, but throughout the whole substance of the wings, that the anterior pair in Coleoptera are rendered entirely useless, by their rigidity, as organs of flight, and at the same time are made to assume a new form and office, and become the means of protecting the posterior pair, in those insects whose habits might otherwise expose these necessarily light and delicate organs to occasional injury. This modification of structure, then, in the form of *elytra*, consists simply in the solidification, or, if we may venture so to

* Mod. Clas. Ins. vol. i. p. 11.

* Biblia Natura, Tab. xxxv. fig. II. e.

† Dr. Roget's Bridgewater Treatise, vol. i. p. 354.

call it, ossification of the entire organs, and not in any difference in their normal condition. In every instance the anterior pair of wings, or elytra, like the posterior pair, are formed of numerous tracheæ, accompanied by circulatory canals extensively ramifying throughout their whole structure, as may be well seen in the imperfectly solidified wings of Orthoptera and Hemiptera, and in the perfectly formed ones of many of the Coleoptera, although it has sometimes been supposed that the elytra are entirely destitute of these structures.* Excepting in a few instances, as in the Strepsiptera,† the elytra are almost entirely motionless during flight, and are either simply elevated or directed horizontally in order that they may not impede the motions of the true wings. Thus the number and condition of the parts employed in flight are seen to vary in different insects. In Coleoptera the posterior wings alone are actively employed, in Neuroptera and Hymenoptera both the anterior and posterior, but in Hymenoptera the latter are smaller and less important than the former, while in Diptera the posterior are reduced to mere appendages of the atrophied meta-thorax, and the office of flight devolves entirely upon the anterior pair, which are the only ones developed for such purpose. On the other hand, in some species, instead of a reduction in the number of these parts, there is an evident tendency to repetition, as is beautifully shown in the existence of two circular membranous appendages or winglets *(alulæ)* developed at the inner angles of the elytra, and continuous with the delicate membrane that lines the under surface in the great *Hydröus* and the *Dyticidæ*. Similar appendages are observed in the posterior wings of some Lepidoptera and Hymenoptera, and in the proper wings of some Diptera. The non-developement of the posterior wings in Diptera evidently seems to be the natural result of the excessive developement of the meso-thoracic segment, which bears the proper wings, the analogues of the anterior pair in Hymenoptera, and the consequent atrophied condition of the adjoining meta-thoracic segment, from which a posterior pair ought to have been developed. But that all insects, even the Diptera, have primarily the same number of these organs, is exemplified in this order in the existence of a pair of appendages to the meta-thorax, in the form of little club-shaped bodies denominated *haltères* or poisers, and which exist modified in form in every Dipterous insect. In the common gnat they are simple footstalks surmounted by a round knob, attached one on each side of the atrophied meta-thorax. This is their form in the house-fly and many other genera. That these are the proper representatives of the posterior pair of wings is now the opinion of the most recent observers, and is most decidedly confirmed by the results of our own examinations. They are generally more or less concealed beneath the winglets, from which they are perfectly distinct, being always connected with the meta-thorax, while the winglets are attached to the scutellum of the meso-thorax, and in some instances, as in *Tabanus bovinus*, are continuous with the margin of the meso-thoracic wings.

* Westwood, Text Book, p. 283.
† Dale in Curtis's British Entomology, fol. 226.

The articulations of the wings are formed upon the same principles as those of the legs, but are more simple in their construction. Those at the proximal extremity of the cubital nervures, or *pterigostia*, are of a somewhat cotyloid form to allow of free motion in several directions, and often, as in those at the base of the elytra, are furnished with a long spine or process, to which some of the powerful muscles are attached. Those by which the wings are folded beneath the elytra are imperfectly formed ginglymoid joints in the nervures, and seldom allow of motion in more than one direction. In most Coleoptera, as in *Scarabæidæ, Hydrophilidæ*, &c. there is only one of these joints in each wing, but in the *Brachelytra*, in which the wings are closely packed beneath very short covers, there are often so many as four in each wing,* while in other species, as in the *Buprestidæ*, in which the wings are not folded but are only of the length of the abdomen, these joints are entirely absent. In every instance the membranous portions of the wings are either plaited longitudinally or folded transversely when the wings are concealed beneath the elytra.

In the *neuration*, or distribution of the tracheæ in the wings, *pterigostia*, which by the French entomologists are called *nervures*, on a casual inspection there appear to be many remarkable variations. But when the wings are attentively examined, it is found that there is always a great uniformity in the distribution of the principal nervures, and this is so precise and regular in many orders that it has been employed by some naturalists as strongly characterizing different groups. The irregularity which at first is supposed to exist in the distribution of these nervures in some families arises entirely from the greater or less relative enlargement of the principal trunks or their branches. The characters derived from these parts were formerly employed by Frisch in Germany and Harris† in this country, but have of late years been more particularly applied to the classification of Hymenoptera by Jurine,‡ St. Fargeau, and Mr. Shuckard, the first two of whom have founded their arrangements of Hymenoptera upon characters derived almost entirely from these structures, each of which they have designated by a distinct name. Mr. Shuckard, who has studied this subject with much care, gives the following description of the anterior wing in Hymenoptera.§ " The contour of the wing is formed by its anterior, apical, and posterior margins.

* Straus, Considerat., &c. p. 127.
† Exposition of English Insects, 4to. London, 1782.
‡ Nouvelle Méthode de Classes les Hymenoptères et les Dipteres, par L. Jurine, tom. i. 4to. Geneve, 1807.
§ Transactions of the Entomological Society of London, vol. i. p. 209.

The *anterior margin* is that portion which is situated anteriorly upon its expansion in flight, extending from its base to its distinctly visible extremity of the costal nervure, a little beyond the marginal cell; at its termination the *apical margin* commences, and extends to the *sinus* of the wing, which is the incision at the apex of the *posterior margin*, which latter extends from this sinus back to the base, and it is by this margin that the upper and under wings are connected in flight. The *costal* nervure is the first longitudinal nervure of the wing (*fig.* 393, *a*), and, as we have seen, extends

Fig. 393.

Wing of Hymenopterous insect (Shuckard).

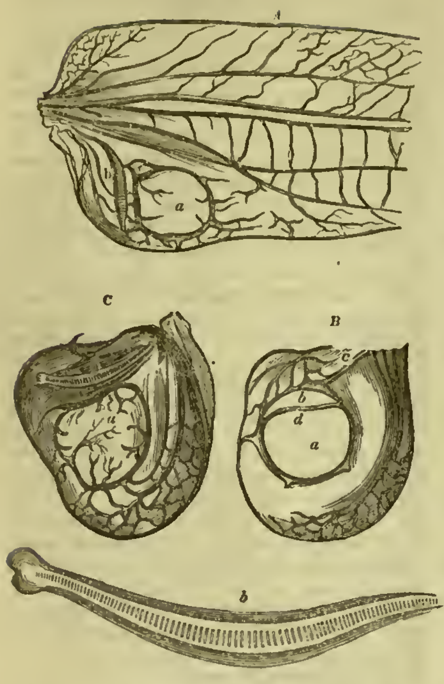
a, costal nervure; *d*, post-costal; S, stigma; *e*, externo medial; *f*, anal; *g*, transverso-medial; 1, costal cell; 2, medial; 3, interno-medial; 4, anal; *h*, radial nervure; 5, marginal cell; 6, cubital nervure.

upon the anterior margin to just beyond the extremity of the marginal cell. The second longitudinal nervure is the *post-costal* (*d*); this extends to the *stigma* (*s*), which is that thickened point or spot upon the wing placed upon its anterior margin at about two-thirds the distance of its base and extreme apex, and appears to me to be a dilatation of the costal nervure. The third longitudinal nervure is the *externo-medial* (*e*), which proceeds in a direct line nearly parallel with the preceding for a little more than half the length of the post-costal, or about one-third of the entire length of the wing, and then leads off at an obtuse angle to join the post-costal just before its junction with the stigma. The *anal (f)* is the fourth longitudinal nervure, which also extends from the base to the sinus at the apical extremity of its posterior margin: a transverse nervure unites the externo-medial and anal, and which I purpose calling the *transverso-medial* (*g*). These nervures, which I consider the primary nervures of the wing, severally inclose what have hitherto been called collectively the basal or humeral cells, but to which I purpose applying different names (derived from the nervures which inclose them), that they may be more readily distinguished from each other. The first, or that very narrow one between the costal and post-costal nervures, is the *costal* cell (1); the second is that placed between the post-costal and externo-medial nervures, and which I call the *externo-medial* cell (2): that inclosed between the externo-medial and anal nervures parallelly, and terminated at its apex by the transverso-medial, is the *interno-medial* cell (3); and the cell seated between the anal nervure and the posterior margin of the wing is the anal cell (4).

"From the interior margin of the stigma arises the *radial nervure* (*h*), which makes a curve and then joins the costal upon the margin of the wing: the lanceolate space thus inclosed forms what is called the radial or *marginal* cell (5). The *cubital nervure* (6) is nearly parallel with the radial and originates from the externo-medial near its junction with the post-costal; this extends to the apical margin of the wing just below its extreme apex (6 *i*). The space thus inclosed is divided by three transverse nervures, which I propose calling the *transverso-cubitals* (*m*, *m*, *m*, *m*), inclosing as many spaces forming so many cubital or sub-marginal cells, a fourth being formed in consequence of the nervure extending to and joining the apical margin (*g*). The third nervure, originating from the primary nervures of the wing, is what I call the *discoidal* nervure (*k*), (it is from this that I anticipate the chief results), and which, commencing at the transverso-medial, extends in a direct line to the disc of the wing directly between the stigma and the sinus, when it makes a sudden curve at a right angle backwards and joins the anal nervure close to the sinus (*k*). From this discoidal nervure at the centre of its apical return another springs, forming what I call the *sub-discoidal nervure* (*l*), and which here extends to the posterior margin of the wing. From the cubital nervure two others originate; these are called the *recurrent* nervures, the first of which always inosculates at the angle of the discoidal nervure, and the second just beyond the centre of the sub-discoidal. By the reticulation of these four nervures several cells are formed upon the disc of the wing; the first of these, which is inclosed between the discoidal and anal nervures, I call the *first discoidal* cell (10). The *second* is that placed between the externo-medial cubital, first recurrent, and discoidal nervures (11). The *third discoidal* cell is that inclosed by the second recurrent, sub-discoidal, discoidal, and first recurrent nervures (12). The space inclosed between the second recurrent, sub-discoidal, and cubital nervures, and the pical margin of the wing, forms the *first opical* cell (13), and there is a second only when the sub-discoidal nervure extends to the apical margin, by which and a portion of the discoidal cell it is inclosed."

The distribution of the nervures in the wings of the males of some of the Orthoptera affords some curious peculiarities, by which the pterigostia become instrumental in the production of sounds. At the base of the superior pair of wings in *Acrida*, at the inner angle of each wing, is an oval or nearly circular space (*fig.* 394, *a*), in which the membrane is more transparent and free from ramifications of nervures than in any other part of the wing. These spaces have long been known to be connected with the production of sound. The membrane itself appears to be thinner than in other places, and more tense, and the nervures by which it is inclosed are thick and strong.

Fig 394.



A, inferior surface of left wing of *Acrida viridissima*.

B, upper surface of the right, and, C, under surface of left wing of *Acrida brachelytra*, shewing the tympanum *a*, and bow *c*, across which the file *b* acts.

b, the file magnified.

Until recently it has been supposed that these were the only parts in the male Acrida concerned in the production of sound, the mechanism of which has been explained by Burmeister* as consisting in a quick attrition of the wings against each other during a forcible expiration of air from the thoracic tracheæ and spiracles, which are situated beneath, and are covered by the edges of the wings; that the air in rushing out of these spiracles is driven against the tympani, which are thus occasioned to vibrate and produce the sound. But this ingenious explanation is not entirely correct; the means employed do not appear sufficient to explain the phenomenon, besides which a part of the structure that is chiefly instrumental in producing the sound has been overlooked. In addition to the tympanum, and parts by which it is inclosed, there is also another part which has not until recently been described. It is a strong, transversely elongated horny ridge, situated immediately behind the tympanum, near the base of the wing, and is most distinct on the upper surface of the wing of the left side. This part was first shown to us by the late Mr. William Lord, in the wing of *Acrida viridissima*, in February 1838, but it had previously been described by M. Goureau, in an elaborate paper on the Stridulation of Insects.* When examined minutely, this ridge, which is of the colour and appearance of tortoise-shell, is found to be striated transversely, so as to resemble a rasp or file. Goureau has called it the *bow;* a similar ridge or file exists on the under surface of the right wing, but less strongly notched, and is called by Goureau the *false bow*. When the wings are rubbed briskly together, these rasps or bows produce a loud grating against some projecting or elevated nervures on the borders of the wings, by means of which the drum is made to vibrate like any other tensely stretched membrane when agitated, the intensity of the sounds produced depending entirely upon the rapidity and force employed by the insect during the attrition of the parts concerned, and being entirely independent of any forcible expiration of air from the thoracic spiracles, which is thus seen to be unnecessary for the production of the sound. That this is really the case is proved by the fact that in *Acrida brachelytra* (B, C), the wings are so exceedingly short and narrow that they do not cover, nor are they even near any part of the spiracles, so that the air in passing out of these orifices cannot possibly be driven against the tympanum. On the other hand the tympanum in this species (*fig*. 394, B, C) is considerably larger than in others of the same genus, and not only has its margins more elevated, but has also a strong bar extended across near its base (*c*), is itself more tense and vibratory, and has a short, strong bar (*d*), connected with the ring by which it is inclosed, and also, at a right angle, with the origin of the great marginal nervure of the wing. It is remarkable that both in *Acrida viridissima* and *Acrida brachelytra*, the tympanum in one wing differs from that of the other in being less regular in its form, much more opaque, and traversed by several tracheæ, a circumstance which leads us still further to infer that the sounds produced result from the vibrations of one only of these organs, besides which the proper tympani are not in corresponding wings in these two insects. In the former, in which the base of the left wing is covered by that of the right, the proper tympanum is in the left wing, while in the latter insect, in which the right wing is covered by the left, the tympanum is in the left wing, which is remarkable in being entirely deficient of the file or bow, but which is largely developed on the under surface of the left wing. The analogue of the file in the right wing is evidently a strong portion of the rim of the tympanum nearest to the base of the wing. It is remarkable also that in this species the whole surface of the right wing, in which the tympanum is situated, is more transparent and free from nervures than the corresponding part of the left wing, so that the whole surface of the wing may perhaps be rendered sonorous. It is remarkable also that

* Manual (translat.), p. 470.

* Annales de la Société Entomologique de France, 1837, p. 31. Entomological Magazine, January, 1838, p. 89 et seq.

in newly developed specimens, particularly in *Acrida viridissima*, the teeth or markings on the file are more distinct than in those which have been a longer time in the perfect state, in which the teeth appear as if partially obliterated by use. The sounds, as remarked by M. Goureau, may be readily produced in the dead insect by gently rubbing the bases of the wings together, a further proof that the rushing of air from the spiracles is totally unconnected with their production. A similar structure exists in the wings of *Acrida grisea* and others of the same genus. In the *Achetidæ* the parts for stridulation are somewhat differently constructed. The wing of the common house-cricket, *Acheta domestica*, differs materially in the two sexes. In the male (*fig.* 395) the two

Fig. 395.

Wing of the male House-Cricket, Acheta domestica, shewing the file, b, and tympanum, a.

wings exactly resemble each other, and the nervures are more irregularly disposed than in the female, in which they are arranged either longitudinally or diagonally with but very few that run in a transverse direction. When the wing of the male is attentively examined, nearly one-half of its surface is found to be adapted to perform the office of a tympanum. This part is more transparent and elastic than the other, and is crossed by many nervures in a manner somewhat similar to the tympanum in *Acrida brachelytra*. Besides these there is on the under surface of each wing a large nervure, which is curved and placed somewhat transversely near the base of the wing, as in *Acrida*. It is the file or bow, and is covered by a vast number of minute, but freely elevated, semicircular teeth, which gradually decrease in size as they approach the external angle of the wing (*fig.* 396). The smallness of the teeth, and the extent of surface over which they are passed when the two wings are rubbed briskly across each other, is probably the cause of the very acute sounds produced by this insect. In *Gryllotalpa*, which is said to produce a hoarse croaking sound, the two wings exactly resem-

Fig. 396.

The round file of Acheta domestica.

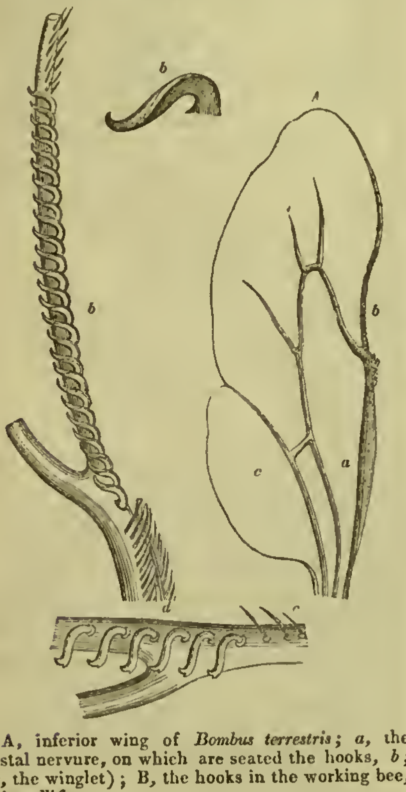
ble each other, as in *Acheta*. The nervures are thick and strong, and there is no distinct vibratory membrane, but on the under surface of each wing are a vast number of minute sharp-pointed teeth arranged closely together along the middle of the nervures, not only upon that one which is analogous to the file in *Acrida* and *Acheta*, but also upon three others which run in a parallel direction with it, as well as on their transverse or connecting branches, so that the whole of the nervures at the base of each wing are covered with files, which, when the two wings are rubbed across each other, produce, owing to the shortness of the nervures, a low grating sound. We do not at first perceive the necessity for a stridulatory apparatus on the under-surfaces of both wings, if the sounds produced result simply from the attrition of the wings against each other, and the wings have always the same relative position. But on close examination it is found that, although in the *Gryllidæ* the right wing either constantly overlaps the left or the left the right, in the *Achetidæ* this is not the case, but that sometimes one wing and sometimes the other in the same insect is the superior. With regard to the acuteness of the sounds produced by the house-cricket, it probably depends much upon the length of the vibrating nervures on the large tympanum, as well as the smallness of the teeth in the file, as the hoarse sounds do, perhaps, upon the shortness of the nervures in *Gryllotalpa*. In *Locustidæ* the stridulation is not connected with the structure of the wings.

Besides these various parts for the production of sounds, the wings of some insects are furnished with others equally remarkable, but designed for a different purpose. These consist of certain little hooks and foldings on the margins of the wings, by means of which in some families the two pairs are united during flight, in order that the motions of these organs may be in perfect unison with each other. In some genera, as in the Lepidoptera, the males alone are provided with these hooklets, as was formerly noticed by Mr. Haworth* in *Apatura Iris*, in which the wings of the male are connected at their base by means of a strong elastic spring, which arises from the base of the costal

* Lepidoptera Britannica, 8vo. Londini, 1803.

nervure of the inferior wing, and is received into a socket near the base of the main nervure on the under side of the upper wing. This apparatus for connecting the wings appears to give additional strength to the insect, since it exists only in those species which fly most rapidly, and continue for a great length of time on the wing. But in those insects in which the body is very large in proportion to the size of these organs, and which are necessitated by their habits to be constantly abroad, and to fly to a great distance, as is the case with the Hymenoptera, the means of uniting the wings is more perfect. It consists not of a single hooklet, as in Lepidoptera, but of a series of very minute hooks of a somewhat spiral form (*fig.* 397), and arranged along a curved portion

Fig. 397.



A, inferior wing of *Bombus terrestris*; *a*, the costal nervure, on which are seated the hooks, *b*; (*c*, the winglet); B, the hooks in the working bee, *apis mellifica*.

of the costal nervure, at the anterior superior margin of the second pair of wings. These hooks are described by Mr. Kirby,* and are found in nearly all the Hymenoptera. They are arranged in a slightly twisted or spiral direction along the margin of the wing, so as to resemble a screw, and when the wings are expanded attach themselves to a little fold on the posterior margin of the anterior wing, along which they play very freely when the wings are in motion, slipping to and fro like the rings on the rod of a window curtain. The form of the hooks is very similar throughout the whole order, each hook being twisted at its extremity a little to one side and recurved. They are always situated at the same part of the wing, but vary in number in different genera, and even in the sexes. In *Uroceridæ*, *Sirex juvencus*, they are few and scattered along the margin of the wing, and this is also the case in *Trichiosoma*, but we have found them far more numerous in *Ichneumon Atropos*. In the sterile female or worker of the common wasp, *Vespa vulgaris*, we have found them very strong, and about twenty in number, besides five stiff spines which are not bent in the form of hooks. In most instances, particularly in the *Bombi*, the hooks are less numerous in the males than in the females. Thus, in the male of *Bombus terrestris* there are but eighteen in each wing in the male, but twenty-five in the fertile female. In the male of *Bombus lapidarius* there are only eighteen in each wing, and there is the same number in the worker or sterile female, but there are twenty-three in each wing of the fertile female. In *Anthophora retusa* there are only twenty in the male, but twenty-two in the female. In *Osmia* there are twelve in the male and fifteen in the female. But the reverse is the case in *Anthidium manicatum*, in which there are thirty in the male, but only twenty-five in the female. In *Megachile* there are sixteen in the female, but in the cuckoo-bee, *Melecta punctata*, there are thirteen hooks and four imperfectly developed spines. In the male of *Eucera longicornis* there are only thirteen hooks, but in the female twenty-three, while in the female *Cœlioxys conica* there are only twelve. In the queen or fertile female of the common hive-bee there are only seventeen slender hooks, arranged at some distance apart, and different in their appearance from those of the common humble-bee. In the sterile female or worker there are nineteen, but in the heavy male, or drone, there are twenty-one. In the male, as in the fertile female, of the hive-bee, the hooks are placed further apart, and are more slender than in the workers, besides which they are differently shaped in the neuter, in which each hook has also a little tooth near its apex. On reviewing this difference in the number of hooks in the two sexes, we are certainly confirmed in the opinion that it has some relation to the comparative powers of flight of the respective insects, and is not a sexual distinction. The great object of the hooks evidently is to keep the wings steady during flight, in order that they may act in unison, and thereby enable the insect to continue much longer on the wing with less muscular exertion, because, when the two wings are made to act but as one, the effort of flying becomes more concentrated, and the wings strike the air with greater effect than if they were separated or but imperfectly connected. It is well known that the males of the humble-bees, *Bombi*, are much feebler on the wing than the fertile females, and it is the same with the individuals of the genus *Osmia*,

* Monographia Apum Angliæ, vol. i. tab. 13, fig. 19. Ipswich, 1802.

and perhaps also with those of *Anthophora*, in which, although the flight of the males is as rapid as that of the females, we suspect that it is not so long continued. But in *Anthidium manicatum* the number of hooks is in correspondence with the apparently greater power of wing in the male, which pursues his partner unceasingly, and darts down upon her with great rapidity at the season of connubiality. A similar remark is applicable to the male of the hive-bee, which at the period of swarming is exceedingly active, and constantly on the wing in the open air, in search of the queen or solitary female, who leaves the hive but for a few hours on the first or second day after swarming. Now we have seen that the number of hooks in these males is greater than in the females, and that their powers of flight are also greater, and that in the *Bombi* the reverse is the case with regard to both these circumstances. Consequently it is but fair to infer that the number and strength of the hooks are in direct relation to the powers of the insect.

We have before remarked that the different forms and appendages of the body are invariably the result, not of the introduction of new elements into the composition of parts, but of the greater or less extent to which those primary parts are developed. There is a beautiful illustration of this principle in the development of the *hamuli*, which are only spinous processes often observed on the wings of other insects. In proof of this we need but examine the wing of the common working-bee, in which there are several of these spines arranged in a line with the hamuli, and inserted in a similar manner into the nervure of the wing upon which the hooks are situated. In some instances the transition of form from that of spines to hooks is distinctly marked. Those which are most distant from the proper hooks retain the perfect form of spines, while those which are nearest are bent in the same direction, but to a less extent than the proper hook, but sufficiently so to mark very distinctly their proper analogy.

In Hemiptera, instead of being connected by hooks as in Hymenoptera, the whole margin of a portion of the anterior wing is hooked over a corresponding recurved part of the posterior, as formerly noticed by Chabrier* in the *Pentatomidæ*. In the Homoptera the wings are connected in the same manner as in Hemiptera, as noticed by Mr. Ashton† in *Membracis cornuta*. This is also the case in other Homoptera. Thus in *Tettigonia bifasciata* there is a triangular membranous process extending from the anterior margin of the inferior wing, and which on its distal border is furnished with four very distinct but exceedingly minute hooks, resembling those of Hymenoptera. This process of the posterior wing is curved a little upwards and received into a fold of the posterior margin of the anterior wing. There is a similar structure in the wing of *Cercopis sanguinolenta*, with this difference, that the hooks are very indistinct, while the triangular process of the wing is more pointed and hooked upwards. In *Tettigonia spumaria* the structure is exactly the same. In *Iassus viridis* the triangular process is shorter, but more extended along the costal margin of the wing, and is furnished with a great many very minute imperfectly developed hooks, which attach themselves to the folded linear margin of the anterior wing.

The legs, the proper organs of locomotion, are constantly six in number in every order of insects, but are subject to much variety of form. Each leg is composed of five distinct parts. First, (*fig.* 332 and 398,) the *coxa* (*a*) or basial

Fig. 398.

Legs of insects, from Burmeister, Curtis, and Hope.

joint, which is inserted into the acetabulum, and connects the limb with the thorax. Of this part the *trochantin* is believed to be an appendage. Secondly, the *trochanter*, a minute joint attached to the extremity of the coxa. It is not lettered in our figure of the leg (*fig.* 332, 3, 4), but is placed between the coxa and the third portion of the limb, the *femur* (*b*), with which it is freely articulated. The femur is the proper thigh of the insect, and in general is of considerable size. It is connected by ginglymoid articulation to the fourth portion of the limb, the *tibia* (*c*), which is usually a long slender joint, at the extremity of which is articulated the fifth and last portion, the *tarsus* (*d*). This part is always composed of several distinct joints, varying in number in different insects from two to six. The more common number is five. These are the pri-

* Sur le Vol des Insectes.

† Proceedings of the Entomological Society of London in Transactions, vol. ii. p. 20.

mary divisions of the leg, connected together by distinct articulations, and in the most developed condition of the limb are almost invariably found in every insect. The articulation of the coxa with the acetabulum is either *ginglymoid*, as in the Lamellicornes and many others, or *cotyloid*, as in most of the Rhinchophora; that between the coxa and trochanter, and between the trochanter and femur, is chiefly of the former kind, which also invariably exists between the femur and tibia, while the articulations of the different joints of the tarsus with one another, and also with the tibia, are almost invariably cotyloid, as in *Lucanus*, except in the four posterior legs of the Hydradephaga and other water insects, in which they are usually ginglymoid, because the tarsi of these insects being used chiefly for one purpose, that of swimming, this form of joint appears to be necessary to give greater strength to the tarsus, which is employed to strike the water almost wholly in one direction.

Although the number of joints in the tarsus varies in different insects, it is very constant in some families, which are also connected by other circumstances. Thus in a large group of the Coleoptera the tarsi are invariably composed of five joints, besides a terminal claw, and upon this character they have been formed into one group, the *Pentamera;* while in another, the *Heteromera*, there are constantly five joints in each tarsus of the pro and mesothoracic legs, but only four in each of the two metathoracic. This tendency to the production of the full number of joints is remarkably shewn in many instances. Thus in a large number of families, *Pseudo-tetramera*, in which on a cursory examination there appear to be only four joints in each tarsus, it is found on a closer inspection that a fifth joint actually does exist, in the form of a very minute articulation (*fig.* 398, A, 4), at the base of the terminal joint in each tarsus. So again in another group, *Pseudo-trimera*, in which there appear at first to be only three joints in each, it is found that there are actually four (B, 3), the additional joint being, as in the preceding instances, developed at the base of the terminal one, but more distinctly than in the *Pseudo-tetramera*. This tendency to a reproduction of parts is also shewn in the *claws* at the extremity of the tarsi. In many Coleoptera, as in the *Melolonthidæ* (C), each claw is double; while in others, as in *Lucanus*, in which the proper claw is simple, and articulated to the terminal joint of the tarsus, there is also an *unguicula* or little claw, supported upon a distinct joint, which is articulated separately from the proper claw, with the last joint of the tarsus, in the middle line below the larger one.

The variations that occur in the form of the parts of the leg, as in other parts of the body, are directly referable to the habits or necessities of the insect. Thus where the legs are employed chiefly in *running*, as in the *Cicindelidæ*, *Carabidæ*, *Scaritidæ*, and *Harpalidæ*, they are usually long and slender, particularly the tarsi and tibiæ; the coxæ are very freely articulated with the body, and the trochanters, particularly those of the hinder pair of legs, are remarkably large. But when, as in the *Gyrinidæ*, *Dyticidæ*, and *Hydrophilidæ*, they are employed entirely in *swimming*, they are long, as in running insects, and the tarsi of the second and third pairs are flattened and broad like oars, and their margins, apparently to increase the breadth of their oar-like form in the water, without the inconvenience of an actual enlargement of the limbs, are densely clothed with long stiff hairs (K). Besides this, the posterior pair, on which the chief action of swimming depends, are much longer than the others, and the tarsi are ciliated to the very articulation of the unguis. The extremity of each tibia is also armed with one or more long spines, which may assist the insect perhaps in burrowing into the mud. When the legs are employed simply in *walking*, and the motions of the insect are slow, the legs are all of the same length, and, as in the *Chrysomelidæ*, are often covered on the under surface of the tarsi with little hairy cushions, *pulvilli*. These are generally present also in *climbing* insects. In the common house-fly, and others of the same genus, instead of hairy cushions the terminal joint of each tarsus is furnished near its extremity with two funnel-shaped membranous suckers (E), by means of which the insect is enabled to adhere to smooth surfaces, and suspend itself in an inverted position. Each of these is concave, and covered by a membrane, and the manner in which the insect attaches itself is by exhausting the air beneath each sucker. The cushions are particularly large in those anomalous insects the Strepsiptera, in which they form a broad heart-shaped surface to each joint of the tarsi (M). They are also present, but in a less perfect form, in some of the running insects, the *Cicindelidæ* and *Carabidæ*, as in *Dioryche torta** (Mac'L.), in which the joints of the anterior tarsi are furnished with a little hairy cushion. But in these families the tarsi of the anterior legs of the males are always enlarged for the same purpose as in the *Dyticidæ*, that of more securely attaching themselves to the female. This is also the case in *Hydrous*, in which the terminal joints of the anterior tarsi (*fig.* 330, A) are very much dilated. In the *Dyticidæ* the first three joints of the anterior tarsi are consolidated together, and form a broad circular disc, covered with many minute funnel-shaped suckers, two or three of which are much larger than the others; in some, as in *Hyderodes Shuckardi*, Hope,† a New-Holland species (H), all the suckers are of nearly the same size. They exist also in the first three joints of the second pair of tarsi (I). A somewhat similar structure exists in the males of some of the sand-wasps, *Crabronidæ* (F). It is supposed to be designed for the same purpose as in the *Dyticidæ*. But in those insects it consists of a broad and slightly convex dilatation of the anterior tibiæ, and not of the

* Coleopterist's Manual, Part ii. tab. 2. fig. 4, *d*.

† Op. cit. pl. 3, fig. 5. *a. b.*

tarsi, as in the latter instances.* Those insects which support themselves upon the surface of water, as the common gnat, have the under surface of each tarsus covered with rows of fine hairs, which repel the water, and support the insect upon the surface. If the under surface of the tarsi be wetted with spirits of wine, the insect can no longer support itself upon the surface, but immediately sinks down.† When the legs are employed in *jumping*, as in *Haltica*, the destructive flea-beetle of the turnip, and the *Gryllidæ* and *Locustidæ*, the posterior pair, upon which devolves the greatest effort, as in the swimming insects, are considerably larger than the others; the thighs in particular are enlarged and lengthened, to allow room for the insertion of the muscles. But when the legs are employed in *digging* or *burrowing*, it is the anterior pair that become the most important, as in the mole-cricket, *Gryllotalpa* (G). In that insect the coxa (*a*) is of an enormous size, and the trochanter attached to its inferior margin consists of two distinct articulations, one of which projects in a lobulated form, and probably is useful in assisting to remove the earth during the operations of the insect. The femur (*b*) is short and broad, and is articulated both to the coxa and trochanter, and thus derives additional strength from its more secure connexion with the base of the limb; while the tibia (c), which is the part immediately employed in burrowing, is also short, and divided at its extremity into four strong curved spines, directed outwards, and forming as it were a broad hand, like the claw of the mole, for digging into and rapidly removing the earth in its burrow. The tarsus (*d*), which appears to be almost useless in these subterranean labours, consists of three short articulations, which are attached to the external surface of the tibia. A similar conformation of the tibia exists in other burrowing insects, since it is always this part of the limb that is employed in digging, and not the tarsus, which is used only in scraping or scratching away loose soil, as by the oil-beetles, *Meloë*, and the sand-wasps. Thus in the *Scarabæidæ* and *Geotrupidæ* the anterior tarsi are broad and dentated laterally, and the posterior ones are armed with strong spines. In some genera, as in the *Coprides* and *Onthophagi*, the extremities are not only strongly spined, but are also broad and club-shaped, to assist them in penetrating into the loose excrement beneath which they are accustomed to burrow.

There are circumstances connected with the organs of locomotion in insects of considerable interest, and which cannot be passed over. These are the aberrations of form which they undergo as a consequence of incomplete development, and the occasional existence of supernumerary limbs, the result of an opposite tendency in the development of the germ. We have already alluded to the changes of form occasioned by the former of these circumstances, and we have now to notice the not less remarkable occurrence of the latter. Although every part of the body is subject more or less to these occurrences, the supernumerary parts are almost always antennæ or legs. We do not remember a single instance of a supernumerary wing, or elytron, or organ of manducation, although the whole of these parts are occasionally subjected to an aberration of form in consequence of imperfect development. Many instances of this kind are given by Dr. Herrmann Asmuss,* who has collected a multitude of facts connected with this interesting subject, from which it appears that abnormal forms are more frequent in the antennæ and legs than in other parts of the body. Only one instance is given of abnormal form of the mandible from arrested development, but several of the antennæ and legs. But the most frequent abnormal condition is found in the existence of supernumerary parts. Of these he has given two instances in which the antenna on one side of the head was double. These occurred in one of the *Elateridæ*, *Athous hirtus*,† and *Carabus auratus*,‡ and one instance also in which it was trifurcated, in *Helops cæruleus*.§ But it is remarkable that the most frequent occurrence of supernumerary parts is of the legs. Of these Asmuss has collected eight examples, and it is remarkable that in six of them the parts on one side are treble. Of the two instances in which the parts were double the first occurred in *Agriotes obscurus*,‖ in which there were two perfect prothoracic legs on the right side of the body, connected with the sternum by two distinct coxæ. In the other instance, which occurred in *Telephorus fuscus*,¶ there were two meso-thoracic legs on the left side, connected together, and attached by a single coxa to the sternum. To these we may add a third instance, which occurred in *Chrysomela hæmoptera*, captured by Mr. Curtis, and described in his British Entomology.** In this specimen the supernumerary part is a tibia, apparently moveable, and developed from the extremity of the femur of one of the hinder pair of legs. A similar remarkable condition is described by Tiedemann†† as having occurred in *Melolontha vulgaris*, in which three tibiæ and tarsi originated from a single coxa of the right metathoracic leg. Asmuss alludes also to the specimen of *Oryctes nasicornis* described by Audouin,‡‡ in which a similar number originated from the right prothoracic leg; and to a second example of *Melolontha vulgaris*,§§ in which three tibiæ and tarsi originated from a triangular, spatula-formed femur of the right prothoracic leg. In

* Degeer Mémoires, t. ii. p. 810, pl. 28.

† Dr. Roget's Bridgewater Treatise, vol. i. p. 334.

* Monstrositates Coleopterorum, Rigæ et Dorpati, 1835.

† Bassi.

‡ Doumerc.

§ Seringe.

‖ Germar.

¶ Bassi.

** Pl. 111. Apr. 1826.

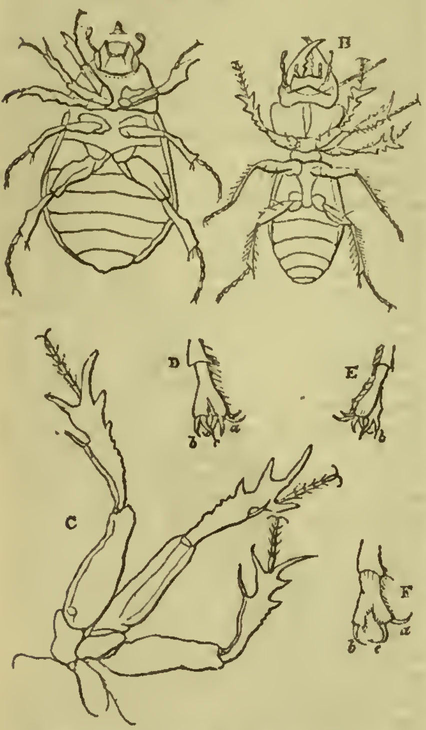
†† Meckel's Archiv für Physiologie, t. v. 1819. p. 125. tab. 2, fig. 1.

‡‡ Annales de la Soc. Entom. de France, 1834.

§§ Doumerc.

another of the *Melolonthidæ*, *Rhizotrogus castaneus*,* three distinct legs originated by separate trochanters from a single prothoracic coxa of the right side (*fig.* 399, A). But per-

Fig. 399.



A, *Rhizotrogus castaneus*; B, *Scarites Pyrachmon*; C, legs of ditto; E, F, G, different views of a treble tarsus of *Carabus perforatus* (Asmuss).

haps the most remarkable example is that given by Lefebvre† of *Scarites Pyrachmon* (B), in which from a single coxa on the left side of the prosternum two trochanters originated (*fig.* 399, B, C). The anterior one, the proper trochanter, supported the true prothoracic leg; while the posterior one, in the form of an oblong lanceolate body, attached to the base of the first, supported two additional legs equally well formed as the true one. Dr. Asmuss has also given an example in *Carabus perforatus* of a treble fifth joint in the tarsus of the left meta-thoracic leg (E, F, G), in which all the claws of three distinct tarsi exist.

The principles upon which the modifications of form, and the existence of supernumerary parts depend, as attributable to retarded or excessive development, have been particularly insisted upon by Saint Hilaire, Professor Grant, and other comparative anatomists, in reference to the development of the body in vertebrata, and are equally applicable to that of the invertebrata. That these aberrations of form really depend upon an arrest of development is well shown in the instance we formerly gave of *Geotrupes stercorarius* (*fig.* 332), in confirmation of the views of Savigny, respecting the different kinds of appendages in each segment being simply modifications of the same normal structure. That retarded development is capable of producing these aberrant forms we once satisfied ourself by experiment made on a specimen of *Sphinx ligustri*. We carefully watched a larva that was about to undergo its change into the pupa state, and when it was beginning to assume that condition, retarded its development by repeatedly touching and otherwise disturbing it, the result of which was that the projecting case that usually exists on the point of the perfect pupa of this insect was not developed in the pupa in question, which we still possess, and which exhibits an uniform appearance of its exterior almost precisely similar to that of *Sphinx populi*. With regard to the existence of supernumerary limbs, it is presumed, in the absence of any evidence that these additional parts exist also in the larva, as we suspect they do, as well as in the perfect insect, that they do not originate simply by a greater development of one part than of another during the changes of the insect, but upon an original tendency to the production of them which existed in the germ itself. This opinion seems to be supported by the circumstance, that although there is a tendency to the reproduction of the same parts as a normal condition of the wings in some insects, such reproduction is not known to occur as an abnormal condition, which appears to be accounted for by the circumstance that the wings themselves are simply developments of parts of other structures, the respiratory organs.

The muscular system of Insects, like that of other Articulata, is contained within the dermo-skeleton. It is composed of an immense number of distinct, isolated, straight fibres, which are not constantly aggregated together in bundles, united by common tendons, or covered by aponeuroses to form distinct muscles, as in Vertebrata, but remain separate from each other, and only in some instances are united at one extremity by tendons. The greater number of these fibres are flat, thin, and of the same size throughout their whole length, a few only being slightly conical. They are arranged parallel to each other, and form layers, or series of fibres. These series of fibres, or layers, we prefer to regard as separate muscles, rather than as aggregations of muscles, as they were formerly regarded by Lyonet,* because we are thereby enabled to simplify our description of the muscular system of these animals. But besides these layers of fibres, which form the greater part of the muscular system, there are also certain sets of fibres which are united by tendons to constitute distinct muscles, but they are not inclosed by aponeuroses. The muscles of insects differ, then, as remarked by Straus,† from

* Bassi.

† Guerin's Magasin d'Entomologie, fascicul. 5, tab. 40.

* Traité Anatomique de la Chenille qui ronge le bois de Saule, 1760.

† Considerations, &c. p. 145.

those of the larger animals in not being inclosed by aponeuroses, and in being formed of fibres which are always free, straight, and frequently are not connected with or arise from tendons. There is no instance, as Straus has correctly remarked, of a digastric muscle in insects. *Each fibre* is composed of a great number of very minute fibrillæ, or fasciculi of fibrillæ, into which the fibre may be easily torn, after it has been hardened for some time in spirits of wine. Professor Wagner has seen transverse striæ on the fibres of insects as on those of vertebrated animals, and we have also observed them very distinctly on the dorsal longitudinal fibres of *Lucanus cervus*, and more particularly on the fibres of the longitudinal muscles of the back, in the abdominal segments of the larva of *Odonestis potatoria;* Professor Muller states that the voluntary muscles of insects are wholly constituted by these transversely striated fibres, each of which has a very delicate sheath, which can often be perceived forming a transparent border to the fibre.* Those fibres which are entirely without tendons are attached by their whole breadth either directly to the flat internal surface of the dermo-skeleton or to elevated ridges, which are intussuscepted portions of the tegument within the body, the apodemata of Audouin, of which the phragmata before described are examples. *The tendons*, or hard uncontractile ends of the muscles, like the phragmata, are formed by an elongation inwards of parts of the internal lamina of the dermo-skeleton.† They exist more generally in the perfect insect than in the larva, and in the muscles of the head of the larva than in other parts of the body. The cause of this appears explicable by the fact that there is a higher developed condition of body in the perfect insect than in the larva, and in the head of the latter than in other parts of its body. Distinct tendons exist most frequently in the muscles of the extremities and organs of manducation, as in the *Lucanus cervus* (*fig.* 388, 2), in which a large flat tendon, of great strength, is attached to the external condyle of the mandible, and on each side of which the fibres that compose the great extensor penniform muscle are inserted. Tendons exist also of great length in the legs of Orthoptera (*fig.* 409, *a*, *b*, *c*), and between the forked processes of the thoracic segments, and the margins of the coxæ. *The muscles with tendons* are arranged by Straus under two divisions:‡ first, the *conical*, in which the tendon is short and occupies the axis of the muscle, where it is expanded into a broad plate, unto which the fibres of the muscle, originating from a broad base, and converging to one point, are attached, and the tendon then proceeds alone to the point of insertion; second, the *pyramidal*, in which the tendon, as in the conical, is surrounded by short fibres, and is broad and divided into several laminæ; third, the *pseudo-penniform*, in which the fibres originate in a row, and, converging, are attached sometimes on one side, and sometimes on both sides of a long narrow tendon; fourth, the *penniform*, which differ from the last in the margin of the tendon being fibrous. Like the latter the fibres orignate sometimes on one side only, and sometimes on both. Fifth, the *compound*, or those which consist of several muscles, each formed of two or more fibres, united by a tendon, and these tendons of two or more muscles united into one bundle; or in which the tendons of several bundles of muscles are united. Unto these five forms Burmeister has added a sixth, the *cylindrical*,* the tendon of which is a flat round plate, to which the fibres are attached on one side, and from which a process extends on the opposite to the point of insertion, as in the muscles of the wings. Audouin calls these tendons *epidèmes*, and regards them as processes of the thorax.

* Elements of Physiology, (translation,) part iv. p. 882.

† Straus.

‡ Op. cit. p. 146.

The *muscles of the larva* present great uniformity of size and distribution in every segment, the motions of each of these divisions of the body being almost precisely similar. The differences which exist in the number, distribution, and functions of the muscles, are to be sought for in the first four segments, which compose the head and thorax of the perfect insect. Thus, in the head of the larva there is a greater aggregation of muscles than in any other segment of its body, because a greater number of organs exist, and consequently require these additional muscles. The presence of a greater number of organs in this than in the succeeding segments is readily accounted for, when we remember that the head is composed of several sub-segments, and that the appendages belonging to it are those of these originally distinct parts. But the situations and the form of the muscles have become changed from those of the simple muscles of a segment, and some have become united to others. This may explain the cause of the greater complexity of the muscles of the head of the larva than of those of the other segments, and why so few are simple like those of the abdominal regions, but, on the other hand, are frequently complicated, and end in tendons, and more or less resemble in form the muscles of Vertebrata. Hence the muscles of the mandibles are large and occupy the greater part of the lateral and posterior region of the cranium, the extensor muscles being attached to the lateral and posterior surface of the cavity, like the extensor muscles of the legs in the thoracic segments, and the flexor more internally to parts that correspond to the *laminæ squamosæ* in the head of the perfect insect, the analogies of which in the thoracic segments are the forked processes to which the flexor muscles of the legs are attached, like the corresponding muscles of the mandibles on the head. The muscles of the three

* Manual of Entomology, (trans.) p. 249.

segments that follow the head, and form the thorax of the future imago, are more numerous and complex than those of the abdomen, because unto those segments belong the muscles of the proper organs of locomotion; besides which they contain also the rudiments of the muscles for the future wings. The muscles in the abdominal segments are fewer and far more simple than in the anterior part of the body, but their number, even in these, very far exceeds what at first might be expected. So numerous are they in every segment that Lyonet, in his immortal work on the anatomy of the larva of *Cossus ligniperda*, found two hundred and twenty-eight distinct muscles in the head alone, and, by enumerating the fibres in the layers of the different segments, reckoned one thousand six hundred and forty-seven for the body, and two thousand one hundred and eighteen for the internal organs, thus making together four thousand and sixty-one muscles in a single larva. In the larva of *Sphinx ligustri* we have found the muscles equally numerous with those discovered by Lyonet in the *Cossus*, but in attempting to describe them it has appeared preferable, as we have stated, to consider each layer of fibres collectively as a separate muscle. In describing the muscles of the ventral portion of a segment, we formerly* ventured to designate them by names which were indicatory either of their position or use, and we shall continue to do so on the present occasion. A description of the muscles of a portion of a segment will suffice to convey some idea of their multiplicity and use. We may first state generally that those muscles which form distinct layers or act in concert with each other, are inserted into slightly elevated ridges of the tegument, while a single muscle, or the tendon of many muscles united together, is attached to an elevated process of the tegument, which at that point is thicker than in other places, and thus affords a means of attachment. There are always three ridges for the attachment of muscles between two abdominal segments. The middle one is the largest, and affords both origin and insertion to the straight or longitudinal muscles, while the others in like manner afford origin and insertion to the oblique ones.

On removing the fat and viscera from the abdomen of the larva, the first layer that presents itself, and forms the interior parietes of the body, consists of many longitudinal fibres, which extend from the margin of one segment to that of another as flat, straight muscles, resembling the *recti abdominales* of vertebrated animals. These muscles extend from the anterior margin of the sternal surface of the second segment to the posterior part of the twelfth; but it is only at the anterior margin of the sixth segment, which is in reality the commencement of the true abdomen, that they can properly be considered as recti muscles, since it is at this part of the body that they begin to be fully developed. While passing through the thoracic segment they are narrower, thinner, and somewhat differently arranged. They are connected anteriorly with the head, and posteriorly with the sphincters. They are the most powerful of all the muscles of the abdomen, and are those which are most concerned in shortening the body, and effecting the duplicature of the external teguments, during the changes of the insect. They are also those which mainly assist in locomotion during the larva state. There are four sets of these longitudinal muscles, two on the dorsal and two on the ventral surface of the body (*fig.* 400, A A). Those on the dorsal surface are placed one on each side of the dorsal vessel or heart, and those on the ventral one on each side of the nervous column. The dorsal sets extend from their attachment to the upper part of the head through the thorax and abdomen to the anus, in the thirteenth segment. In the thoracic region they are narrow like the corresponding muscles of the ventral surface, but when the insect is undergoing its changes they become enormously enlarged in this region, and form the great depressor muscles of the wings (*fig.* 402, *x*), which are some of the most powerful muscles of the thorax, and extend between the meso- and meta-phragma. The ventral recti consist of four sets of fibres, two on each side of the nervous cord (*fig.* 400, 1, 2), and between which there is a slight interspace. That set which is placed nearest to the nervous cord and median line of the body, is composed of only three narrow fasciculi of fibres, and may be called the *recti minores* (2), while the other set, situated more externally and covering the greater portion of the ventral surface of the segment, is broad and powerful, and consists of from twenty to twenty-five distinct fasciculi or fibres, and may be called the *recti majores* (1). The origins and insertions of these are different from those of the smaller recti. The recti majores of one segment arise from the middle ridge between two segments (3), and are inserted close to the origin of the corresponding muscles of the next segment, while the recti minores arise from the most posterior of the three ridges, about one-fifth of a segment posterior to the middle ridge, over which they pass, and proceed in a direction parallel to the larger ones to be attached to part of the corresponding ridge in the next segment. There is a small muscle that originates from the same ridge as the greater rectus, between it and the smaller, which, from its passing directly to the alimentary canal, and connecting that viscus to the exterior tegument of the body, may be called the *retractor ventriculi* (5). There is one of these muscles, as shown also by Lyonet in the Cossus, on each side of the nervous cord, from the fourth to the eleventh segment. On removing the recti, we expose two layers of very fine thin muscles. The upper layer (B) consists of nine distinct fasciculi of fibres, which pass backwards and outwards, in a slightly diagonal direction (6), but less diagonally than the second layer (7), that lies immediately

* Phil. Trans. part ii. 1836.

Fig. 400.

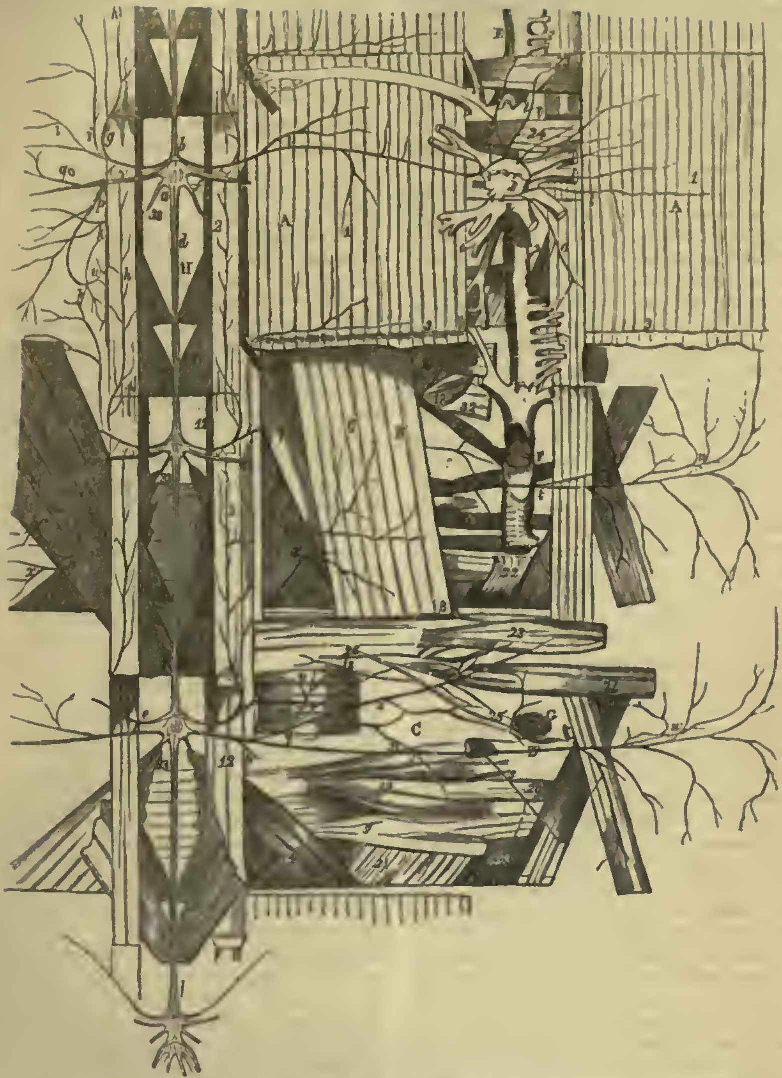


Diagram of the muscles and nerves of the ventral surface of the segments in the larva of Sphinx ligustri. (Newport, Phil. Trans.)

beneath the upper one. The second layer consists of seven distinct fasciculi, which extend from the anterior margin of the segment, close to the smaller rectus, and beneath the larger, about half their breadth across the segment. They run backwards and outwards in a diagonal direction, and are attached to the middle ridge below the rectus as far across the segment as the outer margin of that muscle (8). These layers of muscles when in action draw the outer part of the anterior margin of the following segment diagonally forwards in the direction of the median line of the body, and, consequently, when these muscles in several segments on one side of the body act ogether, they bring forward the posterior porion of the body of the same side, and bend it in a semicircular direction. When these layers on both sides of a segment act together, they draw forwards the posterior part of the body in a straight line. The most internal of these layers (6) which lies close to the rectus may be called the *first oblique*, and the other the *second oblique* (7). Beneath this there is another diagonal layer of fibres which originates close to the median line of the body (9), beneath the nervous cord, almost in a line with the insertion of the smaller rectus. The origin of this set is exceedingly narrow and distinctly tendinous, and the fibres diverging pass diagonally upwards and outwards, forming a flat triangular muscle, the *third oblique* (9, 10), which is attached to the posterior ridge, and extends outwards to the margin of the greater rectus. These oblique muscles are the antagonists of the recti, and when acting alone draw the posterior part of each segment backwards and to the median line; consequently, when the layers of only one side are in action, the anterior part of the body is flexed laterally in the form of a curve, but when those on both sides are in action the anterior part of the body is carried directly backwards. Beneath these oblique muscles there is another, which is formed of only two broad fibres. It arises from the anterior of the three ridges of attachment in the median line, and passing diagonally forwards and outwards parallel to the third oblique, beneath its inner margin, is attached to the third ridge of insertion. This may be called the *fourth oblique* (11). Beneath the posterior extremity of this muscle lies the *third rectus* (12), which is formed of three fibres, somewhat broader than those of the second or smaller rectus, but running longitudinally in exactly the same direction, and having the same origin and insertion. On removing the third rectus we expose the eighth layer of muscular fibres. This arises from the anterior ridge, and is formed of three broad fibres which are partially crossed at their origin by the third rectus. It passes diagonally outwards, and is attached to the third ridge, extending as far as the margin of the rectus and third oblique, by which it is concealed. This is the *fifth oblique* (13). When this layer is removed, the triangular and transverse muscles are exposed. The *triangularis* (14) is composed of nine distinct fibres, which originate in a longitudinal series that extends about half-way across the segment. The fibres pass from their origin diagonally backwards and outwards, with varying degrees of obliquity, and are inserted by strong tendons into the anterior of the three transverse ridges (16). They arise also by distinct tendons, which indigitate with a set of short transverse fibres, ten in number, and which occupy the median line beneath the nervous cord, and form the *transversus medius* (15). This muscle contracts the diameter of the middle of the under surface of a segment. The triangularis, when acting with its fellow of the opposite side, shortens the posterior half of the ventral surface of the segment; but when acting singly, or in conjunction with the third oblique, shortens that side of the segment, and assists to bend the body laterally. It is a very powerful muscle in locomotion, and probably is of great use in shortening and contracting the segments during the transformations. The *transversi abdominales* (17) are six short broad and thick fibres, that form two sets, and originate at some distance from the median line, posteriorly to and on the outer side of the tendons of the third oblique, and passing transversely outwards are inserted directly into the tegument, about half-way across the segment. Like the transversus medius they contract the diameter of the ventral surface of the segment, and bring the sides towards the median line. Anteriorly to these muscles, but further from the median line, is another set of six short fibres, the *abdominales anteriores* (18), which arise at some distance from the median line, and passing transversely outwards are inserted into the lateral part of the segment. The *abdominales laterales* (19) are situated in the posterior half of the segment. They are inserted by three great fasciculi of narrow tendons into the inner and inferior part of the segment, and consist of eight muscular fibres connected in the first tendon, four in the second, and seven in the third. They form very powerful muscles, which interlace with each other, and originate directly from the tegument of the sides of the segment, at different distances posteriorly to the spiracle. Some of them (20) are much longer than others, and the whole of them are connected with the false feet of the abdomen. On removing these muscles we expose the attachment of the *obliquus posterior* (21), which is composed of nine small fibres that pass diagonally outwards from their origin, the anterior ridge, to their insertion in the tegument at different distances beneath the lateral abdominal muscles. Another set of nine distinct fibres, the *postero-laterales obliqui* (22), which originate from the same ridge at the lateral part of the segment, cross over the last lateral abdominal muscle, and are inserted between it and the one immediately before it. Besides these layers of fibres there are four other sets which seem to be particularly concerned in the function of respiration. Of these the *transversus lateralis* (23) arises tendinous from beneath the lateral part of the great rectus, and passing upwards, internal to the great longitudinal trachea (E), which it crosses, is inserted beneath the external margin of the dorsal rectus (A). The second *transversus lateralis* (24) arises posteriorly to the first, crosses the trachea, and continuing its course upwards is inserted into the tegument of the back, about half-way across the dorsal rectus. These muscles appear to be directly concerned in contracting the segments during expiration. Besides these muscles there are also the *retractor spiraculi* and the *retractor valvulæ*, which belong also to the ventral and lateral surface of each segment. The *retractor spiraculi* (25) is attached by a long tendon (26) to the third ridge of insertion. It is a long, fleshy, and somewhat conical muscle, which passes upwards and obliquely backwards to the spiracle, unto the lower margin of which it is attached, and is blended with the circular fibres that constitute an orbicular muscle to that orifice. It appears to be directly concerned in forcible expiration, and draws the spiracle inwards and downwards, and when the orbicular muscle acts in conjunction with it assists in closing the spiracle. The remaining muscle, the *retractor valvulæ* (27), is the direct antagonist of the last. It is composed of five distinct fibres (*fig.* 401, *c*), which arise from the posterior margin of the spiracle, and partly also from the attachment of the *retractor spiraculi* (*e*), and then, converging, end in a tendon that passes diagonally upwards and backwards, and is inserted into a little elevation in the tegument. It is the proper retractor or levator muscle of the spira-

Fig. 401.

Internal view of spiracle of larva of Sphinx ligustri. (Newport, Phil. Trans.)

a, anterior margin of spiracle with portion of the trachea; b, the valve; c, retractor valvulæ; e, retractor spiraculi; d, nerve supplying these muscles.

cular orifice, and acts upon the internal valve (*b*), which is situated a little within the spiracle. This valve is a thick, moveable, dark-coloured duplicature of the lining membrane of the posterior border of the spiracle, and closes on that of the opposite side (*a*), which is a concave crescent-shaped margin, not acted upon by muscles—like a cushion or pad.

These muscles of the larva of the Sphinx differ but little from those described by Lyonet in the Cossus. In all insects they give passage between them to the ramifications of tracheal vessels, which are most extensively distributed throughout the whole body, to every muscle, nerve, or other organ. They are also covered in many places by numerous connected vesicles filled with adipose matter, which exist in the greatest abundance in the larva state in all insects, occupying the interstices between the muscles and tracheæ. The same general structure of the muscular system as that which we have just described in the Sphinx exists in all larvæ that undergo a complete metamorphosis, whether they belong to the Coleopterous, Hymenopterous, or Lepidopterous classes, although in the particular distribution and form of the muscles in each there are necessarily some differences dependent upon difference of species and habit. Thus Burmeister found a similar general conformation of parts in the larva of *Calosoma sycophanta** (*fig.* 354), one of the more perfect Coleoptera, both in the existence of the rudiments of muscles for the wings and in the longitudinal muscles of the dorsal and ventral surfaces of the body. The muscles of the larvæ of Coleoptera, as Burmeister has remarked, bear a greater resemblance to the muscles of the perfect insects than those of the larvæ of other classes. It is not difficult to recognise in them the same general arrangement of particular muscles which are afterwards found in a more or less developed state in the perfect insects. An admirable exemplification of the muscular system of Coleoptera is given by Straus Durckheim in his splendid work on the anatomy of *Melolontha vulgaris*, in which many of the muscles that exist in the larva state may be distinctly identified, although greatly modified in form and size to fit them for new modes of action, which have been rendered necessary by the changes that have taken place in the habits and modes of life of the insect. Thus, as also remarked by Straus,† the great ventral series of recti muscles which we have just seen in the larva, form successively the retractor muscles of the labium, the depressors of the head, the retractors or depressors of the pro-sternum, or those which draw that part to the meso-sternum, and the pretractors of the post-furca or triangular process of the metasternum; and, lastly, the inferior recti muscles of the abdomen. But in each of these instances the size and form of the muscles are greatly altered, more especially in the thoracic region, while in the abdominal region those of the posterior segments exist with less change of form than in the thoracic, but are greatly reduced in size, and those of the anterior abdominal segments, in which the ventral plates of two or more segments have become consolidated together, are atrophied and have almost disappeared. In like manner the dorsal recti of the larva exist in the imago in the new form of elevators of the head, superior retractors or elevators of the prothorax and scutellum, and levators, depressors, and adductors of the wings and dorsal longitudinal recti of the abdomen. In the latter region neither their form nor direction have been changed, but like the ventral recti they have been much reduced in size, because there is less necessity for their active employment in the perfect than in the larva state, in which nearly the whole of the locomotive powers of the individual are entirely dependent upon those muscles. Their form and direction have not been changed because the direction in which they are employed in the perfect state is precisely similar to that in which they are employed in the larva. But this is not the case in the thoracic region, in which not only have they been enormously increased in size and changed in form, but their relative position has also been altered, owing to the changes that have taken place during the metamor-

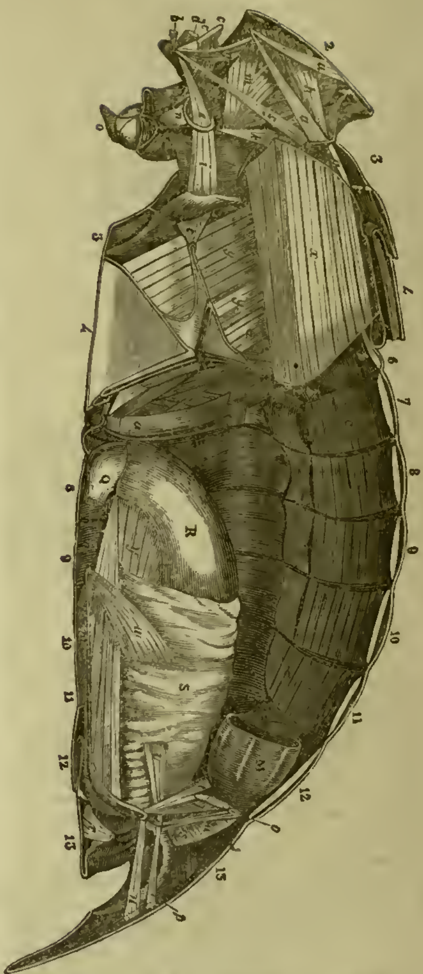
* Trans. Entom. Society, Lond. vol. i. p. 335.
† Considerat. Generales, p. 149.

phoses in the position of parts of the tegumentary skeleton, to which the muscles are attached. Hence the direction in which these muscles are now required to act is also changed, and from constituting, as in the larva, only one continuous series of uniform muscles, acting in one direction, in the perfect insect they become muscles that act in several directions, at different angles of the body, and in some parts exceed in importance and size every other division of the muscular system. Thus, in the thoracic region, the dorsal muscles, which were parts least employed in the larva, are those which are of the greatest importance in the perfect insect, both as regards size and function. In the larva, as we have seen, locomotion depends chiefly upon the abdominal recti; but in the perfect insect, on the contrary, nearly the whole of this power is transferred to the dorsal muscles of the thorax. Hence the arrangement of these muscles is more or less intricate, and differs in different classes, according to the habits of the insects. Thus, in those classes in which the prothorax is short, and almost or entirely anchylosed to the meso-thorax, as in the Hymenoptera, Lepidoptera, and Diptera, and in which, consequently, scarcely any motion of the prothoracic segment is required, the muscles become almost entirely atrophied and cease to exist, or, as is sometimes the case, their attachments are transferred to a different part of the tegumentary skeleton.

The most generally developed form of the muscular system of the thorax is found in the Coleoptera, of which Straus has given so admirable an illustration in his anatomy of *Melolontha*. It is from his description of the muscles of that insect that we shall chiefly derive our general description of these parts in perfect insects. We shall, however, for the sake of uniformity, adopt the nomenclature applied to these parts by Burmeister, identifying it with the names originally employed by Straus.

The muscles that connect the head with the thorax are contained within the prothorax (*fig.* 402,2), and are of three kinds, *extensors*, *flexors*, and *retractors*. The extensors, *levatores capitis* (*a*, *a*), consist of two pairs, one of which arises from the middle line of the pronotum, and diverging laterally from its fellow of the opposite side, passes directly forwards and is inserted by a narrow tendon into the anterior superior margin of the occipital foramen. The other arises further back from the prophragma. It is a long narrow muscle that passes directly forwards through the prothorax, and is inserted by a tendon near the superior median line of the foramen; so that while this muscle and its fellow of the opposite side elevate the head almost in a straight line, the one first described, when acting alone or singly, draws the head a little on one side; but when the whole of these muscles act in unison, they simply elevate the head upon the prothorax. The depressors or flexors, *depressores capitis* (*b*), are exceedingly short muscles, which arise from the jugular plate, or, when that part does not exist, from the border of the pro-sternum, and are attached

Fig. 402.



Section of the body of Melolontha. (Straus.)

to the inferior margin of the occipital foramen. They simply flex the head on the prothorax. The lateral flexors, *depressores externi* (*d*), are two little muscles that arise from the same point as the preceding, and are attached to the lateral inferior margin of the occipital foramen. The rotatory muscles, *rotatores capitis* (*c*), are two flat muscles like the elevators, which arise, one at the side of the ante-furca and the other from the posterior jugular plate, and passing upwards and outwards are attached to the lateral margin of the occipital foramen. The *retractor* or flexor of the jugular plate is a small muscle (*e*) that arises from the margin of the ante-furca, and passing directly forwards is inserted by a small tendon into the middle of the jugular piece. The *oblique extensor* of the jugular plate is a long slender muscle (*f*) that arises from the external margin of the pronotum, and passing obliquely downwards and forwards traverses the prothorax and is inserted by a narrow tendon to the jugular plate immediately before the retractor. The other retractor (*g*) arises from the anterior superior boundary of the pronotum, and passing downwards is inserted into the jugular plate between the larger levator and the flexor capitis.

The muscles proper to the prothorax consist of four pairs, by which it is united to the succeeding segments. The first of these, the superior retractor, *retractor prothoracis superior* (*h*), arises by a broad fleshy head from the anterior external margin of the pronotum, and passing directly backwards is inserted by a tendon into the prophragma a little on one side of the median line. The next muscle of importance, the *inferior retractor* (*i*), arises from the anterior border of the medi-furca, and is united to the posterior of the ante-furca, thus forming with that muscle part of the great recti of the larva. This muscle must be considered as the proper depressor of the prothorax. The *elevator prothoracis* (*k*) is narrow, pyramidal, and arises fleshy from the lateral surface of the prophragma. It passes downwards and is attached by a narrow tendon to the superior portion of the ante-furca. The *rotatores prothoracis* are the largest of all the muscles of this segment. They arise, one on each side (*l*), by a narrow head from the posterior part of the pronotum, and passing beneath the prophragma are considerably enlarged and attached to the tegument between the two segments, and also to the anterior portion of the mesothorax. The remaining muscle proper to the prothorax is the closer of the spiracle, an exceedingly small muscle not shewn in the drawing. The other muscles of this segment are those of the legs, which are of considerable size. There are three distinct flexors of the coxa (*m*, *n*, *o*). The first of these arises from the superior lateral border of the pronotum, the second from the superior posterior border, the third from the sides of the prothorax, and the fourth a little nearer posteriorly, and the whole of them are attached by narrow tendons to the sides of the coxa. But there is only one extensor muscle to this part. In like manner the extensor of the trochanter is formed of three portions, (*fig.* 403, *a*, *b*, *c*,) but there is only one flexor (*d*) and one abductor (*e*). In the femur there is one extensor (*f*), a long penniform muscle that occupies the superior part of the thigh, and is attached by a tendon to the anterior posterior margin of the joint, formed by the end of the tibia. There is also but one flexor (*g*) in the femur, which, like the preceding muscle, is penniform, and occupies the inferior portion of the femur, and its tendon is attached to the inferior border of the tibia. In the tibia itself there is also one flexor and one extensor. The flexor (*i*) occupies the superior portion of the limb, and ends in a long tendon (*l*) that passes directly through the joints of the tarsus on their inferior surface, and is attached to the inferior margin of the claw (*g*). The *extensor* (*h*) occupies the inferior portion of the tibia and is shorter than the preceding muscle, like which it ends in a long tendon that is attached to the upper margin of the claw. Besides these muscles, which are

Fig. 403.

Muscles of the anterior leg of Melolontha vulgaris. (Straus.)

common to the joints of the tarsus, there are two others belonging to the claw, situated in the last joint. The first of these, the *extensor* (*m*), is short and occupies the superior portion of the last phalanx of the tarsus, and the other, the *flexor* (*n*), is a much longer penniform muscle, which occupies nearly the whole of the upper and under surface of the posterior part of the phalanx, and is attached, like the long flexor of the tarsus, to the inferior part of the claw. These are the muscles of the prothorax and its organs of locomotion, as shewn by Straus, and exemplify the extent unto which the muscular system is developed in perfect insects. The muscles of the other segments of the thorax differ considerably from these in their form and arrangement, but the length unto which this article has already been carried prevents us from entering particularly into their consideration. The great depressor muscle of the wings, *musculus metanoti* (*fig.* 402, *x*), occupies with its fellow the chief portion of the dorsal surface of the meso- and meta-thorax, and the elevators and pretractors, *musculi laterales metanoti* (*y*, *y*), the lateral superior parts of the same segment, and descending obliquely backwards are attached to the metaphragma and base of the post-furca. The other muscles which belong to the legs and those that connect the thorax to the abdomen are of considerable size. One of those of the posterior legs, the second *flexor* (*z*), is seen immediately behind the muscles of the wings, and the *extensors* (*a*, *a*) at the posterior part of the segment. In the abdomen the chief muscles are the dorsal *recti* (*c*, *c*) on the upper surface, and the corresponding ones on the ventral, which are now chiefly subservient to the motions of the organs of generation.

From the number and complexity of the muscles in these "miniatures of creation"—insects—we feel less surprised at the agility of their movements and the variety of motions which many of them perform, and less astonishment at the wonderful strength which many species possess. But still there are instances of some of them possessing a degree of power that is almost incredible. The great stag-beetle, *Lucanus cervus*, which tears off the bark from the roots and branches of trees, has even been known to gnaw a hole an inch in diameter through the side of an iron canister in which it was confined, and on which the traces of its mandible were distinctly visible, as proved by Mr. Stephens, who exhibited the canister at one of the meetings of the Entomological Society,* an indication of an amount of strength possessed by these insects of which before we could have had no conception. But hardly less surprising is the strength possessed by *Geotrupes stercorarius*, which can support uninjured, and even elevate an immense weight, and make its way beneath almost any amount of pressure. In order to ascertain the amount of strength possessed by this insect, we have made a few experiments from which it appears that it is able to sustain and escape from beneath a pressure of from twenty to thirty ounces, a prodigious weight when it is remembered that the insect itself does not weigh even so many grains. But this amount of strength is not confined to the short thick-limbed beetles. We once fastened a small *Carabus* (——— ?), weighing only three grains and a half, by means of a silken thread to a small piece of paper, upon which the weight to be moved was placed. At a distance of ten inches from its load the insect was able to drag after it, up an inclined plane of twenty-five degrees, very nearly eighty-five grains. But when placed on a plane of five degrees it drew after it one hundred and twenty-five grains exclusive of the friction to be overcome in moving its load.

The *motions* of the insect in *walking* as in *flying* are dependent in the perfect individual entirely upon the thoracic segments, but in the larva chiefly upon the abdominal. Although the number of legs in the former is always six, and in the latter sometimes so many as twenty-two, progression is simple and easy. Müller states † that on watching insects that move slowly he has distinctly perceived that three legs are always moved at one time, being advanced and put to the ground while the other three propel the body forwards. In perfect insects those moved simultaneously are the fore and hind feet on one side and the intermediate foot on the opposite, and afterwards the fore and hind feet on that side and the middle one on the other, so that, he remarks, in two steps the whole of the legs are in motion. A similar uniformity of motion takes place in the larva, although the whole anterior part of the body is elevated and carried forwards at regular distances, the steps of the insect being almost entirely performed by the false or abdominal legs.

In *flight* the motions depend upon the meso- and meta-thoracic segments conjointly, or entirely upon the former. The sternal, episternal, and epimeral pieces, freely articulated together, correspond in function with the sternum, the ribs, and the clavicles of birds.* The thorax is expanded and contracted at each motion of the wings, as in birds and other animals, and becomes fixed at each increased effort as a fulcrum or point of resistance upon which the great muscles of the wings are to act, thus identifying this part of the body in function as in structure with that of other animals.

The Nervous System.—Comparative examinations of the nervous system in Articulata, and the changes which it undergoes, more especially in Insects, as well as the existence in it of parts which we regard as analogous to the motor and sensitive portions of the spinal cord in vertebrata, have invested this division of our subject with more than a common amount of interest.

It has been shewn in a former part of this work,† that in Articulata the most rudimentary condition of the nervous system exists in the form of two longitudinal cords, extended along the median line of the under surface of the body, parallel with each other, and nearly close together, excepting at their anterior part, where they diverge, and pass upwards, to embrace between them the commencement of the alimentary canal. In a more advanced stage of organization each of these cords has a series of enlargements or ganglia in its course, situated at certain distances apart, and varying in number according to the number of segments into which the body of the animal is divided. These enlargements correspond precisely in situation in both cords, so that the nervous system in this condition may be described simply as composed of two knotted, parallel cords. The enlargements in one cord are either placed close to the corresponding ones in the other, or are separated only by a very slight interspace. This is the form in which the nervous system exists, as we have seen, in the Talitrus,‡ in which the ganglia are approximated together, but are still distinct from each other, and form a double series of enlargements, united by intervening cords. This is also the condition in which the nervous system exists in its most rudimentary state in the larva of hexapodous insects. But these parallel cords, which together form the analogue of the cerebro-spinal system of vertebrata, and correspond one to each side of the body, are not in themselves simple structures, each one being composed of

* Transact. Ent. Soc. Lond., vol. ii. Journal of Proceedings, p. xxii.

† Elements of Physiology, p. 970. (Transl.)

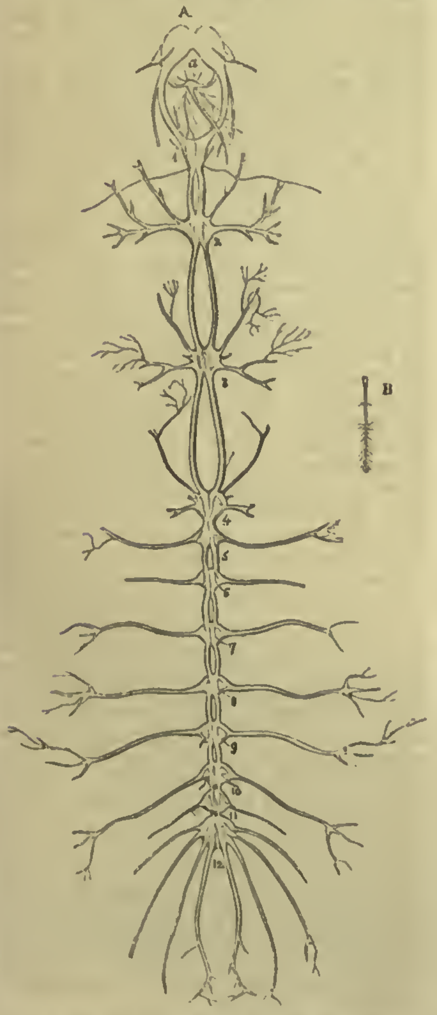
* Bennet on the anatomy of the thorax in insects, and its function during flight, Zoological Journal, vol. i. p. 394.

† Art. CRUSTACEA, ENTOZOA, ANNELIDA.

‡ CRUSTACEA, vol i. p. 763, fig. 391.

two distinct columns of fibres, placed one upon the other, and closely united together in every instance. The under or *external* column, which is nearest to the exterior of the body, is that in which the ganglia or enlargements are situated. The upper one, or that which is *internal* and nearest to the viscera, is entirely without ganglia, and passes directly over the ganglia of the under column without forming part of them, but in very close approximation to them. In some species, as in the larvæ of *Timarcha tenebricosa*, (*fig.* 404, 2, 3, 4,) and *Proscalabæus vulgaris*, among the Coleoptera, and of the Bee and other *Aculeate* Hymenoptera, this column is more apparent than in the larvæ of Lepidoptera, in which it is indistinctly seen, excepting when it is beginning to pass over or is just leaving the surface of a ganglion.

Fig. 404.



Nervous system of the larva of Timarcha tenebricosa. B, natural size.

The ganglionless upper or internal column of fibres is the part which we believe to be analogous to the motor column of vertebrata, and the external or under one, in which the ganglia are situated, we regard as the analogue of the sensitive. Thus the two cords are each composed of a motor and a sensitive column, and represent, we believe, the cerebro-spinal system of vertebrata. In the Aculeate Hymenoptera, the ganglia of the cords are in a state of development similar to those of the Talitrus; they are approximated together laterally, but still remain distinct from each other, and thus present a transitory condition in the larva state of an insect similar to their permanent one in the lower Crustacea. In the *Timarcha*, the anterior pair, or supra-œsophageal ganglia, still continue distinct from each other, (*fig.* 405, A A,) and retain their rudimentary form, as in the Talitrus, and the cords are also separated; but the several pairs of subœsophageal ganglia have each coalesced into a single mass.

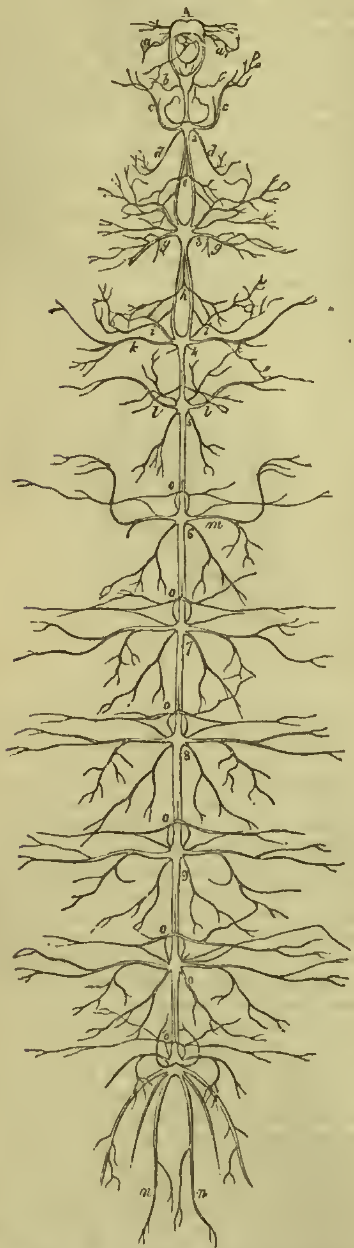
Fig. 405.

The supra-œsophageal ganglia, or brain of larva of Timarcha tenebricosa. (Newport, Phil. Trans.)

A similar coalescence of the ganglia, but carried to a less extent, exists in the larvæ of Lepidoptera, in which the form of the nervous system of insects has been most frequently examined. Malpighi and Swammerdam examined this structure in the Silkworm, and Lyonet in the larva of the Goat-moth, *Cossus ligniperda*. We have also examined it in the larva of the Privet Hawk-moth, *Sphinx ligustri*, in which we shall now describe its general form and distribution.

Cord and nerves of the larva.—In the larva of the Sphinx, (*fig.* 406,) as in most others of the vermiform type, the normal number of double ganglia is thirteen. The anterior pair (A) situated above the œsophagus, represent the *brain*, and the first of those which are situated below it, (*b*,) the *medulla oblongata*. These are the proper ganglia of the head or first segment, and the cords by which they are connected together, and which descend one on each side of the œsophagus, in like manner represent the *crura*. Posteriorly to the medulla oblongata, which we shall distinguish as the first subœsophageal ganglion, the cords pass directly backwards into the second segment, where they form the second subœsophageal ganglion (2). They then diverge a little from each other, and include between them the insertions of the first set of diagonal muscles, and at the posterior part of the third segment again approach each other, and form the third ganglion (3).

Fig. 406.



Nervous system of the larva of Sphinx ligustri.
(Newport, Phil. Trans.)

They then again diverge, and continuing their course into the next segment, pass on each side of the insertion of a second set of muscles, and approaching at the hinder part of the fourth segment form the fourth ganglion, (4,) from which they continue their course side by side, and in the next segment form the fifth and last ganglion, (5,) that enters into the composition of the thoracic portion of the nervous cord in the perfect insect. From the fifth ganglion the cords are continued in a direct line, into the sixth, seventh, and succeeding segments, forming in each a double ganglion, to the eleventh, where they form the terminal ganglion (11, 12). This is considerably larger than any of the preceding, being in reality composed of two distinct pairs, which originally were separated from each other by intervening cords, and belonged to the eleventh and twelfth segments, but which seem to approach and become closely approximated to each other during the earlier period of the larva state, as suggested by Dr. Grant, and supported by the fact that these ganglia are found more or less approximated together in different individuals, the terminal ganglion in some being distinctly formed of two pairs, scarcely united, and in others so completely coalesced as hardly to be distinguished. In other Lepidoptera, as in *Odonestis potatoria* and *Lasiocampa neustria*, and as represented also by Lyonet, in *Cossus ligniperda*,* the ganglia continue distinct, and are separated by a very short portion of the cords. But in the *Timarcha*, the eleventh and twelfth ganglia have completely coalesced, and it is remarkable that they are also united even in the rudimentary form of the nervous system in the aculeate Hymenoptera, as in the larva of the bee, and even in its still more rudimentary state in the larva of *Ichneumon Atropos*, in both which there are originally thirteen distinct pairs of ganglia, including the supra-œsophageal ones, although Burmeister has imagined that the apodal larvæ of Hymenoptera have a nervous system without ganglia,† similar to what he has observed and figured in the larvæ of some Diptera. It was shown by Swammerdam,‡ that in the Lamellicornes, as in *Oryctes nasicornis*, the cords are united laterally, and do not extend beyond the fourth segment, from whence the nerves radiate into the abdomen. In *Dyticus*, according to Burmeister,§ the two approximated cords are very short, and the pairs of ganglia are contiguous to each other, and he has found a similar form of the nervous system in the Hog-beetles, *Calandra sommeri*, in which there are twelve pairs of closely approximated subœsophageal ganglia. The supra-œsophageal pair in this species are distinct, as in Timarcha, but each pair of the subœsophageal has coalesced into a single mass, as in that insect, and the whole do not extend beyond the fifth segment, from whence the nerves radiate into the abdomen, as in the Lamellicornes. These are the conditions which the double cord presents in the different classes. In describing the nerves that proceed from it, we shall divide them into those of the head, the thorax, the abdomen, and the organic functions.

* Plate ix.
† Manual, (translat.) p. 279.
‡ Biblia Natura, Tab. xxviii. fig. 1.
§ Op. cit.

Nerves of the head.—When the first pair of ganglia, which always constitute the brain, are viewed from above, they each present a convex uniform appearance, and are distinguished from each other by a depression between them, which is more apparent on their anterior than their posterior surface, and is occasioned by the lateral part of each lobe or ganglion being carried a little forwards, so that the two lie across the œsophagus in a curved or lunated direction. On their under surface they are concave, to adapt them to the form of the œsophagus, above which they are situated. From the anterior and lower part of each lobe originate four remarkable nerves, which belong to the organs of sense and the viscera. The first and largest of these, the *optic*, passes a little forwards and outwards to the stemmata, a little behind the mandibles; the second, the *antennal*, passes a little more anteriorly, to the palpiform antenna; the third, and most inferior, descends at the side of the pharynx, and uniting with its fellow of the opposite side forms a loop or collar around the œsophagus, to the under-surface of which it distributes a few filaments. We consider it as analogous to the *glosso-pharyngeal* nerve of vertebrata. The fourth is situated between the second and third. It passes a little forwards from its origin, and then ascending above the pharynx, meets its fellow of the opposite side, with which it forms a minute ganglion, from the hinder part of which a single nerve passes backwards (*b*) beneath the brain, in the median line above the œsophagus, to the stomach and viscera. This nerve was discovered by Swammerdam,* who called it the *recurrent*, from the manner in which it originates and is distributed, and it was afterwards minutely figured and described by Lyonet. Müller has since described it minutely, and figured it in many species, in his paper on the sympathetic nerves of insects, as the proper visceral nerve, analogous to the *sympathetic*. In a paper in the Philosophical Transactions in 1832, we described it as the *vagus*,† of which we believe it is the proper analogue. At that time we were led to suppose that it had previously been so described by Straus Durckheim, but such, as we have since found, was not the case. We shall presently return to our description of this nerve, in the perfect insect, as belonging to those of the organic functions. Besides these four pairs of nerves from the anterior part of the brain, there is also one minute pair from the posterior, which is directed backwards, and developed on each side of the head into two pairs of little ganglia, (*a*,) which constitute part of the *sympathetic* system. The first of these ganglia was discovered and rudely figured by Swammerdam,‡ and afterwards more correctly by Lyonet, and the second by Straus Durckheim. We have designated them from their situation the *anterior lateral ganglia.*§

* Op. cit. tab. xxviii. fig 2.
† Part 2, p. 386.
‡ Op. cit. tab. xxviii. fig. 3 i.
§ Philosophical Trans. p. 2, 1832, page 387.

These are the proper cerebral nerves of the larva, and belong to the senses and organic functions. The *medulla oblongata*, or first subœsophageal ganglion, also gives origin to four pairs of nerves. The most anterior pair of these is given to the labium; the next to the palpiform maxillæ; the third, the analogue of the fifth of vertebrata, conjointly to the muscles of the mandibles and maxillæ; and the fourth, the most posterior pair, to the silk vessels, the proper salivary organs of the larva.

The nerves of the thorax belong to the second, third, fourth, and fifth subœsophageal ganglia, and their intervening cords. The first pair of nerves from the second ganglion (2) are exceedingly small, and are given to the retractor muscles of the head. The second pair (*c*) are large, and are divided into many branches that are given to the whole of the muscles of the lateral and superior part of that segment, and the third (*d*) are directed backwards, and supply the anterior or prothoracic legs. The third ganglion (3) produces also three pairs of nerves. About midway between the second and third ganglion the cord produces on each side a single nervous trunk (*f*), which is directed a little backwards, and unites at an angle with the first nerve from the third ganglion. These together from a single trunk, which in the early stage of the larva is exceedingly small, but increases much in size as the period of changing into the pupa state approaches. It is the first *alary* nerve, and is given to the future anterior pair of wings, and is now distributed among the muscles of the anterior part of the segment. It is also connected with one set of the transverse nerves (*e*), which exist in each segment loosely attached to the cords, and which we shall describe more particularly hereafter. The second pair of nerves from this ganglion produce each at their base a small branch, which has the appearance of a distinct nerve, and which is distributed laterally to the deep-seated muscles, while its main trunk (*g*) is given to the second, or mesothoraçic pair of legs. Half-way between the third and fourth ganglion the cord again produces on each side a single nervous trunk (*i*), which, like the corresponding one in the preceding segment, is directed backwards, and unites with the first nerve from the third ganglion. It is the second *alary* nerve given to the muscles of the future second pair of wings. Like the corresponding nerve in the preceding segment, it is very small during the early period of the larva state, but is greatly enlarged as the period of transformation approaches. It also unites, like the former, with a set of the transverse nerves (*h*), and then passes outwards about midway across the recti muscles, between which it penetrates, and pursues its course upwards to the lateral and dorsal muscles of the segments, and which are to act upon the future wings. The second nerve from the ganglion divides, like the corresponding one from the ganglion of the preceding segment, into two branches, one of which (*k*) crosses the smaller rectus muscle, and passes beneath the larger to the dorsal muscles of this segment, and the second is given directly to the third pair of legs. The fifth ganglion (5), which is situated at the anterior part of the fifth, or thoracico-abdominal segment, belongs, as we shall hereafter see, to the thorax. Like the abdominal ganglia it gives off two distinct pairs of nerves, the anterior of which crosses the smaller, and descends beneath the larger rectus, and is distributed to the muscles which afterwards connect the thorax and abdomen of the perfect insect; and the second, a smaller pair, passes diagonally backwards below the third rectus, to the triangular and transverse abdominal muscles. These are the nerves of the thorax in the larva of the Sphinx. In other species there are some marked differences in their mode of distribution. Thus, in the *Cossus ligniperda*, as shown by Lyonet, the first and second subœsophageal ganglia are closely approximated together, and have no intervening cords, and their nerves, consequently, pass diagonally backwards, and not transversely, as in the Sphinx. The nerves for the future wings are not derived, as in the Sphinx, from the ganglionless parts of the cord, but from the ganglionated portion alone, and the distance between the fourth and fifth ganglia is considerably shortened. In the larva of the nettle butterfly, *Vanessa urticæ*, as formerly shown by us,* the *alary* nerves are derived directly from the cord itself, between the second and third and third and fourth ganglia, but they do not unite, as in the Sphinx, with a nerve from the next ganglion, but only with the transverse nerves. But in some of the *Bombycidæ*, as in *Odoncstis potatoria*, we have found the same connexion to exist between the alary nerves and those of the ganglia, as in the Sphinx, and a similar union also between them and the transverse nerves. This is particularly interesting from its proving that three distinct branches enter into the formation of the nerves for the future wings. We have found a similar double origination of the alary nerves in the vermiform larvæ of Hymenoptera, as in *Athalia centifoliæ;* and Burmeister has detected a similar condition of the same nerves in the larva of one of the Coleoptera, *Calosoma sycophanta*, and, as we shall presently see, a similar condition exists even in some perfect insects. Burmeister, who observed these connexions of the nerves in *Calosoma*, and called them *auxillary connecting nerves*, has somewhat curiously remarked that he believes they have not before been observed in any insect, particularly in the Lepidoptera, in proof of which he adduces Lyonet's description and delineation of the nerves in *Cossus*, in which, as we ourselves have found, they certainly do not exist. The reason for this difference of manner in which nerves that are given to similar parts in insects of the same order and family originate, is a matter worthy of much consideration.

Nerves of the abdomen.—All the nerves from the sixth to the terminal ganglion belong to the abdomen, and are nearly uniform both in number and distribution in the segments. Each ganglion produces one pair of large, and one of small nerves, entirely distinct from the series of transverse nerves (*o*) that lie loosely upon the cord.

It will be remembered that, according to our view of the structure of the cord and nerves, each nerve from a gangliated portion of this cord is formed of one set of fibres from the external or gangliated part, and one from the aganglionic or motor column (*fig.* 400), which passes over the ganglion (*a*), but so closely attached to it as to appear as if it formed a part of that structure. These, therefore, are quite distinct from the transverse nerves (*c*). The anterior pair of these nerves from the gangliated cord pass laterally across the smaller rectus, having first received a minute branch from the transverse nerves, and, while passing beneath the larger rectus, each one gives off its first branch (*p*), and when passing between the second and third oblique muscles its second branch (*q*), which is directed forwards, and a little farther onwards its third (*r*), and its fourth (*s*), which are directed backwards. The main trunk (*t*) then crosses the great lateral trachea, and having received another filament from the transverse nerve (*n*), divides into two branches (*t*), which pass upwards between the dorsal oblique and recti muscles, and are divided into numerous ramifications. About midway across the dorsal recti some of the branches form a small plexus (*v*), before they are ultimately distributed to the muscles and tegument. The two first divisions of this nerve merit particular attention. The first (*p*) passes backwards beneath the greater rectus, and divides into two branches. The anterior one (*v*) is distributed to the four oblique muscles, and to the external or under surface of the rectus, which, as we shall presently show, is supplied on its internal surface from the transverse nerves (*l*). The second division passes backwards and is given, one portion to the under surface of the smaller rectus, and the other to the great oblique, while the termination of this portion (*w*) is continuous with a filament of the second branch of the transverse nerves (*l*). Some branches from this nerve pass between the triangular and second oblique muscles (*x*), and others are given to the latero-abdominal. The second branch (*q*) of the great moto-sensitive nerve passes beneath the great oblique, and gives off branches to the transverse abdominal muscles (*y*), and the latero-abdominal (*z*), while another supplies the latero-abdominal (31) and the oblique constrictor of the spiracle (25), and then divides into two portions, one of which is given to the *retractor valvulæ* (27), and the other to the transverse lateral muscles (24). The divisions of this branch of the moto-sensitive nerve are particularly interesting. Before dissecting these nerves we had supposed that the constrictor of the spiracle (25) and the retractor of the valve (21) were supplied by the transverse nerves, and hence were surprised on finding that their nerves were derived from the great moto-sensitive of the gangliated cord,

* Phil. Trans. 1834.

by which it is presumed they are thus endowed with voluntary power and sensation. But on reflection it will appear that this ought really to be the case. To enable the insect to make a forcible expiration and close its spiracle, which is evidently an act of volition, the great constrictor of the spiracle ought to be endowed with voluntary nerves. On the other hand, since, as we know from experiment that the insect has a voluntary power of closing, it must also have a similar power of opening the orifice, and, consequently, the retractor valvulæ ought to be supplied from the same source as the constrictor. The remaining portion of the trunk of these nerves passes forwards and outwards, crosses the retractor of the spiracle and gives off its third branch, which is again divided, and sends one portion backwards to the anterior (18) and the transverse abdominal muscles (17), and the other forwards to the transverse lateral (23). The remaining portion of the nerve is distributed to the dorsal muscles and teguments. The second nerve from the gangliated part of the cord is much smaller than the first. It passes diagonally backwards and outwards, and divides into two branches, the first of which is given to the latero-abdominal muscles, and the second to the triangular and transverse median, while the other (*k*) passes downwards and outwards, and is continuous with part of the third branch of the transverse nerves (*i*).

Besides the nerves thus described as belonging to the moto-sensitive cord in the thorax and abdomen, there are others that merit particular consideration, both from the circumstance of their lying loosely above the cord, and from their special distribution. These nerves, which were formerly distinguished by us* as *transverse nerves* from the direction of their principal branches, and as *respiratory* from their special distribution to the respiratory organs, were discovered by Lyonet, and are delineated and particularly described in his anatomy of *Cossus ligniperda*. There is a plexus of them in every segment of the thorax and abdomen. Like the alary nerves of the cord in the thorax, there is a little difference in the distribution of some of them in the Sphinx from that of the corresponding plexus in the Cossus. In our earlier examinations of these nerves† we believed them to originate from the posterior part of each ganglion of the cord, and this also was the opinion of Lyonet with reference to those in the Cossus which constitute the second and third plexus of the thorax, and the last of the abdomen, and which, he expressly states, do not come from the cords, but from the ganglia.‡ We have since been satisfied that the plexus in one segment is connected with that in each succeeding one by means of a minute filament, derived from the transverse portion of these nerves, and which, passing laterally over and very close to the ganglion of the cord, joins its fellow of the opposite side, in the middle line behind it, to form the longitudinal portion of the next plexus, such filament gathering a few additional ones from the upper or motor surface of the cords. Hence, as we have stated,* these nerves are of mixed character, and contain some voluntary motor fibrils. Each plexus is formed of these two filaments, which, closely approximated together, pass backwards along the median line above the cord, until they arrive just before the next ganglion, where they diverge nearly at right angles, and are closely approximated to another series of fibres that runs in a commissural manner transversely across the body, from one side to the other. On each side a filament (*e*) is given off from the transverse nerves to unite with the moto-sensitive (*f*) close to the inner side of the smaller rectus. Near the external margin of that muscle it gives off another branch (*g*), which passes forwards upon the muscle, unto which it gives filaments, and then turns suddenly outwards (*h*), to join a branch from the great moto-sensitive nerve, while a smaller branch is continued onwards to supply the remainder of the muscle. This union is exceedingly interesting, and illustrates the fact that, even in the Invertebrata, some of the nerves in one part are connected by loops with those in others, as noticed by physiologists in the Vertebrated classes. The next branch (*i*) of the transverse nerves is equally interesting from the same circumstance. It is continuous in the same manner with another branch of the moto-sensitive (*k*). This branch is composed of fibres that are approximated to the transverse trunk, and pass some from without inwards, and others from within outwards, to form the nerve (*i*), leaving between them at its base a little triangular interspace, covered by a membrane and resembling the plexus (*b*). This nerve passes directly forwards until it arrives at the insertion of the greater recti (*j*), where it gives off a large branch to those muscles, and then passing beneath the oblique muscles, unto which it is distributed, and to the triangularis, becomes connected by loops with the second pair of moto-sensitive nerves (*k*) in the preceding segments. Neither of these two branches have been delineated by Lyonet in the Cossus. The next branch (*l*) of the transverse nerves is given to the tracheæ and visceral surface of the great rectus, after which the trunk of the nerve passes outwards until it arrives at the tuft of tracheal vessels which are situated just behind the spiracle (F). It there divides (*m*) into two branches, one of which passes on each side of these tracheæ. Some filaments from the anterior branch pass inwards along the trachea towards the alimentary canal, while others are distributed to the transverse lateral muscles, dorsal recti, and lateral muscles of the dorsal vessel. The other division of the nerve also gives branches to the tracheæ

* Phil. Trans. 1832, part ii. p. 389, and 1834, part ii. p. 401, also 1836, part ii. p. 544.
† Op. cit. 1832.
‡ Traité Anat. de la Chenille, 1760, also 1762, p. 98 and 204.

* Phil. Trans. part ii. 1836.

and to the moto-sensitive nerve (n), and, like the other, the obliqui and recti muscles and dorsal vessel. This division of the transverse nerve into two branches before it arrives at the trachea is not figured by Lyonet in the Cossus. In his delineation the transverse nerve crosses the trachea singly, posteriorly to the spiracle, where it communicates, as in the Sphinx, with the first moto-sensitive nerve from the gangliated cord, but does not give off a large branch anteriorly to the spiracle. We are thus particular in our description of these nerves, because it has sometimes been supposed that their distribution is precisely the same in all Lepidoptera, but which it is thus seen is not the case.

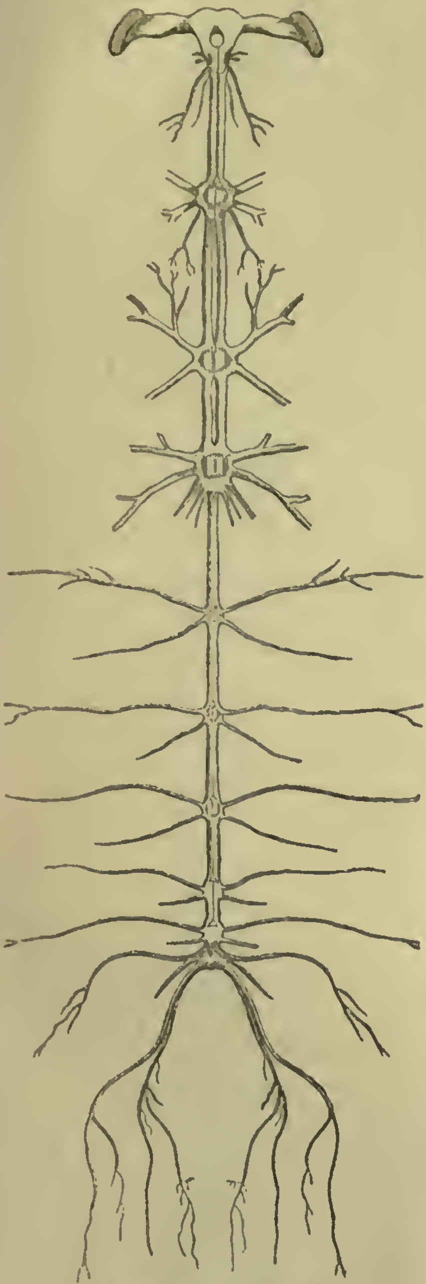
Such, then, are the origins and the distribution of the nerves in the larvæ of Lepidoptera, into the description of which we have entered thus minutely in order to show that some nerves are distributed, more especially than others, to parts concerned both in the organic functions and the voluntary motions of the animal, and that others are given almost exclusively to parts that minister entirely to sensation and volition. Of the first kind are those which we have designated respiratory nerves; of the second are those we have described as the moto-sensitive, the proper nerves of the cord. The distribution of the first so especially to the respiratory organs is a circumstance which justifies us, we think, in still regarding them by that designation, whether they be considered as constituting a distinct system, as formerly supposed, or as being of a mixed character, connecting the organic with the voluntary functions of the body, as suggested by Professor Müller, and as we now regard them. In our earliest inquiries into the structure and uses of parts of the nervous system in insects, we first described these nerves with reference to function, as *respiratory* nerves, but it was afterwards suggested by Professor Grant that these '*might* be motor nerves,' an opinion founded analogically upon the existence of a loose and easily detachable structure situated upon the nervous cord in the Scorpion and the Centipede, and which was imagined to be the motor tract, but which has since been shown to belong to the *vascular* instead of the *nervous* system. The structure which we regard as the true motor column, we have always found in close apposition with the sensitive, and in no instance lying freely upon or loosely attached to it. That the transverse nerves are indeed of a mixed character may readily be inferred from the description we have above given of their peculiar structure, which was in part noticed by Lyonet,* who called these nerves *brides epinières*. It is distinctly seen that three sets of fibres enter into the composition of them. The commissural set, which runs transversely across the cord to each side of the body, is perfectly distinct from the longitudinal that form the single loosely attached longitudinal portion of each plexus above the cord. The peculiarity of their distribution is also as remarkable as their structure. We have seen that they are given to the muscles of the wings, not separately, but approximated to other nervous trunks, which are derived both from the compound cord and from the ganglia; that they are given to the muscle that connects the alimentary canal to the general muscular structures of the body; that they are connected with the nerve from ganglia of the cord in each segment, are also given separately to the organic structures, the tracheæ and dorsal vessel; and that these nerves alone follow the course of the tracheæ inwards to their distribution on the alimentary canal; from all which it may be inferred that their function is certainly in part organic; while the fact of their being also in part continuous with some of the nerves from the cord which are distributed to voluntary muscles renders it equally apparent that they are in part also connected with the function of volition.

The nervous system of the perfect insect differs considerably in the size and relative position of its parts from that of the larva. Instead of its being almost equally distributed to every segment of the body, the greater proportion of it is removed forwards and concentrated in the head and thorax. This concentration takes place in every insect that undergoes a complete metamorphosis. The great principle upon which the development of the nervous system depends, is the approximation and concentration of the ganglion of the different segments, the shortening of the cords, and the formation of new trunks, by the enlargement, the changing of place, and the aggregation of several nerves into one bundle, occasioned and rendered necessary by other changes that take place in the body at a certain period. A concentration, therefore, of the nervous matter is regarded, both in the perfect and larva condition, as a proof of a higher stage of development in an insect than when the nervous matter is more equally distributed. On this account partly it is that the Coleoptera are considered the higher forms of insects, because, in addition to a more perfectly developed form of the tegumentary skeleton, there is also in them a concentration of the nervous masses, which, in the more perfect species of the order, are confined entirely to the region of the head and thorax. This is the case even in the larva condition of some of the Lamellicornes, *Scarabæidæ*, *Geotrupidæ*, and *Melolonthidæ*, in which the nervous masses are confined to the first five segments, and the nerves radiate from them into the abdomen, as formerly shown by Swammerdam in *Oryctes nasicornis*. But although an aggregation of the nervous masses into one region of the body is usually, it is not invariably, a proof or an accompaniment of high development; since a condition similar to that of the larvæ of the *Melolonthidæ* exists even in some of the lowest forms of larvæ of other orders, as in the larvæ or common maggots of Diptera, and in some of the perfect insects, as in the Gad-fly, *Œstrus equi;* while, on the contrary, a lengthened

* Op. cit. p. 201.

form of cord and distribution of ganglia exists even in many of the more perfect Coleoptera, as in the *Carabidæ* (*fig.* 407) and *Hydrophi-*

Fig. 407.



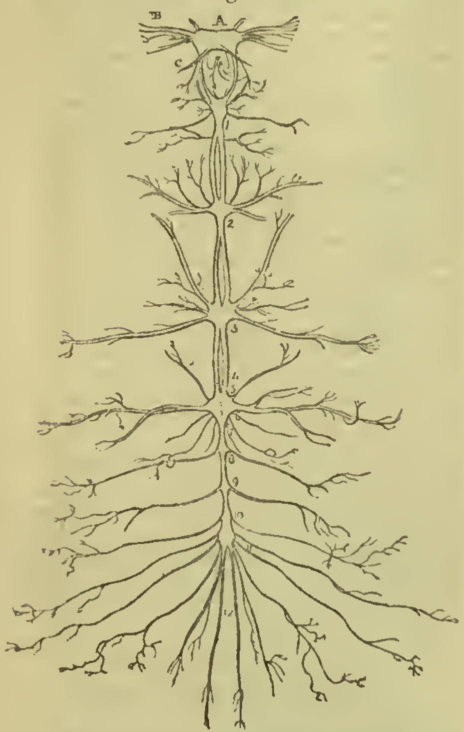
Nervous system of Carabus monilis.

lidæ. Swammerdam long ago showed this aggregation of nervous matter in the maggot of the cheese-hopper, and Burmeister has since observed even a more concentrated form in the larva of *Eristalis tenax*, the rat-tailed maggot of cesspools and privies. In the latter instance, as seen also by ourselves, the nervous system consists of a short nodulated cord, which does not extend beyond the three very short thoracic segments, and the greater portion of the body, the nine posterior segments, receives its nerves directly from the cord in the thorax, and not from a ganglion in each segment. This is a circumstance the more remarkable, if, as believed by Straus and others, the existence of the ganglia is regulated entirely by the mobility of the segments or the existence of appendages, because, in these instances, the extremities of those segments in which the cord is placed are undeveloped, or only, as in Eristalis, in the most rudimentary form and almost useless, the sole organs of locomotion being the abdominal or false legs, while in the common maggots (*fig.* 358) both the abdominal and thoracic legs are absent, and locomotion is performed equally by every segment of the body. In addition to this it may be stated that in some of the active larvæ of the most perfect Coleoptera, as in the *Carabidæ*, there is a lengthened form of cord and a ganglion in almost every segment of the body. Burmeister found the brain and twelve sub-œsophageal ganglia in the larva of *Calosoma*, and yet the insect possesses only six thoracic legs, the abdominal ones being entirely absent, excepting only the caudal leg or extremity of the abdomen, in which segment there is no ganglion. These facts will prove that although a concentrated form of the nervous system usually exists with a more perfect development of other parts of the body, it exists also when the development of other parts is imperfect. It is not, then, the immobility of the segments that regulates the disappearance of the ganglia, since, as Burmeister has justly remarked, there is as little motion of the segments of the abdomen in the perfect *Carabidæ* and *Lucanidæ*, in which cords and ganglia exist, as in the *Melolonthidæ*, in which they are absent. Neither is it necessary that ganglia should be present as a means of supplying energy in segments upon which, as in *Eristalis*, the entire locomotive power of the insect depends, or that when ganglia are present they are necessarily connected with the function of motion.

The most concentrated form of the nervous system in all its states exists in the *Lamellicornes*, the *Scarabæidæ*, and *Melolonthidæ*; but it is remarkable that even in these the development of the brain or supra-œsophageal ganglia is less perfect in the larva state than any of the other ganglia, and is not more advanced than in the Lepidoptera, in which, in the caterpillars of the nettle butterfly, *Vanessa urticæ*, so late as the middle of the last period of the larva state we have found these ganglia very distinct from each other, being only approximated in the middle line by their convex surfaces. Towards the latter period of the larva state they become rapidly more and more united, and at the time of change have formed one continued mass, placed transversely across the œsophagus. A similar condition of the brain exists in the soft-bodied larvæ of the

Lamellicornes, as shown in Swammerdam's drawing of *Oryctes*,* and Burmeister has delineated a like condition in the larva of *Calandra Sommeri*.† We have before seen (*fig.* 405) that such is also the case in the brain of *Timarcha*. From this it would appear that the cerebral ganglia are the parts of the nervous system last perfected in the larva, while it is interesting to observe that the reverse is the case as respects the terminal ganglion; that part, as correctly remarked by Professor Grant,‡ being the first to advance forwards and become united to the penultimate ganglion, to form the great caudal mass, at an early period of the larva. This is evident in the *Timarcha*, in which the eleventh and twelfth ganglia have coalesced into a single mass, while the cerebral ganglia only just meet above the œsophagus. But this is not the case in the perfect insect, (*fig.* 408,) in which the cerebral ganglia (A)

Fig. 408.

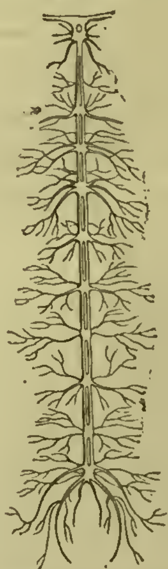


Nervous system of perfect state of Timarcha tenebricosa.

A, cerebral mass or brain; B, optic nerves; C, origin of sympathetic.

have become greatly enlarged, united together, and represent a distinct brain, from which proceed the nerves of sense, and united by long crura to the medulla oblongata (1), from which are given off as before the nerves of the organs of manducation. The cords are enlarged, as also are the three ganglia of the thorax and their nerves, and a coalescence has taken place between the fourth, fifth, and sixth ganglia, their intervening cords being entirely obliterated, and the nerves aggregated together are now derived from one mass, the great meta-thoracic ganglion, the last part of the nervous system in the thorax. A similar change has also taken place in the remaining part of the cord and ganglia, which now forms the abdominal portion. The cord between each of the ganglia has been shortened, and the tenth, eleventh, and twelfth are united and form the caudal mass, which is situated about half way across the abdomen. Such are the changes that take place in the nervous system of an inferior type of Coleoptera; in the higher forms, as in the *Melolonthidæ*, the series of approximated ganglia does not extend beyond the middle of the meta-thorax, the cords being terminated by a kind of *cauda equina*, all the nerves that go to the abdomen are aggregated together and extended into that region over the post-furca. A similar structure, but in a less complete form, exists in the *Dytiscidæ*, in which, as in the *Hydaticus cinereus*, a short cord is found with seven constrictions upon it, corresponding to that number of ganglia which probably existed in the larva state, but have nearly disappeared during the metamorphoses. But that this concentrated form of the nervous system is not necessarily connected with high development of other parts of the body is further shown in the common Earwig, *Forficula auricularia*, in which there are ten distinct sub-

Fig. 409.



Nervous system of the Earwig (Forficula auricularia).

œsophageal ganglia. The first, or medulla, is large and closely connected by very short crura with the brain, there being only a narrow

* Biblia Nat. tab. xviii. fig. 1.

† Zur Naturgeschichte der Gattung Calandra, fig. 13, Berlin, 1837.

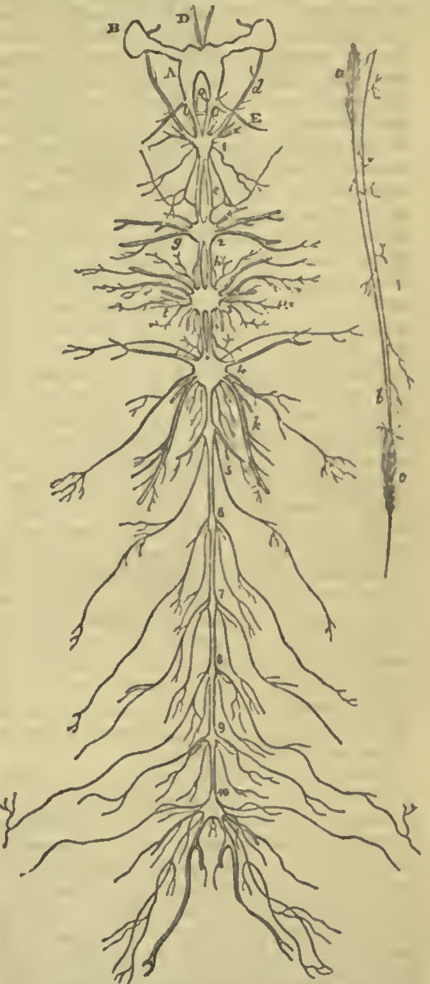
‡ Phil. Trans. 1832, part ii. p. 384. Outlines of Comparative Anatomy, p. 193.

passage between the two for the œsophagus. Each segment of the thorax contains a ganglion, the meta-thoracic one, which gives nerves to the wings, being the largest. In the abdominal portion of the cord, which extends as far as the penultimate segment, there are six double ganglia very distinct from each other. This is exactly the number found by us in the same portion of cord in the *Carabidæ*, although, according to Burmeister, there are only five. Thus, then, in the *Forficulidæ*, in which there is the most extensive motion of the segments of the abdomen, there is the same number of ganglia as in the *Carabidæ*, in which most of the abdominal segments are anchylosed together and immovable, as in the Lamellicornes, in which the whole of the cord is situated within the region of the thorax. In the oil-beetles, as in *Proscarabæus vulgaris*, there are as usual three thoracic ganglia, the largest being the meta-thoracic, although the proper wings, and scarcely even the elytra, do not exist. In the abdominal region there are five ganglia, but smaller than those of the thorax, although it is stated by Burmeister* that these ganglia of the thorax are larger than those of the abdomen when perfect organs of flight are developed, but smaller when they are absent. So far as our own observations have extended, we have invariably found the thoracic ganglia larger than the abdominal, whether organs of flight exist or not, a condition that might naturally be expected whether the ganglia be connected with the production of nervous energy in the parts, or be only the centres of sensation. In the full-grown larva of this insect, of which we have examined a considerable number, but which at present appears to be scarcely if at all known to naturalists, we have found twelve perfectly distinct sub-œsophageal ganglia. Of these the fifth was the largest and separated from the fourth only by a very short cord, as were also the eleventh and twelfth, besides which the twelfth was larger than the eleventh, and appeared as if formed at an early period of two approximated ganglia. That in the earliest state of this insect there are thirteen sub-œsophageal ganglia seems highly probable. On watching the changes that take place it is found that this double terminal ganglion becomes united to the eleventh, and that a similar union takes place between the fourth, fifth, and sixth, so that only five separate abdominal ganglia exist in the perfect insect. In the *Forficula*, which does not undergo a perfect metamorphosis, a similar change appears to take place at a much earlier period, the terminal ganglion being distinctly formed of two masses, and the ganglion of the meta-thorax or wing-bearing segment of three. A similar change appears also to occur in the *Staphylinidæ*. In *Creophilus maxillosus* (*fig.* 341), in which the abdominal segments are as freely moveable as in the Earwig, but which undergoes a more complete metamorphosis, there are nine sub-œsophageal ganglia, only the last three of which are abdominal, the last five segments being entirely without ganglia.

* Op. cit. p. 281.

There is exactly the same form and position of the nervous system in the common species, *Goërius olens*. On comparing these circumstances it is found that a much smaller number of ganglia in general exists in those perfect insects which have undergone a complete metamorphosis than in the larva state, and than in those that scarcely change their form. In the *Gryllidæ*, *Acrida viridissima* (*fig.* 410), there is

Fig. 410.



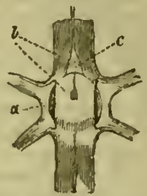
Nervous system of Acrida viridissima.

A, brain; D, antennæ; B, optic nerves; *d*, mandibular nerve; *e*, auxillary connecting nerve; *g*, nervo of prothoracic legs; *i*, of second pair of legs; *k*, third pair; *a*, tendon of flexor muscle with its nerve accompanying it to its insertion at extremity of the femur; *c*, second head of the same flexor muscle at the end of the tibia.

the same number of ganglia as in the Forficula, and a similar difference in the size of the thoracic ganglia. But in this insect there is also a closer lateral approximation of the abdominal cords, and a comparatively smaller size and more elongated form of their ganglia, evidently shewing a tendency to a more concentrated structure, although the cords still remain more distinct from each other than in the higher forms of Coleoptera. In the *Achetidæ*, of which the Mole-cricket affords us an example, as combining amazing strength and activity with apparently highly developed instinct, there is a more complete general form of the nervous system than in the *Acrida*. The ganglia of the thorax are particularly large, but the ganglia of the pro-thoracic segment, in which, and in the enormous limbs, nearly the whole strength of the insect, as we have before seen, is concentrated, does not equal in size the meta-thoracic ganglion, which is nearly one-third larger than either of the others, although the wings unto which it is given, as well as to the legs, are only of secondary importance as organs of locomotion, and although a fifth and much smaller ganglion is also attached to the meta-thoracic. The cord of the thorax is also large in proportion to the size of the ganglia. In the abdomen the relative size of the cord is less than in the *Acrida*, and there are only three small oval ganglia in it besides the large terminal one, so that the cord is extended scarcely half way through the abdomen, and yet the whole of the segments, and more especially the posterior ones, are capable of the most free and extensive motion. Thus, then, although in these and other forms of insects, particularly in the Hymenoptera, Lepidoptera, and Diptera, the ganglia are usually aggregated together in certain segments, apparently as a means of concentrating the energies of the animal when one particular region of its body is more actively employed than another, the presence of ganglia in the different segments is not more indispensable to the mobility than to the sensibility of these parts to external impressions, since the nerves that convey both motion and sensation to them may be derived from ganglia in distant segments, and yet the freedom of motion be not less than when each segment contains its own ganglion, and derives its nerves immediately from it.

The *structure of the cords* in the perfect insect is almost as distinct as in the larva, although the whole of the parts have become more opaque and closely connected together. In some instances it is more strongly marked than in others after the cord has remained for some time in spirits of wine, which is necessary before an examination of its structure is attempted. In many of the Coleoptera the motor column is seen passing in almost a direct line over the ganglia of the sensitive, but the transverse nerves are less easily detected, and in many instances appear to have become united with the other structures. We have, however, seen what we regard as such in the *Gryllidæ*, and more distinctly in *Gryllotalpa*, lying upon and above the motor column. In some specimens we have not found them from their being easily detached in those insects, and, probably, removed during dissection. But in these families we have always found the motor column strongly marked, particularly while passing over the ganglia of the thorax. In the *Carabidæ* (*fig.* 411) the course of the motor column (*b*) is distinctly indicated as it passes over the surface of a ganglion (*a*) by a

Fig. 411.



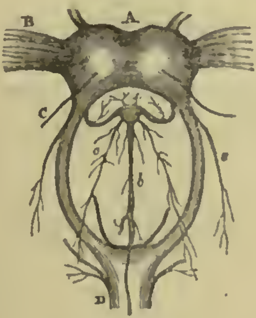
A portion of the gangliated abdominal cord of Carabus monilis.

a, a ganglion of the external or sensitive column; *b*, the upper or motor column; *c*, a ganglion of the transverse nerves.

longitudinal sulcus. Just as it is entering upon and also as it is leaving the surface of the ganglion, the motor column gives off a minute branch to join with the large branch from the ganglion of the sensitive column, and with it form a compound nerve. At a part of the cord corresponding to the anterior margin of each ganglion, lying upon and attached to the motor column on each side, is a minute gangliform mass (*c*), which we regard as the analogue of the plexus of the transverse nerves. It is of an obtusely angulated shape, and is attached to the motor column by a minute filament from its base on either side, and which passes outwards in the direction of the anterior pair of nerves. From its upper part in the median line extends another filament, the course of which we have not been able to follow. In *Lucanus cervus* the motor column is slightly elevated while passing over the ganglia, and at the anterior margin of each gives off a filament to join with the nerve from that part of the cord. We have sometimes observed attached to the motor column, just as it had passed over the meta-thoracic ganglion, on each side a little gangliform mass, which may possibly be part of a series of nerves like those on the cord in the *Carabus*. In the aculeate Hymenoptera, in which the ganglia of the thorax are large, the motor column is readily observed, but in some of the Terebrantia, as in the Turnip-fly, *Athalia centifoliæ*, when the cord is examined by a strong light, the motor column is most distinctly seen both on the ganglia of the thorax and abdomen, and in this insect exhibits an appearance which we have not observed in any other. This is a slight increase in the diameter of the column when it has passed about half-way over a ganglion, and a decrease to its original size when leaving it. Two filaments appear to be given off from the column to join the nerve from the ganglion, one as usual at the anterior margin of the ganglion, and the other, which appears to be the analogue of the transverse nerves, united to the motor column when about half-way over the ganglion. This enlargement of the motor column is greatest where it is passing over the thoracic ganglion, but is best seen on the abdominal ones. This fact has appeared particularly interesting to us, as we have elsewhere remarked,* from its seeming to be analogous to similar enlargements on those parts of the spinal cord in man and other vertebrata, from which proceed the nerves to the arms and lower extremities of the body, and corresponds to the apparent greater necessity for accumulations of nervous matter at those parts of the cord. In Lepidoptera the cord is less easily examined in the perfect than in the larva state owing to its increased opacity, but the transverse nerves are not only distinct but have been removed forwards and now pass off on either side midway between the ganglia.

The brain and its nerves do not acquire their full development until near the termination of the pupa state. The supra-œsophageal ganglia (A) of the larva, which, for convenience of description, we have called after Burmeister the *cerebrum*, are in reality the analogues of the *corpora quadrigemina*, and the first sub-œsophageal of the *medulla oblongata*. Burmeister has designated this the *cerebellum*, but of that part of the brain in vertebrata we believe there is no analogue in any of the invertebrata. Instead of the cerebral mass being divided into two ganglia, as in the larva, it has now (*fig.* 412, A) acquired a compact form; it is

Fig. 412.



A, *brain of Timarcha tenebricosa*; B, optic nerves; C, origin of the sympathetic and the crura; D, the medulla oblongata; *b*, the vagus or visceral nerve passing back from its ganglion; *e*, lateral nerves from the ganglion.

convex on its upper surface with a slight depression in the middle line, and concave on its under, to adapt it to the form of the œsophagus, across which it is placed. At its sides it gives off the large optic nerves (B), which are almost equal to it in diameter. They pass directly outwards and are usually swollen into the form of an oblong ganglion, but are again constricted before they arrive at the optic foramen, through which they pass and are immediately expanded into an immense number of fine filaments for the complicated organ of vision. There are enlargments upon these nerves at their base even in the larva state (*fig.* 405). From the most superior portion of the cerebrum originate the nerves of the *ocelli*. They vary in number from one to three, and are little pyramidal elevations situated on each lobe, as seen in *Acrida* (*fig.* 410), posteriorly to the antennal nerves (D). They are each covered by a dark choroid, and in other respects are distinct nerves of vision. When three exist, as in Hymenoptera, the third is situated in the middle line between the others, and appears to be derived in part from each lobe, so that in this ocellus the vision of both sides of the brain is combined. In the *Vespadæ*, however, according to Burmeister, the three ocelli originate from a single foot-stalk, and not separately, as in the *Apidæ*. On its anterior surface the cerebrum gives off the antennal nerves. These also, in many instances, have a ganglionic enlargement at their base, as is well seen in some of the *Ichneumonidæ* and other Hymenoptera, and as shown by Straus Durckheim in *Melolontha*. The antennal nerves vary in position, being sometimes near the middle line and at others close to the base of the optic, but in every instance anterior to them. At its anterior and inferior surface the cerebrum produces the two remaining pairs of nerves. The most external, the glosso-pharyngeal, unites with its fellow of the opposite side to surround the œsophagus, as in the larva. It is seen very distinctly in the pupa state (*fig.* 415, *f*) of the sphinx, and also in many perfect insects, as in *Acrida* (*fig.* 410). It supplies the under-surface of the throat and part of the œsophagus, and a small branch is also given from its base to the sides of the mouth. At its inner side originates the recurrent or *vagus* nerve, which, after passing a little forwards, ascends and forms its ganglion on the upper surface of the pharynx, and then passes backwards along the œsophagus, as in the larva. In some insects, as in Orthoptera, it originates from a portion of the crura, as in Crustacea, but its course and direction are always the same although appearing to vary, as we shall presently show when describing it as an organic nerve. The sympathetic originates, as in the larva, from the posterior part of the brain. One circumstance that particularly distinguishes the brain from the other ganglia is its more uniform opacity and greater softness, and disposition to deliquesce when exposed for a short time to the air. It is usually larger than most of the other ganglia, excepting perhaps the mesothoracic. In Hymenoptera it is larger than in other insects, a curious circumstance this if it may be supposed to have any reference to the comparative instinct of different species. In Diptera and Orthoptera it is also of great size. We were once desirous of knowing whether it contains any cavities or ventricles, but after the most careful search we have been unable to detect any. It is an almost homogeneous mass, penetrated throughout its whole substance by minute air-vessels, which ramify within it and also in the substance of the optic nerve. This is one of the circumstances that lead us to suspect, as formerly suggested by Dr. Kidd in his anatomy of the Mole-cricket,* that the course of the blood in the different structures

* Prize Essay, p. 11.

* Phil. Trans. 1826.

always accompanies that of the trachea. The *crura* vary much in length in different species. In Neuroptera, Hymenoptera, Lepidoptera, Diptera, and Homoptera they are short and thick, and form with the medulla a thick collar, through which the œsophagus passes as a narrow tube; but in the *Gryllidæ (fig.* 410), and more particularly in the *Lucanidæ (fig.* 413), they are excessively elongated, and they are also of great length in the *Timarcha*. The *medulla oblongata* varies much in size; in some, as in the Lepidoptera, it is as large as one of the lobes of the cerebrum, while in others it is scarcely thicker than the crura. It is always largest where large nerves are required for the parts of the mouth, which in all cases are derived from it. In this respect there is a striking analogy between it and the medulla oblongata of vertebrata. The anterior pair of nerves from this part are given to the labium and lingua, while the two next pairs are given to the mandibles and maxilla. In the distribution of these nerves there is great similitude to that of the fifth pair in the higher animals. In the larva state these nerves are always distinct from each other, but in the perfect they are often united at their base into one trunk. This is the case in the *Timarcha* and *Gryllidæ*. The anterior pair is the largest in mandibulated insects, and supplies the powerful mandibles, while the posterior pair is given to the maxillæ. The union of these nerves at their base is interesting from the circumstance that during manducation a consentaneous movement of these parts is required, since, while the mandibles are employed in chewing, the maxillæ are also employed in turning and assisting to pass the food into the pharynx. In the *Sphinx ligustri*, and other Lepidoptera, the chief portion of the mandibular nerve has disappeared in the perfect state, in consequence of the atrophy which has taken place in the mandibles during the transformations; but one branch of the nerve which exists in the larva state appears to have become approximated to the maxillary nerve, which is now greatly elongated and given to the proboscis, the representative of the maxillæ of the larva. The branch that appears to have belonged to the mandibular nerve is extended along the concave or inner side of each half of the proboscis, where the sense of taste may justly be suspected to reside, and is traceable very nearly to the extremity of the organ, where the papillæ we formerly noticed are situated, and in the direction of which this nerve is extended. From this we believe it to be analogous in function to the gustatory portion of the fifth nerve in vertebrata. In *Lucanus cervus* the mandibular nerve is of great length, and is so extensively developed as to afford almost a proof of the elongation of nerves during the metamorphoses of the insect. We have traced this nerve from its origin *(fig.* 413, *c)* into the base of the mandible, which it enters a little external to the insertion of the flexor muscles, where it is divided into three trunks, the inner one of which we have traced very nearly as far as the apex of the mandible. The other two are situated more externally.

Fig. 413.

Nervous system of Lucanus cervus.

A, the brain; B, optic nerves; C, sympathetic; D, antennal nerves; *a*, ganglion of the vagus nerve; *b*, the nerve; *i*, its division on the œsophagus; *d*, nerve to the first pair of legs; *f*, nerve to the wings, giving off at its base a small nerve to the elytra; *g*, nerve to second pair of legs; *k*, to third pair; *l*, abdominal cord and ganglia.

The most posterior one is given to the muscles within the head, and the other passes along the outward part of the interior of the mandible to its apex. The *medulla oblongata* with the continuation of the nervous cord in all Coleoptera passes under the bony arch or *tentorium* at the base of the skull, protected on both sides, as in *Melolontha*,* *Dyticus*, and *Hydröus*, by the *laminæ posteriores*, which inclose it, as in a canal, distinct from the œsophagus, that passes along above it, and from which it is separated by a fine fibrous membrane. The crura and the base of the cerebrum rest upon and are partly protected on each side by the *laminæ squamosæ*, which thus, as it were, form a kind of internal skeleton for the protection of the soft part. The optic nerves at their base rest upon the laminæ in their course to the eye, and extend as far outwards as the *laminæ orbitales* through the foramen in which they pass, and are immediately expanded into an immense number of filaments which form part of the organ of vision, as we shall presently describe. The whole of the cerebrum is loosely covered by a fine transparent membrane that is continuous with the fibrous membrane that covers the cord. In some instances, as in the *Bombus terrestris*, it is very distinct, and in others, as shown by Burmeister, is studded with minute opaque rounded elevations, arranged in the form of squares. It appears to be reflected along the course of the optic nerves, and to be continuous in part with the margins of the *laminæ squamosæ*, and separates the brain from the muscles, by which it is on almost every side inclosed. In *Lucanus cervus*, instead of the medulla passing under a simple arch or tentorium, the laminæ laterales are approximated and form a double ring (*fig.* 388, *f*), through the inferior of which, as through the ring of a vertebra, the nervous cord passes in its course to the prothorax. In the Orthoptera, as in *Blatta Americana* and *Gryllotalpa*, we have seen the same structure, but in these the ring is lengthened and forms a more distinct canal. In the Hymenoptera, as in the hornet and humble-bee, the form of the part is exactly the same, and the cord passes through a short bony ring in its passage to the thorax. There is a somewhat similar structure in Lepidoptera as in *Sphinx ligustri*, only that it is much less complete, the arch being simply a bar extended across the occipital foramen and dividing it into two, through the lower one of which the cord passes, and also on each side of it the flexor muscles of the head. A like form exists in the Homoptera, but much less perfect.

The *cord and nerves of the thorax*, which are usually much larger than those of the abdomen, we regard as the proper cerebro-spinal system, and the abdominal portion as the caudal. This is the view taken of these parts by Burmeister, with whose opinion we perfectly coincide. The prothoracic ganglion is situated immediately before the *ante-furca*, between which the cord passes to the metathorax, when it forms a great ganglion anterior to and beneath the medifurca, and then passes onwards over the post-furca to the abdomen. In the Lamellicornes and others in which the cord terminates in the thorax, and the nerves radiate from thence into the abdomen as a *cauda equina*, they pass over the post-furca in a bundle, and do not separate until they enter the latter region. In the Gryllidæ, in which most of the segments are equally developed, and there are three large thoracic ganglia, the metathoracic one is situated in the middle of the segment, and the succeeding or fourth subœsophageal ganglion on the rudimentary post-furca. In the Hymenoptera, in which there are but two ganglia in the thorax, the anterior and smaller one is situated at the margin of the metathorax, and the great ganglion at the posterior, and the cord continued from it passes through a strong bony canal or ring in the medifurca, somewhat resembling that which exists in the head, and then forms a smaller ganglion before it enters the abdomen. In the Hemiptera, in which it has been supposed that there is only one ganglion in the thoracic region, the cord between the medulla and prothoracic ganglion is exceedingly short, but is protected in its passage through the elongated neck, and then is developed into a large prothoracic ganglion, the second ganglion being situated in the middle of the meso-thorax before the medifurca. These parts are very distinct in *Nepa grandis*. In the Lepidoptera, in which the form of the thorax is more compact even than in the Hymenoptera, the cord passes on each side of the medifurca or part to which the triangular muscles are attached, and is so much enlarged as to appear almost like a portion or continuation of each of the two great ganglia situated before and behind it. The cords and ganglia of the thorax are covered in by a strong white membrane like those of the head. In the Lepidoptera this is particularly firm, so that the nervous system is not included within the cavity of the thorax.

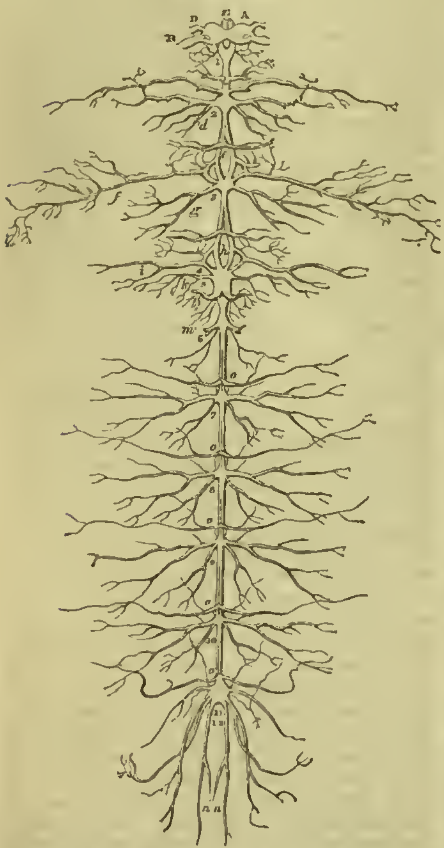
In the *distribution* of the nerves there are some peculiarities. We have seen the *auxillary connecting nerves* of Burmeister, as shown by us formerly in the larva of the Sphinx* (*fig.* 406), in many species. They exist between the cord and all the ganglia of the thorax in the *Gryllidæ* (*fig.* 410, *c*, *h*,) and between the cord and the nerves to the wings in *Athalia centifoliæ* and *Panorpa communis*. We have seen them also in *Oiceoptoma*, *Proscarabæus*, *Creophilus*, *Lampyris*, *Forficula*, *Blatta*, and even in an imperfect form in *Œstrus*, as well as in some of the Lepidoptera. They are invariably connected with the nerves to the wings, of which they form one portion, and are far more frequently met with than Burmeister appears to have supposed. We formerly† remarked on a peculiarity in the distribution of the thoracic nerves in the Sphinx, and the opinion then ventured with regard to its nature we have since had reason to believe was well founded. We have seen the auxillary

* Straus, Considerat. &c.

* Phil. Trans. 1832, part ii. p. 387-8.
† Phil. Trans. 1834, part ii. p. 394.

connecting nerves in the larva forming one portion of the nerves for the future wing of the perfect insect. The nerves for both pairs of wings are then derived separately from two portions of cord and two distinct ganglia, and this is the state in which they are also found soon after the insect has changed to a pupa (*fig.* 414).

Fig. 414.



Pupa of Sphinx ligustri. (Newport, Phil Trans.)

The connecting nerves are then derived from the cord (*e*, *h*), and being joined each to the first nerve from the next ganglion assist to form the future alary nerves (*f*, *i*). Now as the change to the perfect insect proceeds, the second ganglion (2) becomes approximated to the third (5), which gradually disappears, and the cord between it and the fourth becomes enlarged and shortened, and passes on each side of the insertion of the muscles in the centre of the meso-thorax, the cord between the second and third ganglion having also become obliterated, so that there is then no ganglion intervening between the origins of the two pairs of wings, but only a portion of cord. The nerves for the two pairs of wings then approach each other diagonally, the anterior pair being directed backwards, and the posterior forwards, until they meet and form a plexus, their roots still continuing distinct from each other; the root of the anterior being derived from the cord posterior to the united second and third ganglia, and that of the posterior from the cord connected with the united fourth and fifth ganglia. After forming the plexus, the nerves are again separated and given to the anterior and posterior wings. The reason for this curious union and complexity in the distribution of the nerves to the wings is not at first very evident, but on a little reflexion it is found to be regulated by one of those beautiful provisions in the animal economy by which the most perfect harmony in the exercise of all the functions of the body is preserved. The wings, the most powerful and most constantly employed organs, are not merely required to act with energy, but in the most perfect unison with each other, more especially in insects of long-continued or rapid flight, and hence must be supplied with power from the same centre, not merely that of voluntary motion but also of sensation. That this is the reason for this curious union of the nerves for the wings seems apparent from the circumstance that it exists in very many tetrapterous insects of rapid or powerful flight, as in the *Apidæ* and *Ichneumonidæ*, while in others, even of the same order, as in *Athalia centifoliæ*, which is well known to fly heavily and but a short distance, there is no such combination. In the Scorpion-fly also, *Panorpa communis*, it is absent, and the alary nerves originate by double roots without forming a plexus as in the larva of the Sphinx, while the flight of the insect is sluggish and but of short duration. Besides this it may be remarked that in many Coleoptera in which the anterior wings or elytra are merely elevated and nearly motionless during flight, the nerves are derived separately from the cord, and proceed to their destination without being first combined in a plexus.

The cord and nerves of the *abdomen*, as before stated, we regard merely as a *cauda equina*. We have before explained the varieties in the formation of the cord in different insects, and need but further remark that in each instance the cord in the abdomen, as in other parts, is covered in by a strong fibrous membrane, which separates it from the cavity of the abdomen. In the *Gryllidæ* we have distinctly recognised muscular fibres running transversely above the cord from one side of the body to the other. They have also been observed by Burmeister, who supposes them to assist in the function of respiration by contracting the segments, and thus aiding in the act of expiration. We have seen similar trans-muscles lying above the membrane that binds down the nervous cord in the abdomen of *Bombus terrestris*. The membrane is continuous with that which covers the cord in the thorax. A similar membrane was formerly noticed by Lyonet in the Cossus,* and subsequently by ourselves in the Sphinx.† Between this membrane and the cord there is a

* Recherches sur l'Anatomie et les Metamorphoses des differentes Espèces d'Insectes, ouvrage posthume de Pierre Lyonet. Paris, 1832, fig. 18, p. 52.

† Phil. Trans. 1834, part ii. p. 395, pl. xiv. fig. 9.

vessel which we regard as connected with the circulatory system, as we shall hereafter show.

As *nerves of organic function*, we have now to consider those which are especially given to the different internal organs, and not to the voluntary muscles. Having already considered the transverse nerves, which are distributed so especially to the respiratory organs, as nerves of mixed character, those which we regard more especially under the above designation are the *sympathetic* and the *vagus* or visceral nerves. The *sympathetic*, or *anterior lateral ganglia* (*fig.* 415, C), are situated two on each side of the œsophagus behind the brain, and anterior

Fig. 415.

Brain and nerves of the head and first segment of a pupa of Sphinx ligustri.

A, brain; B, optic nerves; C, anterior lateral or sympathetic ganglia; D, antennal nerves; E, frontal ganglion of the recurrent or vagus nerve. (*Newport, Phil. Trans.*)

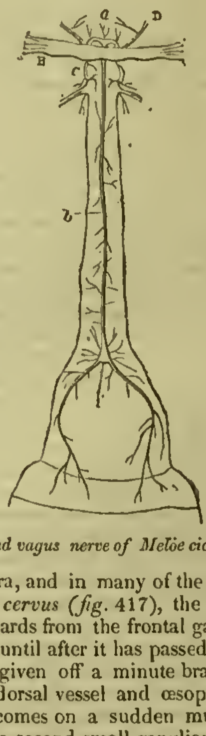
to the great muscles of the œsophagus and pharynx. They are of considerable size, being each about one-third as large as one-half of the cerebrum, and they are connected with most of the other nerves in the head. Thus, besides their connexions (*a*) with the brain, one nerve passes forwards beneath the optic nerves, and joins with a minute filament from the nerve to the antennæ, (*g*,) and also with one to the mandibles, while another passing across the œsophagus is united with the main trunk of the visceral or vagus nerve (*e*), as it passes along to the stomach, and another branch joins with the first set of transverse nerves (*h*), while other filaments passing outwards are distributed to the muscles of the œsophagus and pharynx. This latter fact, which we have most distinctly ascertained in *Meloë cicatricosus*, a large species well adapted both for an examination of this and of the visceral nerve, is particularly interesting from the circumstance that, after the most careful examination, we could not find any other nerve given to those muscles (*fig.* 416, C). We have observed a similar distribution to the muscles of the œsophagus in *Lucanus*, and also in the Sphinx, so that from their connexions we may justly conclude these ganglia to constitute at least a portion of the true sympathetic system. From their relative situation they appear to be analogous to the superior cervical ganglia of the sympathetic in Vertebrata. It is, however, an interesting fact, as noticed by Burmeister,* that these ganglia appear to be largest in some of those insects in which the recurrent nerve which we have described as the *vagus* is least developed. Thus, as shown by Muller, Brandt, and Burmeister, these ganglia of the sympathetic system have a large size in the Orthoptera, and, instead of being traceable scarcely beyond the region of the head, send off one or two branches which run along the sides of the œsophagus to a great distance, while the recurrent or vagus nerve, after uniting with these ganglia behind the brain, appears to terminate or be lost in the nerves that originate from them. In *Gryllus migratorius*, Burmeister has shown† that after the recurrent nerve has formed a minute ganglion just behind the brain, and united with the first of these sympathetic ganglia, it appears to terminate, while the same ganglion sends off posteriorly two branches, which run along the upper surface of the œsophagus, where the external one forms a small ganglion, and that the second, or most external of these anterior lateral ganglia, also sends a large nerve backwards, at the side of the œsophagus, as far as the crop, where it forms a ganglion and sends off nerves, and at the hinder part of the crop a second ganglion, from which nerves are given to the cœcal appendages of the alimen-

* Op. cit. p. 288.
† Id. pl. xxxi. fig. 6.

tary canal. Muller* had previously shewn a similar arrangement of these ganglia in *Gryllotalpa vulgaris*, and Brandt † has since further elucidated the distribution of these structures in the same insects. We have ourselves recently found a somewhat similar distribution of these nerves in one of the Coleoptera, *Buprestis chrysis*, in which the first of the anterior lateral ganglia, on each side, besides its connexion with the brain, gives off three distinct nerves, one of which passes outwards to the muscles of the œsophagus and pharynx, and another inwards to unite with the great trunk of the recurrent nerve, while the third passes backwards for a short distance, and then forms the second of the lateral ganglia, from which, in like manner also, proceed three other nerves. The first of these passes outwards to the sides of the œsophagus, and the second inwards to join a large ganglion formed at the extremity of the recurrent nerve, while the third branch is of considerable length and traceable for a great distance along the sides of the œsophagus. From the ganglion at the termination of the recurrent nerve, and which most certainly belongs to this trunk, are also given off two nerves, which are soon again divided, and distributed along the posterior part of the œsophagus. From these connexions, and the relative size of the parts, it still appears to us that although the sympathetic and recurrent nerves are most intimately connected, and appear in certain instances almost to supply the place of each other, there is reason for still considering them as distinct, and for describing the latter, as we formerly designated it,‡ as the *vagus*.

The *vagus*, or visceral nerve of Professor Müller, after arising, as in the larva, from the anterior part of the base of the cerebrum, and forming a ganglion on the upper surface of the pharynx, always passes backwards beneath the brain, along the middle line of the œsophagus. We shall first describe its course in Lepidopterous insects, and point out what we conceive to be its analogies to the vagus of vertebrata. In the *Sphinx* it originates in the perfect insect, as in the larva, from the lowest part of the anterior surface of the brain by two roots, one on each side, which we regard as analogous to the two vagi in the higher animals. Each root gives off from its base a small branch to the sides of the mouth, after which the two roots ascend, and meeting above the pharynx, form the frontal ganglion, from the anterior surface of which a few nerves are given to the mouth and palate, and also to the bifurcation of the dorsal vessel, which, after having passed along the œsophagus and beneath the brain, is divided in front of the brain into several branches. The frontal ganglion at the junction of these roots of the vagus we regard as analogous to the enlargement on the vagus nerve in vertebrata after it has passed out of the skull by the foramen lacerum posterius. From the ganglion thus formed by the approximation of the two roots, a single trunk passes backwards along the median line, lying upon the œsophagus and beneath the dorsal vessel, and giving to both several branches in its course. When arrived at the dilatation of the œsophagus, the *air-bag* or *crop*, it first distributes a few filaments to that part, and then divides into two primary branches, which run along the sides of the stomach, and are again subdivided and distributed to it. Behind the brain, the vagus in the Sphinx receives but one branch of communication on each side from the sympathetic ganglia, which connexions appear to be analogous to those between the vagus and sympathetic in vertebrata. In passing along the median line of the œsophagus, the single vagus in insects is in close relation with the anterior or aortal portion of the dorsal vessel, which may represent the two carotids of the higher animals united, and thus its relation to these parts is also precisely similar to that of the vagus, carotids, and œsophagus in these animals. There is a like analogy in its distribution to the anterior part of the stomach, beyond the middle portion of which it has never yet been traced. At its point of division the single vagus nerve often forms a very distinct ganglion, as in the Meloë (*fig*. 416, *i*). This is the usual distribution in a large majority of insects, more particularly in the Lepidoptera, Coleoptera, Neuroptera,

Fig. 416.



Brain and vagus nerve of Meloë cicatricosus.

Hymenoptera, and in many of the Orthoptera. In *Lucanus cervus* (*fig*. 417), the nerve, continued backwards from the frontal ganglia (*a*), is of large size until after it has passed beneath the brain, and given off a minute branch on each side to the dorsal vessel and œsophagus, after which it becomes on a sudden much smaller, and forms a second small ganglion, (*e*,) which is connected on each side by a single branch with the sympathetic ganglia (C,) which have assumed an elongated form, and are greatly enlarged. After this the vagus nerve is continued as a single trunk, (*b*,) until it

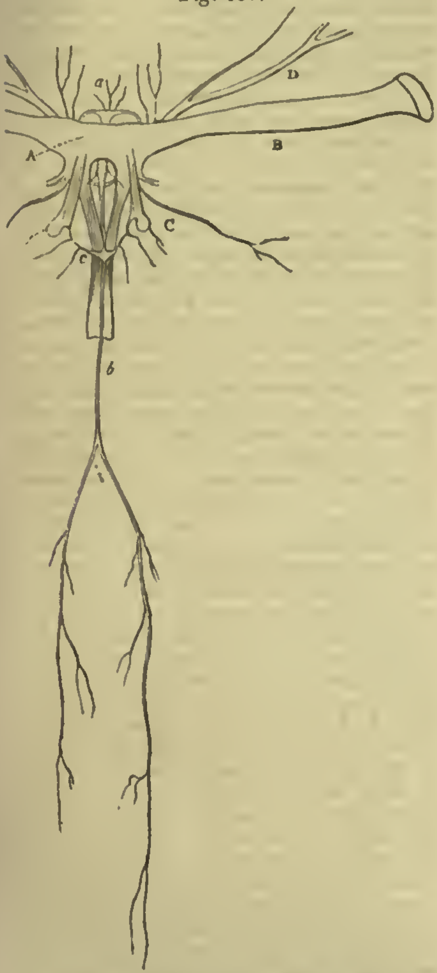
* Nova Acta Curios. Nat. vol. xiv.

† Annal. des Sciences Natur. tom. v.

‡ Phil. Trans. 1832.

has passed half-way along the œsophagus, (*fig.* 428, H,) when it divides into two branches, which pass on each side of the œsophagus as far as the gizzard, (I,) where each forms a very minute ganglion, from which are given a few filaments to the substance of the gizzard.

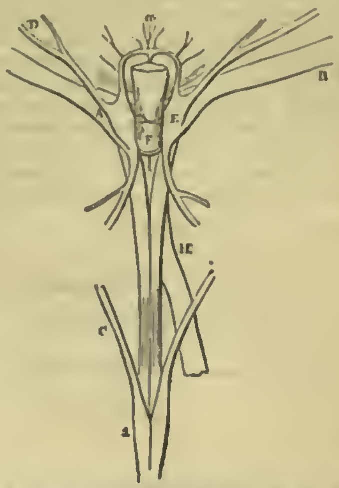
Fig. 417.



Brain, sympathetic ganglia, and vagus nerve of Lucanus cervus.

Each nerve thus passes on to the stomach, (K,) and we have succeeded in tracing it about half-way along that organ, when it can be followed no farther, being lost by minute subdivisions. As connected also with the vagus nerve both in function and by analogy of distribution, is the nerve which we noticed so particularly in the larva, the glosso-pharyngeal, (*fig.* 418, F,) which is remarkably distinct in *Lucanus,* and as in the larva gives branches to the under-surface of the œsophagus. It is remarkable, also, that in this insect each root of the vagus arises from a ganglion on each side, situated below the cerebral lobes, but closely connected to them, and from which ganglion the antennal nerves (D) originate, and a third nerve, which is directed backwards among the muscles, but the course of which we have not yet traced, but which probably is a compound nerve ; it appears to be formed in part by the ganglion, (E,) and partly by a portion of the cerebrum, which is united to it.

Fig. 418.



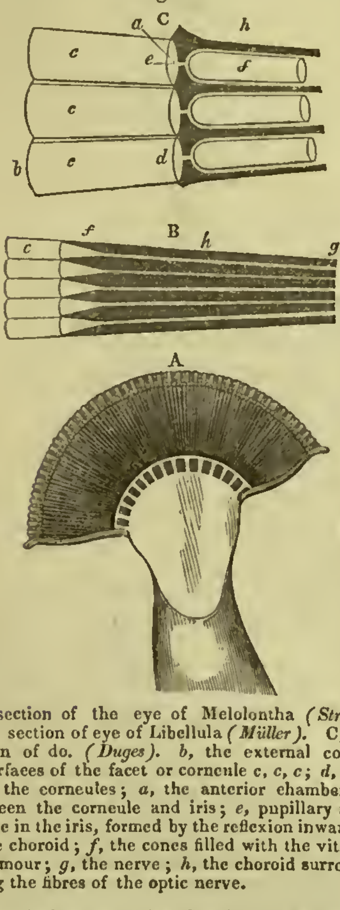
Under-surface of brain, &c. of Lucanus cervus.

The form which the frontal ganglion usually assumes is nearly triangular, but in some instances, as in *Carabus monilis,* it is elongated, oval, lying transversely across the pharynx, but in almost all the insects we have examined, excepting the *Buprestidæ* and some of the Orthoptera both in the larva and pupa state, as in *Timarcha, Meloë, Anthophora,* and *Bombus,* whatever be its form, the single nerve continued from it has more resembled in its distributions and relations the vagus than the sympathetic. These are the reasons for our continuing to describe it as the former rather than as the latter of these nerves. The fact, however, of its disposition to form ganglia in its course appears, indeed, as observed by Professor Müller,* to assimilate it most in character with the sympathetic ; but we conceive this fact to be satisfactorily explained by the anatomy of these nerves in *Buprestis,* in which the middle or recurrent nerve, although exceedingly short, is very large, and is terminated by a ganglion, as in the *Gryllidæ*, and from which, in Buprestis, two small nerves are continued along the œsophagus, while the corresponding nerves in *Gryllus* have become approximated to those from the lateral ganglia, and assist to form the long gangliated nerve at the side of the œsophagus. The functions of the vagus and sympathetic in insects would thus appear to be nearly similar, and that, as is sometimes the case with these nerves in vertebrata, as we have seen, for example, in the neck of the calf, the two become often closely approximated together, as noticed also by Professor Müller, in the Myxinoid Fishes, in which the vagus and sympathetic form only one nerve, the chief portion of which is the vagus, and which is extended to the anus.

* Müller's Archiv, No. v. 1837, Jahresbresht, p. lxxxv. to viii.

Organs of vision.—The eyes of Insects are of two kinds, simple and compound, and have been attentively examined by Professor Müller, Straus Durckheim, Duges, and others, from whose admirable investigations we shall chiefly derive the following description. The large convex corneæ which cover the external surface of the head are divided, as we have seen, into an immense number of facets, generally of an hexagonal shape, or in very rare instances somewhat quadrangular. Each facet, (*fig.* 419, B,) or as it has sometimes been called, *corneule*, is the proper cornea of a distinct eye, and is perfectly transparent. It is somewhat broader at its base or external surface (B, C)

Fig. 419.



A, section of the eye of Melolontha (*Straus*). B, section of eye of Libellula (*Müller*). C, section of do. (*Duges*). *b*, the external convex surfaces of the facet or corneule c, *c*, *c*; *d*, base of the corneules; *a*, the anterior chamber between the corneule and iris; *e*, pupillary aperture in the iris, formed by the reflexion inwards of the choroid; *f*, the cones filled with the vitreous humour; *g*, the nerve; *h*, the choroid surrounding the fibres of the optic nerve.

than at its internal, (*d*,) and each one is separated from those by which it is surrounded by the interposition of a layer of dark-coloured pigment, so that the rays of light can pass through it only in a direction converging to its centre. In some instances, as in Lepidoptera, it is convex both on its external and internal surface, or lens-like, but in general is nearly plane. In the *Libellulina*, according to Duges, (C,) it is convex externally, and slightly concave internally, and it varies considerably in thickness in different insects, and in different facets in the same compound cornea. Immediately behind each corneule is a layer of dark-coloured pigment, (*h*,) which is believed to be continuous with the delicate pigment that is interposed between the corneæ. It covers the whole of the inner surface of the cornea, excepting only in the centre, where it is perforated by a minute hole or pupillary aperture, (*e*,) to admit the rays of light that have passed through the cornea. Between this pigment, which is the curtain or *iris* of the eye, and the end of the cornea, Duges found a space, (*a*,) filled with an aqueous humour. Behind the iris of each cornea is a little cone-shaped transparent body, (*f*,) with its apex directed backwards in the axis of the eye. It is filled with a perfectly transparent tenaceous fluid, the vitreous humour of the eye, into which the rays of light received through the cornea and iris are admitted, to fall upon the retina, or termination of the nerve, (*g*,) at the apex of the cone. The length of the cone differs greatly in different insects. It is shortest in the Diptera, and scarcely exceeds its breadth. In the Coleoptera and Lepidoptera it is five or six times longer than it is broad, and perhaps even exceeds this in some of the Libellulina. The apex of each cone is received upon the extremity of one of the many thousand of fibres (*g*) which we described as radiating from the bulb of the nerve, immediately after it has passed through the optic foramen. The choroid of dark pigment that forms the iris (*h*) is continued backwards over the surface of the cone and optic fibre to the bulb of the optic nerve, thus completely insulating every individual cone and fibre from those by which they are surrounded. It is in the spaces thus occupied by the choroid that the tracheal vessels and circulatory passages ramify, so that the choroid in the eyes of insects, as in those of the vertebrata, is the proper vascular structure of the organ. It is subject to much variety of colour in different insects, being in some nearly black, in others dark blue, violet, green, purple, brown, or yellow. In some there are two or three layers of pigment of different colours. The usual arrangement of these is first a dark coloured portion near the bulb of the optic nerve, then a lighter colour, and lastly, again, a darker near the corneæ. According to Duges, the base of the cone is rounded where it is covered by the iris, but Müller states that this is the case only when the cornea is devoid of facets or corneules, and is perfectly smooth. According to the same authority, the pupillary aperture is most distinct when the cones are short, as in Diptera. This aperture was discovered by Müller, and also the nature of the cones, which had been thought by Straus-Durckheim to be expanded terminations of the optic fibres. We have seen the iris and pupillary aperture very distinctly in the eye of *Pontia brassicæ*, the white cabbage butterfly, and also in *Sphinx ligustri* and *Nepa grandis*. In the two latter instances it is of a dark brown, or nearly black, and is particularly large in *Nepa*. In *Pontia* it is yellow, in the centre of which the pupil exhibits a glassy brightness. The manner in which the extremity of the nervous fibre is connected with the apex of the cone has recently been investigated by Professor

Wagner, who has found that the fibre is prolonged as a sheath over the sides of the cone, of which it is supposed to form a part. In this manner, each of the thousands of corneules or facets that form the compound eye, transmits impressions from without inwards to the optic nerve and brain, the perception of each being confined to that of the object immediately before it, or in a line with its axis of vision. On the exterior surface, between each cornea, there are often some very fine hairs, as on the cornea of the bee, which Burmeister likens to eyelashes, and thinks that they assist to confine the field of vision, as well as protect the cornea. This is the usual structure of the eye. In *Melolontha*, Straus-Durckheim describes the filament of the optic nerve as passing through a second or *common choroid*, and as afterwards uniting to form a general retina, which is connected with the optic nerve by means of short thick columns. The use he assigns to this structure is that of intercepting the impressions of light, which might otherwise be too powerful.

The *ocelli*, or simple eyes of insects, resemble those of Arachnidans,* in being formed of a very convex, smooth, single cornea, beneath which is a spherical crystalline lens, resting upon the plano-convex surface of the expanded vitreous humour, the analogue of the transparent cones of the compound eyes. The vitreous humour, as in Arachnidans, is more convex on its posterior or under surface, and is contained in the expanded retina at the termination of the optic tubercle, upon which each ocellus is situated, the exterior surface of the retina being covered by a dark pigmentous membrane, the proper choroid, which is reflected inwards upon the anterior portion of the vitreous humour, to form the iris and pupillary aperture. Müller, who discovered this structure in the stemmata of insects as well as Arachnidans, concludes that the function of the simple eyes is confined exclusively to the perception of near objects, and that of the compound eyes to more distant ones, and has given many facts in illustration of this opinion, and which shew that in many instances, particularly in the Orthoptera, the ocelli are so placed as to render it almost impossible that they can be used except in viewing near objects. In all insects that undergo a true metamorphosis ocelli constitute the only organs of vision in the larva state. They vary in number in different species; thus in the active larvæ of Hymenoptera, as in Athalia, there are only two, one on each side of the head; this is also the number in some of the carnivorous Coleoptera. But in others there are six on each side, as in Dyticus, and the same number is found in most of the Lepidoptera. We have recently detected what we believe to be organs of vision in a Dipterous larva, *Œstrus ovis*, (*fig.* 360,) which resides in the frontal sinuses of the sheep, into which, probably, a small amount of light may enter through the nostrils. These consist of two brown spots on each side of the head, (*h* 2,) placed at a little distance from each other, immediately beneath a convex and very transparent part of the tegument, which resembles a true cornea. This is the most simple form of eye we have yet met with in insects, and seems to be merely for the perception of light, like the eyes of the *Medusæ* discovered by Ehrenberg, but perhaps more organized, as the spots observed appear to be a choroid, which is seen to descend until it is lost in the substance of the part. No compound eyes exist in any larva that undergoes a complete metamorphosis. In those which undergo an incomplete one, as in the Orthoptera, the facets of the eye are larger and more convex than in the perfect state, and the true ocelli which exist in the perfect state are not developed. In the larva and pupa of *Reduvius personatus* there is an aggregation of simple eyes, like those of *Myriapoda*, very much larger and more convex than the facets of the compound eye of the perfect insect. Simple eyes exist in the perfect state in the Hymenoptera, Orthoptera, Hemiptera, Neuroptera, Trichoptera, Homoptera, and in some of the Lepidoptera and Homaloptera, and in a very few instances in the Coleoptera.

Organ of hearing.—Every naturalist who has at all attended to the consideration of the faculty of hearing in insects, is doubtless convinced that these little creatures are not merely affected by sounds, but that hearing constitutes one of their chief senses; yet it is hitherto undecided what organ or part of the animal is the seat of this function. We have above stated our opinion, (p. 892,) with many others, that it resides in the antennæ, which, if this be not confirmed, is at any rate supported by the experiments hitherto made upon these organs, and also by their structure and the manner in which they are employed by the insect. The nerves distributed to the antennæ have often a ganglion at their base, and are divided into many branches almost immediately after they have entered the organ, so that at present no difference has been detected between the distribution of the nerves to these parts and those to other structures. They certainly exhibit no bulbed extremity like the auditory nerves of the higher animals, while the manner in which the antennæ are employed by many insects has induced some observers to believe that they are simply organs of touch. This cannot be their primary function, since, as formerly remarked, they are too short to be employed as tactile organs by many insects, while their structure, we conceive, is in every instance adapted for hearing or perceiving the pulsations of the atmosphere.

Organs of touch.—The organs which appear specially adapted to the exercise of this function are the *palpi*, which derive their nerves, as above shown, from the medulla oblongata. These organs are employed in a similar manner by all insects to touch the food. It is with these that the insect, as it were, *feels* about when it is in search of nourishment, and hence these may be regarded as the proper tactile organs. It has sometimes been supposed that they are also concerned in the *function of taste*,

* See ARACHNIDA, vol. i. fig. 94.

but this opinion is not borne out by the physical condition of these parts, which, in almost every instance, is unadapted for such purpose, being covered by a hard bony exterior. In some instances the extremities of the palpi are covered with a soft bulb-like extremity, while in many others which are known to perceive the quality of food very quickly, they yet have the extremities of the part covered with a hard imperforate structure.

As to the seat of the *organ of smell* we are quite as ignorant of it as of that of taste. Cuvier and some others have imagined that the faculty of smelling resides in the mucous lining of the spiracles at the sides of the body, but experiment has still left the question undecided. From the few observations we have been able to make on this subject we certainly have been led to conclude that it is confined to some part of the head, and not seated at the different spiracles.

The development of the brain and nervous cord during the metamorphoses exhibits some of the most curious alterations of form that take place in any structure. These changes were first traced by Herold in the great cabbage-butterfly, *Pontia Brassicæ*, and subsequently by the writer of the present article in the privet hawk-moth, *Sphinx ligustri*,* and also in the nettle-butterfly, *Vanessa urticæ*. We have seen from the foregoing details, that during the last period of the larva state, at which time the insect has been most frequently examined, certain changes of form have already taken place in different parts of the cord, so that these changes of structure, which at first appear to be effected so rapidly at a certain period, have been for a long time in progress. We have seen that, besides the lateral approximation of the cords, the first change consists in an union of the eleventh and twelfth ganglia, the latter one being carried forwards; and that, although a complete coalescence of these has sometimes taken place so early as a day or two before the caterpillar casts its last skin, yet even at that period the cerebral ganglia have scarcely become united above the œsophagus. At a still earlier period, when the larva has not yet cast its third skin, we have found the eleventh ganglia perfectly distinct from the twelfth, with a small intervening portion of cord, and the cerebral ganglia scarcely touching each other above the œsophagus, and the distance, or extent of cord, between the fourth and fifth ganglia much greater than at the subsequent period when the insect is preparing to change into the pupa state.

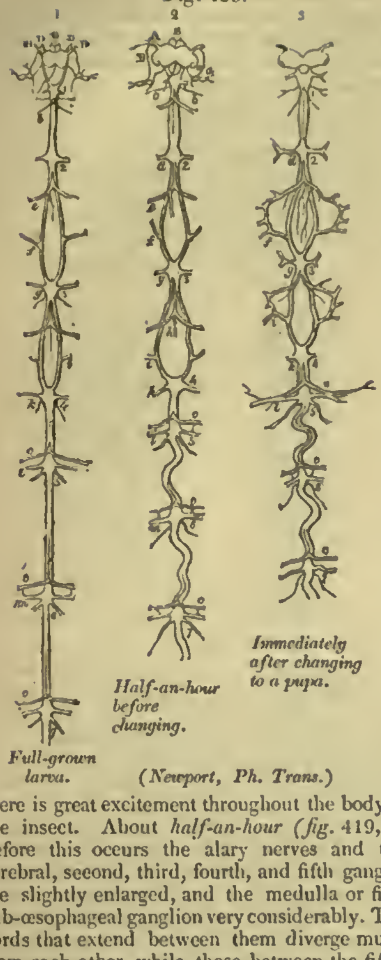
We had commenced our observations on these changes in the nervous system on the larva and pupa of the *Sphinx*, when it appeared desirable also for various reasons to make similar observations on an insect in which these changes were commenced and completed within a short and known period, and for that purpose selected the commonest of our native insects, the nettle-butterfly, *Vanessa urticæ*, which undergoes its changes within fourteen days. The Sphinx remains in the pupa state during the whole winter, by which we are enabled to compare the same changes in an insect in which they have taken place slowly with those in another in which they have been completed more rapidly, and the extent of development at the completion of both is invariably found to be the same. In order to observe these changes correctly, a large number of the caterpillars was collected at the period when they have ceased to feed, and are about to suspend themselves to undergo their transformation, and the moment was carefully watched both when they suspended themselves preparatory to undergoing their metamorphoses, and also when they were in the act of assuming the pupa state. By these means a sufficient number of specimens was obtained, and their periods of transformation accurately known. Previously to commencing these observations on the nettle-butterfly, we had noticed in the pupa of the Sphinx a very singular appearance at the base of each optic nerve, which on close inspection was found to be a dark-coloured membrane of an ovate form, from which is developed the choroid of the future eye. The existence of this spot is exceedingly interesting as illustrating the manner in which the complicated organ of vision in the perfect insect is developed. This spot, which at first appears like a dark gelatiniform deposit, consists of five black tubercular elevations, having the appearance of so many parts of a corrugated membrane, and exists before the larva has changed into a pupa. We have never found it absent in any insect that is about to change, but have not observed it until the insect has ceased to feed.

Two hours after the larva of *Vanessa urticæ* has suspended itself to undergo its transformation, and in which state it remains from six to eight, ten, or even twenty-four hours, according to the strength of the individual and other circumstances, before it throws off its last larva skin a considerable alteration has already taken place in the body of the larva; the cerebral lobes are still distinct from each other, but are a little altered in form, although not yet enlarged. When viewed from above they exhibit a pear-shaped appearance, the anterior part of the lateral surface of each being elongated to give origin to the antennal and optic nerves. At the base of the latter, even at this early period, the dark rudimentary choroid is very distinct. The sub-œsophageal ganglion is enlarged to nearly twice its original size, and the crura are much enlarged and shortened, as well as the cords that connect the second, third, fourth, and fifth ganglia. The last two are separated only by a short interval. The fifth, sixth, and seventh ganglia are drawn closer together, the cords between them disposed in an irregular zig-zag manner, and the longitudinal direction of the ganglia is in consequence altered. The ganglia from the seventh to the terminal one remain as in the active larva.

By unremittingly watching a number of larvæ through all their preparatory stages, we are enabled to judge within a very short period when the transformation will take place. A little while before the old skin is thrown off

* Phil. Trans. pt. 2. 1832, 1834.

Fig. 420.



Full-grown larva. *Half-an-hour before changing.* *Immediately after changing to a pupa.*

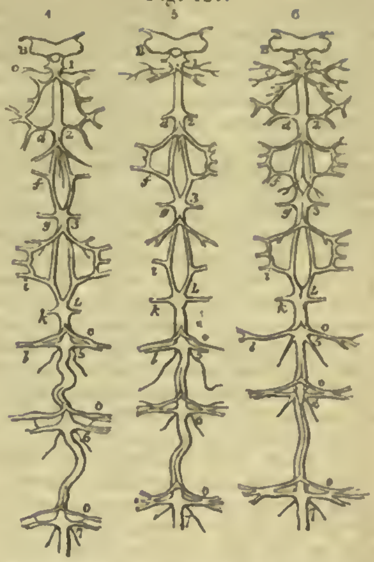
(Newport, Ph. Trans.)

there is great excitement throughout the body of the insect. About *half-an-hour (fig.* 419, 2) before this occurs the alary nerves and the cerebral, second, third, fourth, and fifth ganglia are slightly enlarged, and the medulla or first sub-œsophageal ganglion very considerably. The cords that extend between them diverge much from each other, while those between the fifth, sixth, and seventh ganglia, are disposed in a more zig-zag direction than in other parts of the body.

Immediately after the insect has entered the pupa state (3), all the ganglia are brought closer together in consequence of the cords being disposed more irregularly than at any other period, which has been occasioned by the shortening that has taken place in every segment, by which the cords are rendered too long to lie in a direct line. The cords which connect the first five ganglia are slightly increased in size, and the fourth and fifth and their intervening cords, in which the first great changes commence, are often nearer together, and have become more united at this period of the transformation, in some specimens, than in others at five or six hours later. This is in accordance with what we have observed in the *Sphinx ligustri*, in which the precise period when the union of ganglia takes place cannot positively be ascertained in consequence of its differing in different specimens according to the vigour of the insect, or to the temperature of the season at the time of changing.

One hour after *(fig.* 421, 4) the transform-

Fig. 421.



One hour after changing. *Twelve hours.* *Eighteen hours.*

ation the cerebral ganglia are found to be more closely united, the antennal nerves more distinct, and the optic nerves more enlarged at their base. The fourth and fifth ganglia are approaching each other, and the cords are enlarged at their connexion with the latter, the anterior part of which has become less distinct, and seems about to coalesce with them. The distance between the remaining ganglia is also reduced, and the investing membrane, or exterior surface of the cord exhibits a corrugated appearance as if in the act of becoming shortened. We have seen in the account previously given of the nervous system in the larva of the Sphinx, that besides the longitudinal cords and ganglia, and the nerves distributed from them, there are also the transverse nerves. There are like nerves in *Papilio urticæ*, and which are distributed to the same parts as in the Sphinx. They commence behind the first sub-œsophageal ganglion or medulla, where the first of them pass directly outwards in the course of the tracheæ that come from the first spiracle, and distribute and give some branches to the surface of the medulla and its nerves, and some also to the second ganglion (*d*), while the main branch passes along in the direction of the muscles of the back part of the head. Behind the second ganglion branches of tracheal vessels, and also a nerve from the transverse plexus, are given to the great alary nerve (*f*) that arises in this insect singly from the cord between the second and third ganglion, and not, as in the Sphinx, one portion from the cord and another from the ganglion posterior to it. From the cord between the third and fourth ganglion arises the second alary nerve (*i*), which like the preceding arises singly from the cord, but receives also a

* 1832.

branch from the transverse nerves posterior to the third ganglion. A plexus of these transverse nerves exists, as in the Sphinx, anterior to each ganglion (*o*, *o*), to the nerves of which they give a single filament near their base, and another when arrived near the spiracle, while their main branches, as in the latter insect, are distributed separately among the tracheæ and muscles. Those branches of transverse nerves which pass off laterally from between the fourth, fifth, sixth, and seventh ganglia, become approximated to the nerves from those ganglia, and in the development of the insect at this period afford an example of the commencement of the interesting fact of the formation of nervous trunks by the approximation of many fibres. The transverse nerves anterior to the fifth ganglion (5, *o*) are those that first become united to the moto-sensitive nerves from the gangliated cord, and at this period of the transformation the two are beginning to become united.

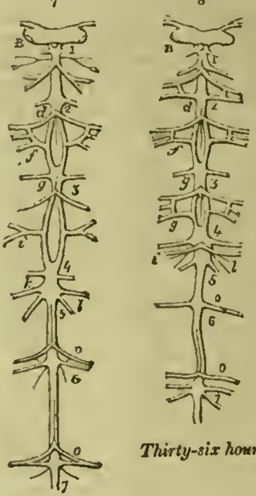
Seven hours after the insect has become a pupa there is a greater enlargement of the cerebral ganglia, optic nerves, and ganglia and cords of the future thoracic segments. The fourth and fifth have advanced closer together, and the cord between them has become so much shortened, enlarged in diameter, and approximated to its fellow, as to resemble in shape a separate elongated ganglion, and strongly to support the opinion formerly advanced by us* of the actual transmission forwards of the nervous matter within the investing membranes of the cord, rather han that of its deposition and accumulation at certain parts through the agency of the nutritive or vascular system. At this period also all the remaining ganglia have become slightly enlarged, and the distance between the fifth and sixth is much diminished, and the cords just anterior to each ganglion are also slightly enlarged and are disposed with less irregularity than at a previous period. At this stage of the transformation the transverse nerves (*o o*) also are beginning to assume their temporary ganglionic appearance, and the terminal nerves from the caudal ganglion are enlarged to supply the developing organs of generation.

At twelve hours (5) the fifth ganglion has almost completely coalesced with the cord and fourth, and has assumed an elongated triangular appearance, and the transverse nerves, which at seven hours were beginning to be united to the nerves from this ganglion, have now so completely joined them as almost entirely to have disappeared, there being in some instances only a triangular elevation upon the gangliated cord, with a portion of nerve passing outwards to indicate their previous separation, thus affording a further proof of the adhesion of contiguous parts, and of the manner in which nervous trunks are formed.

At *eighteen hours* (6) the whole of the ganglia, cords, and nerves have become more enlarged, particularly those of the wings, and the transverse nerves, although continuing separate, give filaments to the nerves from the ganglia, and themselves exhibit at their point of division more the appearance of ganglia; while the fourth and fifth ganglia of the cords have now so completely united as to appear like an irregular elongated mass. The abdominal portion of the cord is now extended in a more direct line in the body, and anterior to each ganglion is still enlarged.

Fig. 422.

7 8



Twenty-four hours. *Thirty-six hours.*

At *twenty-four hours* (*fig* 422, 7) the fourth and fifth ganglia are completely united, the fifth being larger than the fourth. The cords before the sixth are enlarged, as also are the transverse nerves of the thorax, which seem to keep pace with or rather to precede the development of the respiratory organs.

At *thirty-six hours* (8) the optic nerves have attained a size almost equal to that of the cerebral ganglia, and after this period become very little larger. During the preceding stages of the transformation the minute black patch observed at their base has been gradually more and more expanded, and carried forwards from the posterior superior part of each lobe to its lateral part, which at this period it is beginning to cover, while the optic nerves appear as if developing from within outwards, and have a somewhat pear-shaped form. The first sub-œsophageal ganglion, or medulla, now forms with the cerebral ones a complete ring around the œsophagus, the crura having almost disappeared. The fifth ganglion has decreased in size and is now smaller than the fourth, while, in some specimens, the nerves that arise now come from the cords immediately behind it, thus giving a further proof that the nervous substance of the ganglion has been transmitted forwards. The sixth ganglion, which at twenty-four hours was much reduced in size, has entirely disappeared, but the nerves that belonged to it remain and are now derived from the cord, very near to those which belonged to the fifth ganglion, thus further proving, as formerly remarked by us,* that the nervous substance has been transmitted forwards along the cord. This view of the manner in which these changes in the form and

* Phil. Trans. 1834.

size of different parts of the nervous system is effected is in full accordance with the recently developed facts of Ehrenberg and others respecting the tubular nature of the primary nervous fibres.

At *forty-eight hours*, (*fig.* 423, 9) the whole of the cords have regained the longitudinal direction, and the seventh ganglion, which had begun to be decreased in size at the last period, has now also entirely disappeared, and its nerves, like those of the fifth and sixth, come from the cord, while the ganglia of the thorax are acquiring a great size.

Fig. 423.

Forty-eight hours. *Fifty-eight hours.*

At *fifty-eight hours* (10) a further change has been effected. The second and third thoracic ganglia have united, and the double ganglion thus formed is only separated from the larger thoracic mass composed of the fourth, fifth, and part of the sixth ganglia, by the short but greatly enlarged cords which pass, as before noticed, on each side of the central attachment of the muscles. The transverse plexus are united with the nerves to the wings, and the whole of these gangliated portions of cord have been carried forwards, and now occupy the middle portion of the immensely enlarged meso-thorax. The optic and antennal nerves have nearly attained their full development, and those numerous and most intricate plexus of nerves in the three thoracic segments of the larva form only a few trunks, which can hardly be recognized as the same structures. The arrangement of the whole nervous system is now nearly as it exists in the perfect insect. The whole of these important changes are thus seen to take place within the first three days after the insect has undergone its metamorphosis; and they precede those of the alimentary canal, generative system, and other organs, which are still very far from being completed, and indeed, as compared with the nervous system, have made but little progress.

Such is the rapidity of these changes, as observed by us in June, 1832, in a species that usually undergoes its metamorphosis from the larva to the perfect state in about fourteen days. On repeating our observation on the same insect in the following August, when, from the increased temperature of the season, the whole of the changes in the body were completed in about eight days, we did not observe that these had become much accelerated, although the changes in the other structures were hastened. The whole of these phenomena are induced by an alteration which takes place in the external tegument, and the permanent contraction of the longitudinal and diagonal muscles of the body, by means of which the anterior margin of one segment is drawn beneath the posterior of that which immediately precedes it. This is carried to a greater or less extent in the different segments, and the nervous cord being in consequence rendered too long to lie in a direct line, a disposition is thus induced in its various parts to coalesce.

Organs of Nutrition.—The chief organs of nutrition in insects, the *alimentary canal and its appendages*, assume a variety of forms in the different classes, and undergo changes almost as remarkable as those of the nervous system. From being scarcely more than a simple elongated tube, with a few slight enlargements in its course, as in some of the apodal Hymenoptera, the alimentary canal becomes in the perfect individual a long convoluted organ, thick, muscular, and divided into several compartments, each of which is adapted to a peculiar function, but subservient to the more general one of assimilating the food received, into one homogeneous material, fitted for the nourishment of the whole body. But whatever be its particular form, the alimentary canal may be regarded as composed of three distinct coats or tissues, which we shall distinguish as the external or *peritonæal*, the middle or *muscular*, and the internal or *mucous*.

The *peritonæal* coat, or layer, is an exceedingly transparent, white, shining, and delicate membrane, and is observed only with great difficulty. It covers the outer surface of the muscular coat throughout the whole course of the canal, and, as we are strongly induced to believe, although we have not positively ascertained it, is continuous with and reflected along the tracheal vessels that ramify on the stomach, and forms their external covering. We have never been able to detach it from the muscular coat, which it completely invests, and to which it closely adheres, but we have seen it most distinctly in recently killed insects more particularly in the *Apidæ*, as in *Anthophora retusa*, when the canal has been removed from the body and viewed by transmitted light. It is then seen most distinctly extending along the sides of the canal, directly across the angles formed by the contraction of some part of the muscular coat, where this is thrown into folds or depressions.

The *muscular*, or middle coat, is very strongly marked. It is composed of transverse and longitudinal fibres, interlaced with each other, and also of a series of oblique fibres, which, as shewn by Lyonet in the *Cossus*, sometimes in part form the *retractores ventriculi* muscles, that assist to retain the canal in its proper position in the body, and connect it with the whole muscular system. Burmeister states,* that distinct transverse and

* Op. cit. (trans.) p. 121.

longitudinal *vessels* can be discovered in the muscular coat, but we have never been able to observe them. The muscular coat is most distinct in the *proventriculus* or gizzard, the *ventriculus* or digestive stomach, and the *colon*, but may be traced throughout the whole of the canal. The longitudinal and transverse fibres are each developed to a greater or less extent in different insects; in some, more especially in the larva state, as in the Lepidoptera, the longitudinal fibres form six strong bands, arranged at equal distances around the canal, and extended from one extremity of it to the other, more or less developed in different parts of their course; while in other instances, more particularly in the perfect state, the circular fibres are most developed, as in the Hymenoptera, in which the longitudinal fibres on the stomach are scarcely observable.

The *mucous*, or internal coat, analogous to the mucous coat in the higher animals, is divided into two layers, each of which has been considered as a distinct structure by different anatomists. The most internal of these layers forms the proper lining of the alimentary canal, and is a smooth soft membrane, particularly distinct in the upper part of the canal, but less so in the lower. It is continuous with the lining of the mouth and pharynx, and is often plaited or folded longitudinally, but seldom transversely, excepting where it covers a fold of the other structures to form a valve at any part of the canal. It is this membrane which is often solidified at the upper part of the canal, and developed into rows of strong horny teeth, as in the Orthoptera and some carnivorous Coleoptera, or is covered entirely with exceedingly minute ones over its whole surface, as is particularly the case in *Gryllus migratorius*. In some instances it is very loosely attached, and forms, as it were, a soft and easily separated lining to the canal, more particularly in the ventriculus, as in the *Meloe* and some other genera. The other layer of this coat, which has been regarded as a distinct structure, is situated between the proper mucous or lining membrane and the muscular coat. It is this layer which is considered by Straus as the proper skin or lining. It is usually thin, flocculent, and frequently without indications of distinct texture, although it is occasionally found to possess it, as shewn by Burmeister in *Hydrophilus*. Straus has sometimes observed horny prominences in it, which he considers of a glandular nature. The markings in Hydrophilus appear to be of the same description. Ramdohr mistook this layer for a layer of transuded chyle; Straus and Burmeister regard it as perfectly distinct from the mucous coat, and Professor Grant in alluding to it seems to regard it as a loose intermediate *cellular* tissue.* This is our own opinion also of its nature, because we have been unable to trace it as a distinct layer throughout the whole of the canal. It exists most distinct in the ventriculus, but we have not been able to trace it in the colon, excepting, perhaps, in the Lepidoptera, in which it appears to be what we have regarded as an *adipose coat*. The inner or true mucous layer is very distinct, and in some, as in *Cerura vinula*, is covered with minute rounded glands.

The alimentary canal is retained in its position in the body partly by means of the retractores ventriculi, which we have observed most distinctly in the larvæ of Diptera, as in *Eristalis tenax*, as well as in Lepidoptera and others; but more especially by means of ramifications of the tracheal vessels, which pass from the great longitudinal tracheæ, near the spiracles, and are distributed in profusion over the alimentary canal throughout its whole course. Burmeister says that a peritonœum, such as retains the intestines in their place in the higher animals, does not exist in insects. This, however, as we have above shewn, is not strictly the case, since a peritonœum certainly exists as a coat of the alimentary canal, although we have never been able to observe it forming, as stated by Professor Grant,* "a distinct thin mesentery," connecting the convolutions of the intestines with the interior of the abdominal segments.

The parts of the alimentary canal are the *mouth* and *pharynx*, the *œsophagus*, (*fig.* 424, *h*,) and, in the Lepidoptera, (*fig.* 430, *t*,) Hymenoptera, and Diptera, the *crop*, which is a dilatation of the œsophagus carried to so great an extent as to form a distinct appendicular cavity; the *proventriculus* or gizzard (i), the *ventriculus* or proper digestive stomach (*k*), the *ilium* or short intestine (*l*), and the *colon* (*m*, *n*) and *rectum* (*o*). These exist in the most developed form of the canal, but not invariably or to the same extent in every insect. The crop is frequently absent, as are also the proventriculus and the rectum, but the remaining parts are almost constantly present. Besides these as forming parts of the digestive apparatus, there are the appendicular structures, consisting of the salivary glands (*a*), the gastric (*a*, *b*, *c*), and the so-called biliary (*p*) and the anal vessels (*s*). Of these the supposed biliary vessels are almost constantly present, and less frequently the salivary and gastric, and least frequently the anal vessels, which have not been observed in many species.

Alimentary canal of the larva.—The most simple form of alimentary canal we have yet met with in insects exists in apodal larvæ of parasitic Hymenoptera, as in *Ichneumon Atropos*, which undergoes all its changes within the cavity of the abdomen, between the alimentary canal and muscular structures of the larva and pupa of *Sphinx ligustri* or *Acherontia Atropos*. It consists simply of an elongated sac, very much dilated, and greatly resembling a Florence flask, and occupies nearly the whole of the interior of the body of the parasite. The œsophagus is short and very distinct, and terminates in the second segment in a well-developed valve formed by a duplicate of the mucous and muscular coats. Behind this the whole forms one dilated continuous cavity, extended as far as the anal segment, but completely imperforate and slightly intussuscepted at its extremity, where, when the part is carefully

* Outlines of Comparative Anatomy, p. 349.

* Id. loc. cit.

Fig. 424.

Alimentary canal of Carabus monilis.

h, œsophagus; *i*, gizzard, or proventriculus; *k*, ventriculus or digestive stomach; *l*, ilium; *m n*, colon, with cæcal glands; *o*, rectum; *p*, hepatic vessels; *q*, their point of insertion; *s*, anal vessels; *a*, *b*, *c*, a gastric vessel; *a*, *b*, a portion of the lining of the gizzard.

examined by transmitted light, there is a slight appearance of circular fibres. Its texture throughout is distinctly muscular, both longitudinal and transverse muscular fibres being distinctly visible in every part of it, and of nearly uniform size. This is a remarkably low form of development in an insect which afterwards becomes one of the most perfectly organized of its class. The next simple form of alimentary canal occurs in the same order of insects, as in the larva of the common Hornet, *Vespa crabro*, in which it consists of a straight and gradually enlarging tube, extended as far backwards as the eleventh segment, where it becomes constricted, and forms a short small intestine, receiving at the same time the insertions of very minute hepatic vessels, after which the intestine becomes again slightly enlarged to form a rudimentary colon. The next somewhat more developed form is found in the *Apidæ*, as in *Anthophora retusa*, in which the canal forms a distinct œsophagus, which terminates in a very slight dilatation, and then gradually enlarging, passes onwards, as in the Hornet, until it acquires its largest diameter in the eleventh segment, and becomes constricted to form the small intestine, receiving laterally at the same time the insertions of the hepatic vessels. The small intestine then passes forwards, and after making one short sigmoid turn backwards, ends in a straight colon and anal aperture, which is distinctly developed in this insect towards the latter part of the larva period, at which time, after the insect has become full grown and ceased to feed, we have observed fæces passed from it, but we have reason to believe that the anal aperture is not developed until that period, since no fæces are found in the cell in which the larva is inclosed until after the larva is full-grown, and has eaten the whole of the food that was stored up with it when the cell was closed by the parent. In the larvæ of some Coleoptera, as in the *Lamellicornes*, there is almost as simple a form of the alimentary canal as in the *Apidæ*. In these, as in *Melolontha vulgaris*, (*fig.* 425,) it commences in a short and narrow œsophagus, which opens by a valve into a very capacious stomach that extends backwards to the twelfth segment of the body, where it is gradually decreased in size, and ends in a narrowed pylorus, which is divided internally by a valve from a short and narrow intestine, that passes forwards beneath the stomach, and ends in a very large colon, which at its commencement is dilated into an immense cœcum, and is in general distended with fæces. It terminates beneath the middle of the posterior half of the stomach in a rectum, which passes directly to an anal aperture. In our dissection of this larva we did not observe the exact point at which the biliary vessels enter, but nevertheless they exist, although less distinct than in the perfect insect. They were observed by Swammerdam in the larva of *Oryctes nasicornis*,* entering, four in number, at the pylorus. In this and other lamellicorn larvæ the surface of the digestive cavity is increased by the addition of three series of cœcal appendages. The first surround the cardiac extremity, and consist of twelve cœcal tubes, with their apices directed forwards, and dilated on each side into four smaller cœca, so that each one has somewhat the appearance of a fern-leaf. From the situation which they occupy, these may perhaps be regarded as salivary organs. A little beyond the insertion of these

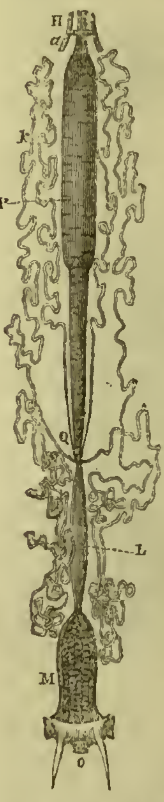
* Biblia Nat. tab. xxvii. fig. V. c.

Fig. 425.

Lateral view of the alimentary canal of the larva of Melolontha vulgaris, with the three series of gastric vessels.

vessels the stomach is slightly constricted, and receives the insertions of another set of cœca, which differ from the last in being single, conical, and directed backwards. At some distance beyond these, the stomach is encircled by a third set of cœca, which differ from both the preceding in being united in pairs at their base, and inserted, with their apices directed forwards, near the posterior part of the stomach. Those cœca, both of the second and third series, which are nearest to the upper part of the stomach, are the shortest. These cœca are not analogous to the hepatic vessels, or rather those usually so designated, but to the gastric glands which cover the stomach in the *Carabidæ (fig.* 424) and *Lucanidæ (fig.* 428), and appear in this voracious larva designed to secrete a fluid that may be necessary to enable the stomach to digest the immense quantity of vegetable matter taken into it. In the Lepidopterous larvæ the canal is scarcely more developed than in the Coleopterous, since, although the œsophagus is elongated, and the larger intestines are somewhat more complicated, no series of gastric glands are developed. We believe we have seen those which surround the cardiac extremity in some *Bombycidæ*, as in *Odonestis potatoria*, immediately after the insect was killed, but merely as little rounded protuberances, the character of which was completely lost after the insect had been preserved for a short time in spirits of wine. They exist also very distinctly in the Sphinx. In this order it commences by a distinct œsophagus *(fig.* 364, *c*), which terminates by a valvular orifice in the third segment in a long and very muscular stomach (C), around which the six longitudinal bands are very distinct, as also are the transverse muscular ones. At the commencement of the eleventh segment it becomes constricted, and terminates in a distinct pylorus, which ends in a short ilium (*e*), into the middle of which, on each side, are received the united termination of the hepatic vessels *(f)*, which, having extended along the sides of the stomach as far forwards as the seventh segment, are convoluted around this and the remaining portion of the canal. Immediately behind the ilium the canal is developed in a six double-lobed cœcum (*g*), and immediately afterwards into an immense sacculated colon (*h*), terminated by a very short rectum. The longitudinal bands are particularly distinct on the colon, and extend from its posterior part to the external muscular tegument forming the retractors of the colon and rectum. In the active larvæ of Coleoptera the alimentary canal becomes still more developed. It commences in the larvæ of the *Carabidæ*, *Calosoma sycophanta (fig.* 426), according to Burmeister,* in a very short œsophagus (H), that opens at the posterior part of the pro-thoracic segment into a large cylindrical stomach (K), which is extended throughout the greater part of the body, very similar in appearance to that of the Lepidoptera. This is called by Burmeister the *craw*. It opens directly into another cylindrical stomach, much narrower and nearly of the same length, but more muscular than the preceding, and receiving its posterior extremity (Q), where it forms internally a distinct pyloric valve, the hepatic vessels. Burmeister remarks that there is no valve of separation between the first and second of these stomachs, nor any rudiment of the gizzard, which exists in the perfect insects of this order *(fig.* 424, *i*). These are succeeded by a small intestine or ilium (L), which is of some length, and together with the second stomach forms several convolutions in the body between the first stomach, or craw, and the great intestine or colon (M), which follows it, and terminates the canal in a protruded anal aperture (O). The colon, as in most larvæ, is very muscular and folded transversely, and altogether the canal is more developed than in the preceding instances, as also are its appendages the hepatic vessels, which are exceedingly long, although no cœca are developed upon them. In the Rhinchophora and Longicornes there is a still higher form of alimentary canal, as observed by Burmeister† in *Calandra*

Fig. 426.



Alimentary canal of the larva of Calosoma sycophanta. (Burmeister.)

* Transactions of Entomol. Society of London. vol. i. part 3.

† Zur Naturgeschichte der Gattung Calandra. Berlin, 1837.

Sommeri, and as seen by ourselves in *Callidium luridum*. In *Calandra*, which in external appearance is scarcely more perfect than the apodal larva of Hymenoptera, the alimentary canal (*fig.* 427) approaches much in form,

Fig. 427.

Alimentary canal of the larva of Calandra Sommeri. (*Burmeister.*)

size, and complication of its parts to that of the perfect insect. It commences behind the pharynx in a very short pear-shaped œsophagus (H), which opens by a valve into a dilated bag-shaped crop (I), analogous probably to the first stomach of the larva of *Calosoma*. This is continuous by a narrowed passage with the proper digestive cavity, around the middle part of which (K) are developed many conical glandular papillæ or gastric vessels, that do not appear to have been noticed in the larva of *Calosoma*, which instead of subsisting upon hard vegetable substances like these *Curculionidæ*, preys upon the soft bodies of living caterpillars, and consequently does not require for the digestion of its soft animal food and juices so complicated a structure as those which devour large quantities of crude vegetable matter, as is the habit of the *Lamellicarnes*, or the hard and less easily solvent woody fibre or coverings of insects devoured by the *Calandra* or the perfect *Carabidæ*. At the posterior extremity of the digestive stomach in this larva are inserted, as before seen, the biliary vessels, not singly around the sides of the canal, but by the union of four of these tubes in a common duct. This peculiarity is remarkable, as it occurs in some species in the perfect insect. Besides these vessels there are two others somewhat smaller, which are inserted separately, a little anterior to the common duct. These have been supposed to be analogous to pancreatic vessels, but they are similar in almost every respect to those which are inserted by a common duct, and hence may be supposed to have nearly the same functions. We have noticed similar vessels inserted separately from the supposed hepatic vessels in the *Dyticidæ* and in *Timarcha*, which certainly leads to the conclusion that they have some difference of function. The ilium (L) is of great length, and more convoluted than we have yet seen it in any larva, and ends in a very muscular cylindrical colon (M N), terminated by a short rectum. A similar and perhaps even more highly developed form of alimentary canal exists in *Callidum luridum*, in which the anterior portion of the œsophagus commences with a small neck, and is then enormously dilated, after which it becomes gradually narrowed and constricted, and is joined to a second stomach, which in like manner is also dilated at its anterior extremity. In the middle part of its course it is twice folded, and is covered with minute cœca, as in *Calandra*, like which it terminates in a valvular pylorus, and receives at the same time the insertions of the hepatic vessels. The ilium is also of considerable length, is exceedingly muscular, and is dilated in two parts of its course before it terminates in a straight and very muscular colon and short rectum, as in *Calandra*. The length and complication of the intestines, therefore, appear to have some reference to the quality of the food to be digested, since it is well known that the food of these latter insects is of difficult assimilation, being as it is chiefly the hard ligneous fibres of vegetable matter; but they cannot be received as always indicatory of a carnivorous vegetable feeder, since, as above remarked, the length of the canal is considerable in one entirely carnivorous larva, while it is much shorter in some herbivorous, and particularly in pollenivorous larvæ, as in the *Melolontha* and the apodal Hymenoptera.

In the perfect insect, the length of the alimentary canal is not more indicatory of the habits of the species than in the larva. It is nearly as long, and is more complicated, in the rapacious *Carabidæ* (*fig.* 423) than in the honey-sipping Lepidoptera, whose food is entirely liquid, while, as we have seen, it is only a very short tube in the pollenivorous larva, which subsists upon a mixture of pollen and honey; but in the perfect insect, which subsists upon honey alone, and which it might be supposed requires little power of digestion, the canal is long and tortuous. In the rapacious *Carabidæ*, it is from two to three times the length of the whole body. At its commencement at the pharynx it is funnel-shaped, and opens directly into the œsophagus (*fig.* 424, *h*), which is gradually enlarged as it passes through the thorax, until it arrives at the meta-thoracic segment, where it becomes greatly dilated, and forms a large bag or crop, which we shall presently see more perfectly developed in the Haustellata. While passing into the abdomen, this part becomes suddenly constricted, and terminates in a short neck, immediately behind which is an oval and very muscular gizzard (*i*), which is developed internally into four broad longitudinal horny ridges (*a*, *b*), armed with strong sharp bristles, as formerly shewn by Leon Dufour* in insects of this family. Between these ridges are two channels armed in like manner with a double row of minute hairs, which assist in more minutely comminuting the hard parts that are passed into the gizzard and escape trituration by the ridges. The substance of the gizzard is particularly muscular, and resembles in colour the gizzard of a bird. On its external surface the thin shining peritonœal coat is very distinctly seen. At its base the gizzard is much constricted, and the ridges within it meet together so as to form a distinct valve, by which this is divided from the next portion of the alimentary canal, the chylific ventricule (*k*). This part is capacious and muscular, and the double mucous lining within it is very distinct. It is of considerable length, and is gradually decreased in size from its commencement to its termination at the pyloric valve, where, as in the larva, it receives the hepatic vessels. It is covered throughout its whole course by an immense number of apparently cœcal vessels (*a*, *b*, *c*), which in the upper half of its course are of considerable length, but in the lower become gradually more and more shortened. Burmeister† thinks these cœcal vessels are derived entirely from the inner or mucous coat of the ventricule by intussuscepted portions, which pass through the muscular coat between the fibres which are pushed aside by them, and consequently that they do not derive any covering from the muscular coat, but of this we have considerable doubt. Internally they certainly open each by a distinct valvular orifice, derived from the mucous lining, as we have seen in *Carabus monilis* (*b*), and externally are covered by the peritonœal coat, and on each side are furnished with a minute ramifying tracheal vessel, derived from the tracheæ which are distributed over the alimentary canal, as shewn by Dufour. We cannot, however, imagine that they derive no covering from the muscular coat of the ventricule, more especially while it is admitted that the cœcal appendages attached to the anterior and posterior portion of the ventricule in the *Gryllidæ* derive a portion of their structure from the muscular coat as well as the mucous. These are most decidedly secretory organs, and elaborate a fluid, probably distinct in its chemical composition from that of the biliary vessels at the pyloric extremity of the stomach. The ilium (*l*) is of considerable length. On its exterior surface the longitudinal muscular bands are distinctly marked. It is much longer in proportion to the other parts of the intestine in the perfect insect than in the larva. It terminates in a very large pear-shaped colon (*m*, *n*), the upper part of which corresponds to the cœcum, which we shall see highly developed in some other species. It is there marked by six elongated elevated glandular protuberances, situated between the longitudinal muscular bands. These elevations seen on the exterior of the part correspond to others which we have found equally strongly marked in the colon of Hymenoptera, and we suspect are the mucous glands of the great intestine. The colon is usually distended with fæces, and terminates in a very short narrow rectum (*o*). At each side of the colon are situated the *anal or urinary* vessels (*s*), which we shall presently describe. This may serve to illustrate the general form of the alimentary canal in carnivorous Coleoptera. In certain parts of its course it is, however, more developed in other species. Thus in the *Dyticidæ*, we have found the œsophagus in *Hydaticus cinereus*, as described by authors in *Dyticus*, expanded into a large crop-shaped bag, and the stomach shorter than that of the *Carabidæ*, and covered by long cœca throughout its whole extent. It receives at its base the insertion of four large hepatic vessels, and also two very much smaller ones, similar to those just seen in the larva of the *Calandra*. The anal vessels are also present, but their excretory bladder is larger, and its neck much shorter than in the *Carabidæ*. The most remarkable structure is in the proventriculus or gizzard. The external appearances of this part resembles that of an acorn in its cup. It is exceedingly muscular, and is armed internally with four remarkable teeth arranged around its inferior portion, between four horny ridges developed from the mucous lining of the part, and covered with very strong stiff hairs, as in the *Carabidæ*. Each of these teeth is broad and somewhat oval at its base, and in shape resembles a helmet, the crest of which is acute, and armed with two sharp-pointed prominences adapted for cutting the food, which it is known is swallowed more rapaciously and less comminuted by these insects than by *Carabidæ*. This form of alimentary canal with a gizzard and gastric cœca exists in the *Silphidæ*,* and most of the carnivorous feeders. Thus it exists also in *Staphylinidæ*,† in which we have found the gizzard in *Creophilus maxillosus* armed with double longitudinal horny ridges, covered with stiff hairs as in *Carabus*, like which also the stomach is covered with gastric cœca, which are larger at the anterior than at the posterior part of the organ. The anal vessels are also largely developed. Dufour has observed the same in *Staphylinus erythropterus*. The gizzard is also found in some of the Neuroptera. It is very largely developed in the carnivorous *Panorpa communis*, in which, however, we have not found it thrown into regular longitudinal folds, but into transverse and oblique rugæ covered with stiff hairs. The alimentary canal in this species is of considerable length, perhaps nearly three times that of the body. The œsophagus is short, but is developed at its under surface into a minute oval crop, perfectly distinct from

* Annales des Sciences Naturelles, tom. ii. pl. 20.
† Op. cit. p. 132.

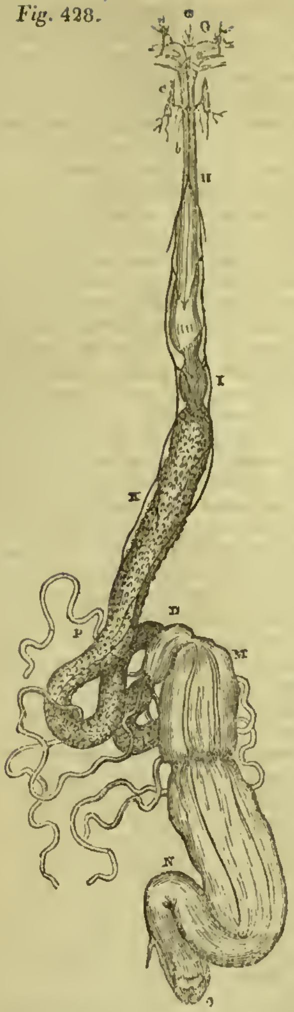
* Dufour, op. cit. tom. iii. pl. 13, fig. 5.
† Id.

the common cavity of the œsophagus, although not separated from it by a valve, neither is the œsophagus separated by a valvular structure from the gizzard. The chylific stomach is exceedingly long and cylindrical, but is without gastric cœca, like the larva of *Carabidæ*, since like that, the *Panorpa* appears to subsist rather by sucking the juices than by swallowing the hard parts of the body of its victims. Thus, then, although in the *Cicindelidæ* (*fig.* 37, vol. 1), the canal is scarcely longer than the body, as formerly shewn by Dufour, and since frequently instanced as proving that the length or shortness of the canal is characteristic of a carnivorous or phytophagous feeder, we cannot admit that the length of the digestive organs, and the existence of a gizzard and gastric vessels, are indicatory of predacity of habits in the insect, because a similar conformation of parts exists often in strictly vegetable feeders. The existence and length of these parts seem rather to refer to the comparative digestibility of the food than to its animal or vegetable nature.

Among the more omnivorous feeders, as in the *Forficulidæ*, the gizzard is still present. In *Forficula auricularia* the œsophagus is long and dilated, and a short, broad, and very muscular gizzard is present. Internally it is thrown into six longitudinal folds, which project for some distance at their extremity into the cavity of the digestive stomach, to the entrance of which, when closed, they serve as a valve. The canal of this insect, which, although in part carnivorous in its habits, certainly is not of the most rapacious nature, but lives equally upon the juices of fruits and flowers, is scarcely longer than that of the most predaceous *Cicindela* or *Dyticus*, since it passes almost in a direct line through the body, making but one slight convolution, a further proof that the *length* of the canal must not be taken as a criterion whereby to judge of the habits of a species. This will apply equally to the omnivorous *Gryllidæ*, in which there exists a short alimentary canal, but a gizzard of more complicated structure than that of *Dyticidæ*. In these insects the two layers of the mucous coat are visible even in the œsophagus. The second layer is distinctly glandular and secretory, and in it there are many thousands of very minute granulary glandular bodies, which probably secrete the fluid that is often ejected from the mouth of the insect when captured. The inner layer, or proper mucous lining, is often folded longitudinally, and in *Acrida viridissima* these folds, which are six in number, assist to form a valve between the œsophagus and gizzard. They are each armed with five very minute hooked teeth, and continued into the gizzard develope many more in their course through that organ. These first teeth are arranged around the entrance to the gizzard, and seem designed to retain the insufficiently comminuted food and pass it on to that organ. Next to these in succession on each of the longitudinal ridges are four flat, broad, and somewhat quadrate teeth, each of which is very finely denticulated along its free margin. These extend about half-way through the gizzard. They appear to be alternately elevated and depressed during the action of the gizzard, and to serve to carry on the food to the twelve cutting teeth with which each ridge is also armed, and which occupy the posterior part of the organ. These teeth are triangular, sharp-pointed, and directed posteriorly, and gradually decrease in size in succession from before backwards. Each tooth is very strong, sharp-pointed, and of the colour and consistence of tortoise-shell, and is armed on each side by a smaller pointed tooth. These form the six longitudinal ridges of the gizzard, between each two of which there are two other rows of very minute teeth of a triangular form, somewhat resembling the larger ones in structure occupying the channels between the ridges. The muscular portion of the gizzard is equally interesting. It is not merely formed of transverse and longitudinal fibres, but sends from its inner surface into the cavity of each of the large teeth other minute but powerful muscles, a pair of which are inserted into each tooth. The number of teeth in the gizzard amounts to two hundred and seventy, which is the same number in these *Gryllidæ* as found formerly by Dr. Kidd* in the mole-cricket. Of the different kinds of teeth there are as follows: seventy-two large treble teeth, twenty-four flat quadrate teeth; thirty small single-hooked teeth, and twelve rows of small triangular teeth, each row being formed of twelve teeth. This is the complicated gizzard of the higher Orthoptera. In the same insect immediately posterior to the gizzard the chylific stomach is expanded on each side into two large rounded cœca, into the upper part of which some minute vessels are traced which in appearance resemble the hepatic vessels. Posteriorly to these cœca the stomach becomes narrowed and makes one convolution, and receives around its termination the hepatic vessels, which are small but very numerous. It then is continued backwards as a long ilium, and terminates in a muscular banded colon without a distinct rectum. The whole length of this alimentary canal does not exceed more than about one length and a half of that of the body. A similar structure exists in the *Blattidæ*. In these insects eight large vessels are inserted around the commencement of the stomach behind the gizzard. Four of these are long and four short, and as observed by Burmeister, these have been thought to be analogous to pancreatic or gastral salivary organs. In the proper *Locustidæ* there is only a rudimentary gizzard, as Burmeister has shown in *Locusta migratoria*, in which the interior lining of the whole œsophagus and crop is covered by an immense number of very minute horny teeth, for the purpose of comminuting the hard ligneous matter which we have sometimes found in foreign specimens. The rudiments of the gizzard exist in six flat pieces, studded with minute teeth like the lining of the œsophagus. The commencement of the stomach is surrounded by two sets of cœcal appendages, six in each set, and similar in form to those of the second set in the larva of *Melolontha*, like which those on the under surface are the

* Phil. Trans. 1826.

Fig. 428.



Alimentary canal of Lucanus cervus.

G, anterior muscles of the pharynx; H, œsophagus; I, gizzard; K, chylific stomach; L, ilium; M, colon (cœcal portion of); N, colon; O, rectum; *a*, frontal ganglion on the vagus; *b*, vagus; c, anterior lateral ganglion connected to the vagus.

longest. These are evidently analogous to the vessels in *Blatta*.

But one of the most remarkable forms of alimentary canal with reference to the habits of the insect exists in the male *Lucanus cervus* (*fig.* 428), which subsists entirely upon fluid aliment, as proved by the observations of naturalists, and confirmed by the fact that its mouth is unfitted for mastication. In this insect the œsophagus (H) is usually long and narrow, and terminates in the meso-thorax in a well developed gizzard (I), as in the *Carabus*, and this is succeeded by a long chylific stomach (K), covered throughout its whole extent by very minute rudimentary cœca, as first noticed by Dufour. It makes three distinct convolutions, and is then divided by a pylorus, which receives four hepatic vessels (P) from an exceedingly short ilium (L), which passes directly in an enormous colon. The upper portion of this (M) is divided from the lower (N), which is thus divided into colon and cœcum. It terminates in a long folded rectum (N, O), and the whole are usually filled with fæces. Now this insect, in which both gizzard and gastric vessels are present, can scarcely require these parts for the purpose of triturating its food, which is entirely fluid, besides which, being one of those species that undergo a complete metamorphosis, it can scarcely be supposed to be simply a remains of what existed in the larva state. The presence of the gizzard may be looked upon as somewhat anomalous. Again it may be remarked, that in Hymenoptera the stomach, which in many species digests only liquid concentrated food in the form of honey, is much longer than in those instances, as in Orthoptera, in which the food is less easily digestible. In the *Apidæ* there is a large alimentary canal with an immense number of biliary vessels attached to it, while in the *Tenthredinidæ*, which, besides honey, subsist partly upon the pollen of flowers, as we have observed in *Athalia centifoliæ*, there is a very short alimentary canal and even a distinct gizzard (*fig.* 429, I), situated between the

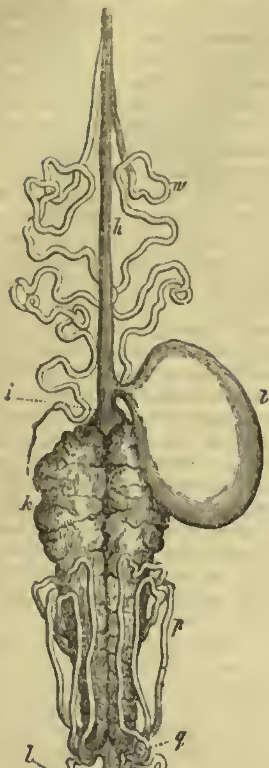
Fig. 429.

Section of the crop (H), *gizzard* (I), *and stomach* (K) *of Athalia centifoliæ.* (*Newport, Prize Essay*).

stomach (K) and the dilated œsophagus (H) or crop of this order. We have detected pollen in the proventriculus of this insect, so that in these we have still further proof that the length of the canal is not always indicatory of the habits of the species.

In the Lepidoptera, which, we have seen, in the larva state have a short intestine, have a comparatively long one in the perfect. In the *Sphinx ligustri* (*fig.* 430), the œsophagus (*h*) is long and narrow, and in the metathoracic segment is dilated into a large crop (*t*) connected by a distinct neck, but not divided from it by a valve. This is usually filled with air, and has thence been called the *sucking stomach*, but in the Diptera, in which it also exists, and commencing much nearer the pharynx is extended backwards as a long and gradually enlarging tube until it reaches the anterior part of the abdomen, where it is expanded transversely into a large bag, we have certainly found it partially filled with food. This has often been found to be the case in the common flesh-fly. In *Eristalis floreus* (?) we have found it partially filled with yellow pollen from the flowers of the ragwort, upon which the insect was captured. We have at the same time observed

Fig. 430.



Alimentary canal of Sphinx ligustri.

the pollen in the canal leading to the bag, in the œsophagus, and in the stomach itself. A gizzard does not exist either in the Diptera or Lepidoptera, but there is a slight rudiment of it in the Sphinx (*i*). The stomach of Lepidoptera is in general short, oval, or a little elongated (*k*), and always very muscular, and as in other insects, the hepatic vessels (*p*) enter at its pyloric extremity (*q*). The ilium (*l*) is of considerable length. In the Sphinx it makes seven folds, and then passes straight to the

Fig. 431.

Alimentary canal of Pontia brassicæ.

colon, which is developed anteriorly into a very large cœcum (*m*), and terminates in a narrow short rectum (*n*). Throughout its whole course it is covered by the hepatic vessels. In the *Pontia brassicæ (fig.* 431), the digestive stomach is preceded by a very muscular and transversely banded portion of canal resembling the stomach of Hymenoptera. It is in the precise situation of the gizzard in other orders, and appears to be the representative of that part in this insect. The true stomach is long and oval, and the ilium is longer than in the Sphinx, and the cœcum, colon, and rectum are all distinct. In the Diptera the alimentary canal is usually very long, and is scarcely at all shorter in the carnivorous than in the omnivorous feeders.

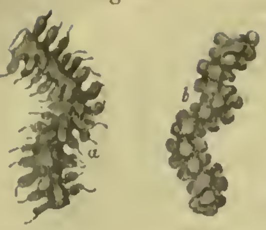
Appendages of the canal.—The first of these, the *salivary glands*, are very frequent in most of the orders, but vary greatly in form and number. In Lepidoptera they are simple elongated tubes (*h*), which extend into the thorax and are convoluted beneath the œsophagus and anterior portion of the alimentary canal. In the larva they constitute the *silk vessels,* and empty themselves by a single duct through the spinneret on the floor of the mouth. They are formed of three portions; first, the excretory, which is thin and transparent, and is gradually enlarged as it passes backwards along the body; second, the apparently secretory portion of the organ, which is of an elongated cylindrical form, externally transversely marked as if formed of muscular fibres, and internally covered with a vast number of rounded glandular bodies, as we have seen in the recently detached vessel of *Vanessa urticæ*; and lastly of a third portion, which consists of a minute vessel, extended from the apparently cœcal extremity of the middle portion of the organ, as formerly shewn also by Lyonet in the Cossus. In the perfect insect these parts still exist, but very much reduced in size. In the Cossus Lyonet has shewn four of these vessels, two of which, the proper silk vessels, open by a single excretory duct, and the others separately into the cavity of the mouth. In some Coleoptera, as in the *Blapsidæ*, these organs are formed of many ramifying tubes united on each side of the œsophagus into a single duct. In others, as in the Orthoptera and Hymenoptera, they consist of an immense number of rounded, opaque, glandular bodies, aggregated together in small clusters, which communicate by many small ducts, inserted at irregular distances, with a large and partially convoluted common or excretory duct, that opens on each side of the mouth, so that each of these collections of glands resembles a bunch of grapes or currants. Each of these rounded granules, or acini if we may so call them, receive a minute vessel, but whether this is distributed over its surface or is received directly into its substance we have been unable to ascertain. These aggregations of salivary glands are usually situated on each side beneath the œsophagus in the prothorax, and are very distinct in the Orthoptera and Hymenoptera, in which they have been often noticed. Müller has seen them in *Phasma*, Treviranus in *Apis*, Burmeister in *Locustidæ*, *Gryllidæ*, and *Termes*, and we have also seen them in *Locustidæ* and *Gryllidæ* among the Orthoptera, and in *Bombus*, *Apis*, *Anthophora*, and *Athalia* among the Hymenoptera. Their existence in the latter genus is somewhat interesting from the circumstance that the large quantity of salivary fluid which these organs seem calculated to produce appears to be entirely employed in moistening the dry pollen of flowers upon which the perfect insect chiefly subsists, before it is passed into the œsophagus, and not in the habits or in constructing of a nest, as is the case with the bee, which always employs it as a solvent for the wax in the construction of its combs. In the latter insect, according to Burmeister, the evacuating duct of these organs is a minute spiral vessel resembling a trachea, and empties itself into the tube of the proboscis or ligula. The form and number of these salivary organs varies in the different classes; the usual number is two, but in *Apis Cimex* and *Pulex* there are four, each pair of which unite into one duct, while in *Nepa* there are as many as six.* In the *Tabanidæ* there are only two short cœcal tubes, into which many minute vessels empty themselves.† Those *gastric vessels*, which are inserted at the commencement of the digestive stomach we have above stated have been regarded as salivary organs, but there is considerable doubt respecting their real function. Burmeister considers them to be analogous to the pancreas, but if this be admitted to be the case in the Orthoptera, those vessels also which cover the exterior of the digestive stomach in the carnivorous Coleoptera must be of the same description, since both empty themselves into the digestive stomach. But we cannot coincide with him in this opinion, since from an experiment which we shall presently notice there is reason to believe that the fluid poured into that cavity during digestion is of an acid nature, analogous to that which is found under similar circumstances in the stomach of vertebrata; while that of the proper salivary organs is believed to be alkaline, as was formerly supposed by Rengger. Treviranus also believed the same of the saliva of the honey-bee, having witnessed its employment by this insect in the formation of its combs. We have also seen this insect reduce the perfectly transparent thin white scale of newly secreted wax to a pasty or soapy consistence, by kneading it between its mandibles, and mixing it with a fluid from its mouth, before applying it to assist in the formation of part of a new cell, so that we have good reason to believe that the salivary fluid thus employed as a solvent for the otherwise brittle wax is of an alkaline quality.

The *Malpighian* or supposed *biliary vessels* (*fig.* 432, *p*) usually enter the canal, as we have seen, at the pylorus. They vary greatly in number from two to twenty or even a hundred, as in some of the Orthoptera and Hymenoptera, but in all insects their function appears to be similar. They are usually from four to six in number, and are very long tubes that pass from their insertion or opening into the canal behind the pylorus directly forwards about half way along the sides of the stomach, and are then reflected backwards as far as the ilium, around which and the colon they make many convolutions, and in the Lepidoptera terminate, or perhaps we ought rather to say originate, each in a minute vessel, which becomes smaller and smaller in proportion to its length, and in which we can perceive no disposition to form a cœcal termination, although we have been unable to trace it to its origin, which is certainly in the vicinity of the posterior part of the colon. Of this we have satisfied ourselves by following these vessels in the larva of *Odonestis potatoria*, which the colour of their contents, an opaque bright yellow, has rendered practicable. We have traced them until the yellow colour has disappeared in an opaque white, and this has been also lost in a perfectly transparent fluid, after which we have been unable to follow the vessels further. In other insects they appear to end in cœcal extremities, but we certainly could not observe this in the larvæ of Lepidoptera. It has also been supposed by some anatomists that these vessels form a double communication with the alimentary canal, but this has entirely escaped our observation. In the larva of *Sphinx ligustri* and most other Lepidoptera these vessels are covered by an immense number of minute oval cœciform dilatations (*fig.* 432, *a*), as is also the case in some of the perfect Coleoptera, *Melolontha*,* as shown by Dufour, Straus

* Burmeister, op. cit. p. 146. † Id. 145.

* See Animal Kingdom, vol. i. fig. 38, c.

Fig. 432.



a, part of the hepatic vessel of the larva of Sphinx ligustri when nearly full grown, showing the cœca; *b*, part of the same in the pupa, the cœca disappearing.

Durckheim, and others. From each of these supposed cœca in the larva of sphinx we have traced an exceedingly minute and transparent vessel which has appeared to be connected with other delicate ramifications, and sometimes with the immense quantity of adipose sacculi with which the whole viscera are surrounded. These Malpighian vessels undergo considerable changes while the insect is passing from the larva to the perfect state. The cœca begin to disappear soon after the insect has entered the pupa state (*b*), and not a trace of them is discoverable in the perfect insect, so that the function of the organ is gradually diminished in activity. During the larva state they exhibit a remarkable peculiarity at their connexion with the alimentary canal which seems to have some reference to their function. It is a dilatation at the point of union of these vessels in the sphinx to form a single duct that opens into the ilium, and if these be hepatic vessels may represent a gall-bladder, as once observed to us by Dr. Grant, but the exact function of the vessels is very difficult to determine. The following observation which we made in the summer of 1832 and have since repeated seems a little to show the nature of the contents of these vessels, and also of other parts of the alimentary canal. We gave sugared water, coloured with indigo, to some specimens of *Vanessa urticæ* which had been confined for several hours without food after they had left the pupa state. On examining the insects about two hours afterwards the stomach was found filled with fluid containing a great quantity of pink-coloured granules, which appeared to be the vegetable indigo acted upon by the acid contents of the stomach by which it had become saturated, thus distinctly indicating the presence of an acid in the stomach during digestion. But it was remarkable that some of the indigo that had passed the pyloric extremity of the stomach, where these supposed biliary vessels enter, and had also passed throughout the whole length of the ilium and even in part into the colon, had been restored again to its original dark blue colour, thus indicating the presence of an alkalescent fluid secreted either by the hepatic vessels or the ilium along which the indigo had passed. But another curious circumstance was that the hepatic vessels also partook of the same pinkish hue as the contents of the stomach, which seemed to indicate that the contents of these also are acid. The conclusions we drew from these observations, which we repeated very carefully in 1834, were, that there is an acid gastric juice secreted in the stomach during digestion, that the contents of the so-called hepatic vessels are probably also acid, and that an alkaline fluid is secreted by the ilium, otherwise the indigo reddened in the stomach could not have been restored to its original colour. These circumstances seem to lead to the conclusion that the Malpighian vessels are rather uriniferous than biliary, more especially as they have been found by Chevreul* and Audouin† to contain uric acid; but if this be really their function, a question then arises why they are inserted so near to the pyloric extremity of the stomach in almost all insects, and the excreted fluid be thus required to traverse nearly one-half of the whole alimentary canal before it is ejected from the body? This consideration still inclines us to suspend our opinion as to their true function, and leads us still to believe that they may be in some way connected with the function of digestion and assimilation.

The anal or proper uriniferous organs.—We agree with Burmeister that the anal are the true urinary organs. They do not in general evacuate their contents directly into the canal, but on each side of the anus. They exist, as we have seen, in the *Carabidæ* (*fig.* 424, *s*), and their general form, as long ago shown by Dufour in these insects, is that of a long vessel convoluted upon the colon and emptying itself into an oval or kidney-shaped vesicle on each side of the colon, and terminating in a single duct close to the anus. Dufour found the minute vessel on the colon connected with an aggregation of rounded glandular bodies, each connected with the vessels by a very minute filament, but we have overlooked this structure in our own examinations. Neither have we seen it in the *Dyticidæ*, in which each uriniferous organ commences in two apparently cœcal tubes, which, after being a little convoluted, unite into one which empties itself into a vesicle on each side of the colon and rectum. Similar vesicles have been shown by Dufour in the *Staphylinidæ*, as in *Staphylinus erythropterus* and in the *Silphidæ*, in both which we have ourselves distinctly seen them arising by a single vessel which empties itself into an urinary bladder on each side of the anus. In the *Silphidæ* this bladder opens directly into the termination of the rectum.

The adipose tissue.—This tissue, which it is necessary to allude to in connexion with the organs of nutrition, consists of an immense number of little transparent membranous vesicles filled with opaque adipose matter, which, in the generality of insects, is perfectly white, but in others, as in the butterflies, is of a bright yellow colour. The vesicles are usually very irregular in form, being sometimes nearly oval and at others elongated or triangular. They communicate freely with each other and form a most intricate web or reticulated structure. They cover the whole of the abdominal viscera

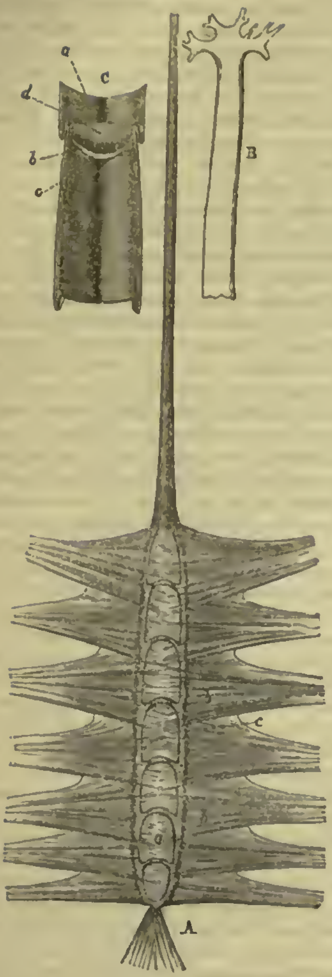
* Straus Durckheim, Considerat. &c. 1828, iv. 251.
† L'Institut. 135.

like the omentum of the higher animals, and they are extended also among the muscles, between which they occupy the interstices, both between the different layers and the tegumentary skeleton. They do not form in the abdomen one continuous surface like the mesentery, but are simply attached to each other, and to the surrounding structures by constricted portions, which allow of the freest communication. They are most abundant in the abdomen, but are extended into the thorax and cover more particularly the nervous cord. There are but very few in the region of the head or in the extremities. We have never yet seen them in actual communication with bloodvessels, although we have observed them attached by minute points along the whole course of the dorsal vessel, in the abdomen, as if they were in some way connected with the return of the blood to the auricular space that appears to surround that organ. It is amongst these vesicles in particular that the Malpighian or so-called biliary vessels extend around the alimentary canal, and the tracheæ ramify among them in the greatest abundance, but we have not observed them distributed over the sides of individual vesicles as over some other structures. These circumstances lead us to suspect that the vesicular structures are in some way connected with the circulatory system, although they cannot be regarded either as arteries or veins. May they not serve the purpose of lymphatics, while they become at the same time depositaries of the nutrient matter? Oken and Treviranus appear to have considered them as analogous to the liver, and the latter author has supported his opinion by the existence of a somewhat analogous structure in the scorpion, which is believed to be the liver of that animal. That they are most intimately connected with the function of nutrition is proved by the circumstance that they exist in the greatest abundance at the period when the larva ceases to feed, just before it enters the pupa state; that their contents are gradually diminished during that condition; and that they disappear most rapidly towards the latter end of the pupa state, when the organs of generation are in the most rapid progress of development. After the insect has entered the perfect state their contents have nearly disappeared. Added to these circumstances we have observed that, during the earliest periods of the larva state, the quantity of adipose substance contained in the vesicles is very small, and also that in all perfect insects that pass the winter in a state of hybernation the quantity of adipose matter is much greater than in those which do not live through the summer, while it has nearly all disappeared in these insects after they have left their hybernacula in the spring. We have remarked these circumstances particularly in the later broods of butterflies, which being hatched at the end of autumn pass the winter as hybernants and appear again in the spring, and we have constantly noticed the same thing in the large females of *Bombus terrestris*, which live through the winter. From these circumstances there can be no doubt but that the adipose matter is intimately connected with the function of nutrition and the circulatory system, while the free communication which we have constantly observed to exist between the vesicles seems to favour our opinion that they may serve the office of lymphatic vessels. That they cannot be supposed to answer the purpose of a liver seems evident from the increase and diminution of their contents at certain periods, while their apparent connexion with the Malpighian vessels seems to support the opinion we have advanced, more especially if these be regarded as uriniferous rather than as biliary organs.

Circulatory system.—It was formerly supposed that there was a total absence of a circulatory motion of the fluids in insects, and that the whole body was nourished by a simple imbibition of fluids that occupied the cavities of its different regions. This opinion was strengthened by the circumstance of the air-vessels being distributed to every separate structure and ramifying extensively even upon the most delicate organs, a fact so remarkable that it appeared entirely to obviate the necessity for a motion of the fluids, and led to the promulgation of Cuvier's beautifully ingenious theory, that as the blood could not be carried to be aerated in a separate organ or lung, the air was in consequence brought into contact with it throughout the whole body. But the discovery of Carus in 1827 of an actual motion of the fluids, and subsequently the discovery by Straus Durckheim of a structure in the dorsal vessel, which clearly indicates the true use of this organ as a centre of circulation, have sufficiently shown that insects do not differ from other animals in the absence of a circulation of their fluids, whatever modifications may exist in the form and situation of the organs by which it is accomplished.

The heart or *great dorsal vessel* (*fig.* 433, A) is an elongated tapering organ, which, in every insect, occupies the middle line of the dorsal surface of the body, and extends from the posterior part of the penultimate segment of the abdomen, through the thorax, into the first segment or head of the animal. That portion of it which is situated in the abdominal region is the proper analogue of the heart of other other animals, and is composed of a certain number of separate compartments or chambers (*a*). It is distinctly muscular, and is of considerable diameter, and is that part which is actively employed in circulating the blood. The other part which extends through the thorax is much narrower than the preceding, and is not divided into chambers, but is one continuous vessel that becomes gradually narrower as it passes through the thorax to the head, where it is divided into separate branches (B). This part is less actively employed than the abdominal, being only the great vessel through which the blood is sent from the muscular heart to the system, and, consequently, represents the *aorta*. In the *structure* of the abdominal portion or true heart we recognize three separate coats, two of which are most distinctly marked, and form the substance of the organ; but the third or external one is very delicate and not easily observed. Straus Durckheim recognises but two distinct structures, the

Fig. 433.



A, *dorsal vessel or heart of Lucanus cervus.*
a, the valves or chambers; *b, b*, the lateral muscles; *c*, the supposed auricular space around the vessel.
B, *the division into vessels of the anterior or aortal portion of the dorsal vessel in the larva of Vanessa urticæ.*
C, *interior of the dorsal vessel (Straus).*
a, interior of the valve, showing the transverse fibres; *b*, the auriculo-ventricular opening and valve into the chambers of the vessel; *c*, semilunar valve; *d*, inter-ventricular valve.

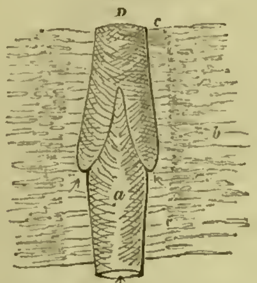
internal one (C, *a*) formed of a transversely folded and striated membrane which is thickest towards the middle of each chamber, and an external one formed of strong, smooth, muscular, longitudinal fibres. Burmeister* has suggested that these may be only two layers of one muscular structure, and that the presence of a structureless lining or inner membrane must then be presumed, although it be too delicate to be actually detected by observation. The third or external coat is a transparent structureless membrane which covers the outer surface of the heart, and is extended directly over it without following the reflexions inwards of the muscular coat, where it forms the valves or separations between the different chambers. The division of the organ into separate chambers is effected by means of an intussusception or reflexion inwards and forwards of the whole muscular structures. A portion of each side of the heart is first extended inwards so as very nearly to meet a corresponding portion from the opposite side, and then reflected backwards forms, according to Straus,* the interventricular valve (*d*), which separates each chamber from that which follows it. Posteriorly to this valve, at the anterior part of each chamber, is a transverse opening or slit (*b*), the *auriculo-ventricular orifice*, through which the blood passes into each chamber, and immediately behind it is a second but much smaller *semilunar valve* (*c*), which, like the first, is directed forwards into the chamber. It is between these two valves on each side that the blood passes into the heart and is prevented from returning by the closing of the semilunar valve. When the blood is passing into the chamber the inter-ventricular valve is thrown back against the side of the cavity, but is closed, when, by the contraction of the transverse fibres, the diameter of each chamber is narrowed and the blood is forced along into the next chamber. The number of these openings and chambers in different species of insects does not yet appear to have been satisfactorily ascertained. Straus has figured nine chambers in *Melolontha*, and consequently eight pairs of openings, but we have not been able to observe more than seven pairs of openings in *Lucanus cervus*, in which the anterior pair is almost hidden at the commencement of the aorta. Burmeister† states that he could not find more than four pairs of openings in the larva of *Calosoma*, while he remarks that according to Müller's description of the heart in *Phasma* there appears to be but one pair in that species. In *Bombus terrestris* we have as yet detected but five pairs, but we nevertheless suspect that these discrepancies, or apparent differences in the number of these openings, arise less from so great a diversity in the actual number than from some of them being overlooked during dissection, since we have invariably found eight pairs in *Sphinx ligustri*, both in the larva and perfect state, as well as in other Lepidoptera; while in the Bombus examined by us the dissection was not so carefully made as to enable us to state positively that there are not more than we have mentioned. The external form of the chambers in the very thick and muscular heart of *Lucanus* is shown in the drawing we have given of this structure. When the heart is examined by transmitted light, there is seen around it a bright space (A, *c*) in which we have observed the blood flowing very freely in living specimens of *Agrion*, and which we regard with Straus as an auricular cavity, apparently bounded by a loose membrane, and

* Op. cit. p. 156.

* Considerat. &c. p. 356.
† Op. cit. p. 154.

into which the blood is received both in returning backwards from the head and thorax and laterally from the sides of the abdomen. We have observed a similar space in many insects, particularly in *Asilus crabroniformis* (*fig.* 434, D), and also in *Bombus terrestris*.

Fig. 434.



One valve of the heart of Asilus crabroniformis.

a, the chamber; *b*, the lateral muscles; *c*, the auricular space; the arrows denote the course of the blood.

In this insect we have observed the fibres of the heart crossing each other in an oblique direction, forming as it were a series of festoons around the posterior part of each chamber. These, like the transverse fibres observed in *Melolontha* by Straus, contract the diameter of each chamber, and extend the vessel. Besides the proper muscular structure of the heart itself, there are attached on each side of the organ several sets of muscular fibres, arranged in pairs along the upper and under surface of each chamber. Each set of these fibres, converging to a tendon, and passing outwards, forms a triangular muscle (A, *b*, *b*), which is attached to the lateral surface of each segment. These, which have been called *the wings* of the heart, assist by their contraction to shorten and expand the chambers at the *auricular*, or receiving period of the heart's motions, while, as just explained, the transverse and diagonal muscles occasion the *ventricular*, by their contracting and narrowing the diameter of each chamber. It is between the upper and under set of the lateral muscles that we believe the auricular space to exist, bounded by a delicate membrane. The thoracic or *aortal* portion of the heart commences at the anterior part of the first abdominal segment, where the organ bends downwards to pass under the metaphragma, and enter the thorax. When it has entered that region it immediately ascends again between the great longitudinal dorsal muscles of the wings, and passes onwards until it arrives at the posterior margin of the pronotum; it then again descends and continues its course along the upper surface of the œsophagus, with which it passes beneath the cerebrum, anterior to which, and immediately above the pharynx, it is bifurcated and divided into several branches, as formerly noticed by us in the sphinx.* Previously to our notice, however, Carus had seen the course of the blood in the head of insects following directions corresponding to the situations in which we have been able to trace a distinct division of the aorta into vessels. We have found a similar division of the aorta into branches in several species of Coleopterous insects, as in *Meloe*, *Blaps*, and *Timarcha*, although we have omitted to trace it in *Lucanus*. In the *Sphinx* and *Vanessa urticæ*, immediately after the aorta has passed beneath the cerebrum it gives off laterally two large trunks, which are each equal in capacity to about one-third of the main vessel. These pass one on each side of the head, and are divided into three branches, which are directed backwards, but have not been traced farther in consequence of their extreme delicacy. Anterior to these trunks are two smaller ones, which appear to be given to the parts of the mouth and antennæ, and nearer the median line are two others, which are the continuations of the aorta. These pass upwards and are lost in the integuments. The whole of these parts are so exceedingly delicate that we have not as yet been able to follow them beyond their origin at the termination of the aorta, but believe them to be continuous with very delicate circulatory passages along the course of the tracheal vessels. It is in the head alone that the aorta is divided into branches, since throughout its whole course from the abdomen it is one continuous vessel, neither giving off branches nor possessing lateral muscles, auricular orifices, or separate chambers. In the larva state it is far more difficult to recognise the true structure of the vessel by actual dissection than in the perfect, because the valves are only in a rudimentary condition. But it is easy to observe it in the bodies of living transparent specimens, as done by Carus, Wagner, Bowerbank, and others in the *Ephemeridæ* and *Agrionidæ*, in which not only the form of the valves and motions of the vessel are distinct, but also the abundance of globules that circulate in every direction. Even in some of the opaque-bodied maggots of Diptera we have seen the form of the valves very distinctly through the tegument in the eight posterior segments. When viewed in that state each chamber appears to be much narrower at its anterior and posterior extremity than in its middle (*fig.* 358, D), and the valves formed by the reflexion of its parietes inwards, although distinct, are very small. Near the middle of each chamber there is attached on each side a narrow muscle, which passing backwards is attached to the anterior margin of each segment. Between the muscle and the heart in each segment, a large tracheal vessel crosses to anastomose with its fellow on the opposite side, and on each side of the dorsal vessel, nearly in the course of the lateral muscles, there is a faint indication of a line which seems to form the boundary of what we regard as the auricular space in which the blood is collected before passing into the chambers, of which there are eight very distinct ones in these larvæ.

The motion and course of the blood, as will be seen from the above account of the structure of the chief organ of the circulation, is first

* Phil. Trans. 1832, p. ii. p. 385.

directly forwards in the middle line of the body, and then backwards by the sides of the thorax and abdomen, to the lateral and posterior parts of the heart, into which it is received, by means of transverse currents in each segment, through the auricular space and orifices. This course, as discovered by Carus, is indicated in the description and diagram given in a former part of this work.* The blood, which is usually of a very transparent greenish or yellowish colour, is filled with a great number of little particles, which were described by Carus as oblong or oval, but more correctly by Mr. Bowerbank † as flattened oat-shaped masses, which retain their form while circulating through the body, but like the particles of blood in Vertebrata become globular immediately they are brought into contact with water. It is stated by Burmeister ‡ that they vary in diameter from $\frac{1}{663}$th to $\frac{1}{300}$th of a line, but they differ also in size in the same individual, and are often rough or tuberculated as noticed by Edwards,§ and as distinctly seen in the blood of *Sphinx ligustri*. The motions of the blood, rendered perceptible by the presence of these particles, was first observed by Carus in the aquatic larva of *Ephemera*, in which, as in other aquatic transparent bodied larvæ, the particles are very distinct. Baker‖ and some of the older observers in this country had long before seen motions of the fluids in the limbs of some insects, but Carus first discovered the existence of a complete circulation. Carus saw the blood distributed in several streams from the aortal extremity of the dorsal vessel in the head returning in currents, that entered the base of the antennæ and limbs, in which it formed loops, and then flowing into the abdomen entered the heart at its posterior extremity. Wagner¶ confirmed Carus' discovery, and added some new observations. He saw the blood flowing backwards in two venous currents, one at the sides of the body and intestine, and the other alongside of the dorsal vessel, and he discovered that the blood not only entered at the extremity of the dorsal vessel, but also at the sides in each segment, at the valves discovered by Straus. Both Carus and Wagner, however, believed that the currents of blood observed by them were not inclosed in distinct parietes or vessels. Mr. Bowerbank,** in repeating these observations, saw also the blood distributed by the dorsal vessel forming loops in the antennæ and limbs, and then passing backwards in lateral and transverse currents, enter at the valves into the dorsal vessel. And he also observed and clearly defined the structure and action of the valves. He discovered, however, that the currents of blood along the sides of the body are really inclosed in distinct parietes, and do not flow in the common abdominal cavity, as previously supposed, the boundaries of the vessels inclosing these currents being clearly definable. He has also expressed his belief that a "much greater portion of the circulation than we can clearly define is carried on within given vessels, as the blood may frequently be seen flowing in curved and other lines, and confined within very narrow limits, but so deeply seated amidst the muscles and intestines as totally to prevent the boundaries of the current from being clearly observed." We are ourselves most distinctly of the same opinion, having formerly, through the kindness of Mr. Bowerbank, been allowed to examine the circulation in *Ephemera* by means of his powerful microscope. We believe also that we have seen distinct vessels passing transversely across the dorsal surface of each segment, in the direction of the anterior part of each chamber of the dorsal vessel, in the large pupæ of *Acherontia Atropos* and *Sphinx ligustri*,* but whether these are vessels returning to or distributed from each chamber, as we are most inclined to believe, is not certain. If they be not vessels distributed *from* the heart, it is a somewhat curious circumstance that the whole of the blood should be first sent to the head of the insect, and the viscera of the abdominal region be nourished only by the returning blood, which has in part passed the round of the circulation. The only instance in which vessels had previously been supposed to be distributed directly from the heart in the abdomen was pointed out so long ago as 1824 by Professor Müller,† who discovered a connexion of the oviducts with the inferior surface of the organ in many insects; but these were afterwards believed by Carus, Treviranus, Wagner, and Burmeister to be only ligamentous connexions. We have observed these connexions in many insects, and certainly believed, when we first noticed them, without being aware that they had previously been seen by Müller, that they were vascular structures. We have traced them, especially in the *Carabidæ*, into direct connexion with the organ, but have been unable to observe at what point the cavity of the ovarial tubes commences, or where the supposed ligamentous portion begins. We have seen these connexions not only in the perfect insects but also in the larvæ, more especially in the males of *Sphinx ligustri* and *Odonestis potatoria*. In these larvæ the two oblong testicles, not united into one mass as in the perfect state, are each attached, side by side, by two short filaments to that chamber of the dorsal vessel which is situated in the ninth segment. One of these attachments proceeds from the anterior and the other from the posterior part of each testicle. Now, if these attachments be not distinct vessels, it is remarkable that these glandular and secretory organs should always be connected by mere ligaments with the great circulatory organ, since, if the object of their connexion were merely to retain them in their place in the abdomen, it would

* See Article CIRCULATION, vol. i. p. 652, fig. 325.

† Entomol. Mag. vol. i. p. 244.

‡ Op. cit. 404.

§ Art. BLOOD, vol. i. p. 408.

‖ On the Microscope, vol. i. p. 130.

¶ Isis, 1832.

** Entomological Mag. vol. i. April, 1833, p. 239.

* Dr. Roget's Bridgewater Treatise, vol. ii. p. 245.

† Nova Acta Nat. t. xii. 2.

probably be as well answered by an attachment to any other part. These considerations certainly lead us to hesitate to admit that they are mere ligaments. Whatever be their nature, as Müller has observed, their existence is indubitable.

Besides the parts now described, there is also another which is connected with and forms part of the vascular system, but the existence even of which has hitherto been almost overlooked. This is a distinct vascular canal, which is extended along the upper surface of the abdominal portion of the cerebro-spinal cord in perfect Lepidopterous insects, and which we have traced from the thorax to the termination of the cord. We have designated this structure the *supra-spinal vessel.* It is placed immediately above the cord, and is covered by transverse muscular fibres, which exclude it from the common abdominal cavity, and give to the whole cord, when removed from the body and examined by transmitted light, a flocculent appearance. This appearance was first noticed by Lyonet,* but the vessel between it and the cord was not detected by him. It was subsequently figured and described by us in the *Sphinx*,† and the whole of our recent observations‡ have confirmed the opinion we then entertained of it. It is a most distinct structure in the abdomen of the Sphinx, and may be readily seen after the abdominal cord has been carefully removed from the body with its surrounding structures and placed for some time in spirits of wine. We believe this vessel to be the chief means of returning the blood from the middle and inferior portion of the body to the posterior extremity of the dorsal vessel or heart, and that it is analogous to a structure which we have found to be a supra-spinal vessel § in the Scorpion and Centipede, that had previously been supposed to be a loose and easily detached portion of the nervous system, but which is now proved to belong not to the nervous but to the vascular structures. We are strongly inclined to suspect that this supra-spinal vessel in insects is connected with the anterior portion of the dorsal vessel or aorta, in a manner similar to the connexion which was shown by Mr. Lord ‖ to exist between the corresponding structure and the heart in Myriapoda. (See MYRIAPODA.) We believe also that we have seen a corresponding vessel in the larva of the Sphinx, but of so delicate a structure as almost always to elude detection. It will thus be seen that the blood certainly flows in distinct vessels, at least in some parts of the body in perfect insects, and that vessels exist even in the larva. But although a circulation of the blood has been seen by Carus, Wagner, and others in many perfect insects, it has been shown only in the appendages of the body, and in those chiefly in recently developed specimens, while it has been supposed to move only in intercellular spaces and not in distinct vessels. This opinion, however, is now invalidated by our discovery of a *supra-spinal* or great ventral vessel. A motion of the fluids has been seen by Carus in the wings of recently developed *Libellulidæ*, *Ephemera latea*, and *E. marginata*, and *Chrysopa perla;* among the Coleoptera in the elytra and wings of *Lampyris italica* and *L. splendidula*, *Melolontha solstitialis*, and *Dyticus*. But Carus was unable to detect it in the wings of Orthoptera, although, according to Humboldt,* Ehrenberg has seen it in a species of *Mantis*, and Wagner in the young of *Nepa cinerea* and *Cimex lectularius* among the Hemiptera; but it has not yet been observed in the Hymenoptera. Burmeister has seen it in *Eristalis tenax* and *E. nemorum* among the Diptera, and Mr. Tyrrel† in *Musca domestica* as well also as in *Geaphilus* and *Lithobius forficatus* in the Class Myriapoda. In addition to these Mr. Bowerbank has seen it in one of the *Noctaidæ*, *Phlagophora meticulosa*‡ in the Order Lepidoptera, in which it was seen also in the rudimental wings of some pupæ by Carus. Some of the most interesting observations that have yet been made upon the motions of the blood in these organs are those of Mr. Bowerbank § in *Chrysopa perla*. Mr. Bowerbank found that in the lower wing of this insect the blood passes from the base of the wing along the *costal*, *post-costal*, and *externo-medial nervures*, outwards to the apex of the organ, giving off smaller currents in its course, and that it returns along the *anal* or *inferior nervure* to the thorax. He states that the blood occupies the chief part of the cavities of these nervures, in each of the largest of which is a very small trachea. From this statement it has been rather hastily concluded that the nervures of the wings are only venous trunks, or passages for the circulatory fluids, and are not formed, as hitherto supposed, chiefly by ramifications of the tracheæ. He found tracheæ existing in the larger of these cavities, which measured only $\frac{1}{2222}$th of an inch in diameter, while the cavities themselves measured $\frac{1}{408}$ of an inch; but in others the tracheæ measured $\frac{1}{1340}$th, while the cavity measured only $\frac{1}{300}$th. He states also that the tracheæ very rarely give off branches while passing along the main nervures, and that they lie along the canals in a tortuous direction. In consequence of these most interesting observations we have examined the wings of some dried specimens of this insect, and have found that there exists, as Mr. Bowerbank remarks, a very large and perfectly transparent space around the tracheæ, which is more or less distinct in different specimens, but in a few instances is not observable. But we have invariably found that the tracheæ not only exist throughout the whole of the ramifications of the wings, but also give off branches at every nervure or space along which the fluid passes.

* Recherches sur l'Anat. et les Metam. de differentes Especes d'Insectes. Paris, 1832, p. 505, pl. lii. fig. 18. and pl. liv. fig. 2.

† Phil. Trans. p. ii. 1834, p. 395, pl. xiv. fig. 9 (a).

‡ Medical Gazette, March 17, 1838, p. 973.

§ Id. March 17, 1838, p. 971.

‖ Id. March 3, 1838, p. 893.

* Burmeister's Manual, p. 408.

† Proceedings of the Royal Society, Jan. 15, 1835.

‡ Entomological Magazine, vol. i. April, 1833, p. 243.

§ Op. cit. vol. iv. Oct. 1836, p. 179, pl. xv.

Now the opinion to which we have been led by our examinations of dried specimens, as we have not been so fortunate as to obtain living ones, since the commencement of these observations, is, that every nervure contains a distinct tracheal or air-bearing vessel, and that the free transparent space by which it is surrounded, and which is not discoverable by the naked eye, but only by the microscope, constitutes alone the proper circulatory passage; that the tracheæ, which are obvious to the naked eye, do not simply lie loosely in these spaces, but that the spaces lie chiefly at their sides and under-surface. These opinions have been derived from examinations of transverse sections of the wings of the *Chrysopa*, at parts in which, on a previous examination of the surface of the wing, we have seen both tracheæ and the spaces around them. On cutting the wing across at these parts, and then examining the edges, we have invariably found the tracheæ hollow, unyielding tubes, while the free spaces on each side, which appear as if bounded by the upper and under membrane of the wing, have appeared collapsed, and almost or completely closed, so as scarcely to exhibit any appearance of hollow spaces. On examining the wing of a dried specimen of one of the Lepidoptera, *Gonepteryx Rhamni*, by transverse sections, we have in every instance found the nervures formed of hollow unyielding tubes, with all the characters of true tracheal vessels, but have not been able to detect the proper circulatory spaces at the sides of these nervures, most probably owing to their dried and collapsed state. From these facts we are led to express an opinion which has been long entertained by us, that the course of the blood, whether simply along intercellular spaces, or bounded by distinct vessels, is almost invariably in immediate connexion with the course of the tracheæ. This opinion is founded upon the circumstance that nearly all the observations that have hitherto been made have shown that the currents of blood in the body of an insect are often in the vicinity of the great tracheal vessels, both in their longitudinal and transverse direction across the segments, and it is further strengthened by Mr. Bowerbank's observations on the course of the blood in the wings. During his observations Mr. Bowerbank observes that he "has used every endeavour to discover, if possible, whether the blood has proper vessels, or only occupied the internal cavities of the canals; and that he is convinced that the latter is the case, as he could frequently perceive the particles not only surrounding all parts of the tracheæ, and occupying the whole of the internal diameter of the canals, but it frequently happens that globules experienced a momentary stoppage in their progress, occasioned by their friction against the curved surface of the tracheæ, which sometimes gave them a rotatory motion." He remarks also that the usual course of the blood through the canals is in one continued stream, without pulsatory motion, excepting only when the insect under examination is struggling to escape, when the continuity of the stream is broken, and there are occasional oscillations, of which he observed, in one instance, in a vessel within a space of about one-fiftieth of an inch, twenty-one oscillations in a minute; and in another, in the same space, so many as eighty-four. He observed also in insects that had been captured and in confinement for several days, that the motions of the fluid became exceedingly languid and almost entirely ceased. These observations are exceedingly interesting in reference to the general velocity of the circulation, and the means by which it is carried on in the wings. The entire absence of pulsations is remarkable, as it completely identifies these vessels as veins, since it is well known that the circulation is carried on through the body by means of regular pulsations of the dorsal vessel. The number of these latter pulsations varies greatly in different insects. Thus Herold found from thirty to forty in a minute in a full-grown caterpillar, and from forty-six to forty-eight in a much younger one; Suckow observed but thirty, in the same space of time, in a full-grown caterpillar of *Gastropacha pini*, and eighteen only in its pupa state. But in one instance, when the insect was in a state of the most violent excitement, we have counted one hundred and forty-two in a female of *Anthophora retusa*. In a number of these insects captured just after they had left their hybernacula in the month of April, and confined for some time in a breeding-cage, we have found that the number of pulsations varies, as might, *a priori*, be supposed, according to their state of excitement. Thus on exposing the dorsal vessel in the morning, before the insects had been excited, we found the number of pulsations was about eighty per minute; at ten o'clock, when they had become active, the number of pulsations ranged from one hundred to one hundred and ten; but at three o'clock in the afternoon, when the insects were quite lively, and had been exposed to the sun for an hour or two, the number of pulsations amounted to one hundred and forty; while on another occasion, on a cold dull morning, when the bees were languid, the number of pulsations did not exceed seventy-five in any specimen that was examined. It has usually been supposed, since the discovery of a circulation in insects, that the pulsations are more frequent in the larva than the perfect state; but this certainly is not the case, if the mean number of observations in the two states be compared. Thus in a series of observations made by us on the *Sphinx ligustri*,* from the fourth day after the larva had left the egg until the perfect insect was developed, it was found that before the larva cast its *first* skin the mean number of pulsations, in a state of moderate activity and quietude, was about eighty-two or three per minute; before casting its *second* skin eighty-nine; while before casting its *third* it had sunk down to sixty-three; and before its *fourth* to forty-five, while previously to leaving its fourth, and before it had ceased to feed, preparatory to entering the pupa state, it was not more than thirty-nine. Thus the number gradually decreases during the growing larva state, but the force of the circulation is very much augmented. Now when the insect is in a state

* Phil. Trans. p. 2, 1837.

of perfect rest, previously to changing its skin, the number is pretty nearly equal at each period, being about thirty. When the insect has passed into the pupa state it sinks down to twenty-two, and subsequently to ten or twelve, and after that, during the period of hybernation, it almost entirely ceases. But when the same insect which we had watched from its earliest condition was developed into the perfect state in May of the following spring, the number of pulsations, after the insect had been for some time excited in flight around the room, amounted to from one hundred and ten to one hundred and thirty-nine; and when the same insect was in a state of repose, to from forty-one to fifty. When, however, the great business of life, the continuation of the species, has been accomplished, or when the insect is exhausted, and perishing through want of food or other causes, the number of pulsations gradually diminishes, until the motions of the heart are almost imperceptible. Insects, then, do not deviate from other animals, as has been supposed, in regard to their vital phenomena, although it has been somewhat curiously imagined that the nutrient and circulatory functions are less active in the perfect than in the larva condition. This supposed inferiority has been attempted to be accounted for on the hypothesis that as insects no longer increase in size after entering the perfect state, there is but little expenditure or waste of body, and that, consequently, they must require less nourishment. But we have elsewhere shown * that the expenditure of the body, whether in the larva or perfect state, is in the ratio of the amount of activity and length of life of the insect, while it will be remembered that those insects which exist but for a short time in the perfect state, and take little or no food, invariably have a supply of nourishment stored up within their own bodies, in immense accumulations of adipose matter; and that those which exist for a long period have within themselves only a small quantity of nourishment, but are by no means sparing in the quantity of food daily consumed by them, being, as they often are, some of the most voracious of the insect race.

Organs of respiration.—All perfect insects, whether inhabitants of air or water, breathe air alone; but some larvæ, that are constant inhabitants of water, respire the air which is mechanically mixed with the water, by means of branchiæ; but respiratory organs in the form of tracheæ *(fig.* 435) are almost as extensively distributed throughout every part of their bodies as in the perfect insects. We shall divide the respiratory organs into external and internal. The external are of three kinds, *spiracles*, *tracheæ*, and *branchiæ*. The internal are either simply *tracheal*, or *tracheal* and *vesicular*.

The *spiracles* are apertures situated along the sides of the body communicating directly with the internal respiratory organs. They are usually nine in number on each side. In Hymenopterous larvæ there are ten. Each spiracle consists of a horny ring, generally of an oval form, within which is a valve formed of a

* Phil. Trans. p. 2, 1837.

Fig. 435.

Portion of a tracheal vessel of the larva of Vanessa urticæ, shewing, a, the spiral fibre; and *b,* the loose investing covering. (*Newport, Phil. Trans.*)

series of converging fibres, and which opens perpendicularly in its long axis, guarding the external entrance. At a little distance within this valve the spiracle is somewhat enlarged, and there is a second valve of a more complicated form. This has already been noticed in our account of the muscular structure, but we must again describe it in connexion with the respiratory organs. The anterior half of this inner or second valve is strong, immovable, and of a horny texture, of the colour of tortoise-shell. It is thin and lunated at its margin. The posterior half is thick, rounded, and freely moveable, and closes on the anterior like a cushion or pad. This is the structure of the spiracle in the *Sphinx* and most other insects. But in some, in which the spiracle is concealed beneath a portion of the skeleton, the horny external ring is absent, and instead of it the entrance, or margin of the spiracle, is merely a little thickened and fringed with short hairs. This description of spiracle exists in the prothorax of some Coleoptera and Orthoptera as in *Gryllotalpa*, in which one portion or lip overlaps the other, thus forming as it were an outer valve or lid. In other instances, as in the Lamellicornes, the spiracles of the abdomen are very minute and circular, and their opening appears to be cribriform, or at most only very minute, and surrounded by short hairs. In others, again, as in some larvæ, the spiracles consist of a broad margin with a narrow middle space and central aperture that leads immediately into the tracheal vessel, the opening into which is exceedingly small. The *size* of the spiracles in different parts of the body varies very much in different insects. Those of the abdomen are always much smaller than those of the thorax, and the most posterior ones, which were of great importance in the larva state, are almost or entirely imperforate in the perfect. The reason for this appears to result from the changes that take place as regards the region of the body in which respiration is chiefly carried on in the two states of the insect. In the larva state respiration is carried on chiefly in the abdominal region, but in the perfect the chief part of the body concerned is the thorax. It is through the thoracic and first pair of abdominal spiracles that nearly the whole of the air enters and is expired at each act of respiration, and consequently it is found that the spiracles in these parts are very much larger than in the abdomen. The largest spiracle is usually the prothoracic, of which we have an example in *Geotrupes* and *Gryllotalpa*, and the next largest, as in *Geotrupes*, is the first abdominal. The *situations* in which the spiracles are placed also vary considerably in different insects. In Coleoptera and Orthoptera the first pair are situated in the membrane between the pro- and meso-thorax, and the remaining ones in the meso-* and meta-thorax and following segments of the abdomen. There is also a similar arrangement of the spiracles in Hemiptera. But in other insects, as in the larvæ of Lepidoptera, the first spiracle is situated in the prothorax, and the remaining eight pairs in the fifth and succeeding segments to the twelfth; while in the larvæ of Hymenoptera, in which there are ten spiracles on each side, they are placed in the second, third, fifth, sixth, and succeeding segments to the twelfth.

The *second* form of external respiratory organs, as Burmeister remarks, are simply elongated spiracles, and are found only in those insects which reside almost constantly in the water, but breathe pure atmospheric air, for which purpose they come to the surface of the water at intervals to respire. They are short horny tubes, which in some instances are surrounded by plumose setæ. They are always open at their extremity, and in general project beyond the body. They are chiefly met with in the aquatic Hemiptera, as in *Nepa* (*fig.* 352) and *Ranatra*, and are usually two in number, projecting from the extremity of the abdomen. In *Nepa* they are about half the length of the body, and in *Ranatra* as long as the whole body itself. It is through these tubes that the whole of the respiratory function is performed, and the air both inspired and expelled. They exist also in the larvæ of the *Dyticidæ* and *Hydrophilidæ*, in which they are the only respiratory passages, although it has been thought by some that lateral spiracles exist also in these larvæ, as subsequently found in their perfect insects. This form of respiratory organ exists also in the aquatic larvæ of some Diptera, as in the rat-tailed maggot, *Eristalis*, and the larva of *Stratiomys*. In the latter instance the insect supports itself at the surface of the water by a coronet of radiating setæ, in which it includes a bubble of air, and descends with it to the bottom of pools for the purposes of respiration, and comes again to the surface for a fresh supply when the store it has carried with it is exhausted. These organs are thus distinct from those by means of which the insects respire the air mechanically mixed with the water.

* Straus.

Branchiæ constitute the third form of external respiratory organ. This form is met with only in the larva and pupa state. These organs are always situated at a part of the body at which the spiracles are subsequently to exist. They are formed, as in the larvæ of Amphibia, of extensions outwards of the exterior or cuticular surface of the body, and are largely supplied with bloodvessels, and tracheæ ramify within them. They are never, as in the gills of fishes, developed internally, excepting when they exist at the anal extremity of the body, as in the *Libellulidæ*, but are extended from the sides as in the Tadpole, being simply expansions of the external surface. We are not aware that cilia have yet been observed on these surfaces, but judging from the analogies of structure and formation that exist between these parts in insects and the analogous ones in the larvæ of Amphibia, there seems reason to expect that they do probably exist. The necessity for such structures on the branchiæ may, however, be rendered less imperative from the voluntary power which the insect itself possesses of moving the branchiæ at pleasure, by which the function of cilia, that of effecting a constant renewal of the water in contact with the surface of the organ, is steadily accomplished. It is the belief of most entomologists,* that branchiæ absorb the air from the water, and convey it by the minute ramifications of the tracheal vessels, with which they are abundantly supplied, and which terminate in single trunks, into the main tracheæ, to be distributed over the whole body, as in insects which live in the open atmosphere. This is supported by the fact that the tracheal vessels, as seen in the transparent bodies of many aquatic larvæ, are filled with air; but the subject still admits of enquiry, why in these instances the usual function of branchiæ is so far departed from as to allow of the air being absorbed from the water into distinct vessels, to be distributed over the whole body, for the purpose of aerating the fluids, rather than that it should be brought into contact with the blood, and undergo the consequent changes at the surface of the branchiæ, as in the larvæ of Amphibia and Fishes.

The branchiæ of insects are of three kinds. The first exists in the form of elongated, slender, hair-like organs, collected together in tufts, that originate by single stems, as in the larvæ and pupæ of gnats.† This form is by far the most common. These filamentous parts are supplied each with a single trachea that is extended throughout their whole length, and which is connected with the great longitudinal tracheæ of the body. In a very few instances, branchiæ of this form originate separately, and not in tufts, as, according to De Geer,‡ in the

* Burmeister.

† Burmeister, op. cit. p. 167.

‡ Mémoires sur les Insectes, vol. iv. pl. 13, fig. 16.19.

larvæ of *Gyrinidæ*, in which they are arranged along the sides of each segment as short stiff bristles. This form of branchiæ is also said to exist in one solitary species of Lepidoptera, *Hydrocampa stratiotata*,* and perhaps, also, in the other species of the same genus, in which branchiæ of this form exist in the neighbourhood of false spiracles.

The second kind of branchiæ exists in the form of flat, oval, or lanceolate plates, extended from the sides of each segment of the abdomen, where spiracles afterwards exist in the perfect insect. In some instances, as in the *Agrionidæ*, these plates exist only at the extremity of the abdomen. In others, as in the *Ephemeridæ*, they exist both at the sides and at the extremity of the body. This form of branchiæ is found only in the Neuroptera and Trichoptera. In many of the latter instances these parts possess also the additional function of being the chief locomotive organs of the insect, and remind us strongly of the branchiform organs of locomotion in the post-abdomen of many Crustacea.

An anomalous insect, recently discovered by Mr. Hogg as a constant inhabitant of the river-sponge, and an account of which was read by Mr. Westwood at a meeting of the Entomological Society on the 3rd of December, 1838, possesses a third and most remarkable description of branchia. This insect, which was referred by Mr. Westwood to the order Neuroptera, genus *Acentropus*, Steph. very much resembles the larva of a neuropterous species, and has filiform branchiæ extended from the sides of the abdomen, which are distinctly *articulated*, and apparently five-jointed. Mr. Westwood informs us that he has distinctly traced tracheæ into the branchiæ, and that the open extremity of each vessel protrudes from the tip of the branchiæ, so that in this respect these organs resemble elongated spiracles.

Very few of those larvæ or pupæ that possess branchiæ have any lateral spiracles, excepting the *Culicidæ*. In some of these, as in the common Gnat, both larvæ and pupæ breathe by means of large tracheal vessels, extended outwards to some distance from the head and thorax, while the body is also furnished with filamentous branchiæ. The larva of *Chironomus*, remarkable for its blood-red colour, and which breathes through tubes, is furnished in its pupa state with branchiæ† at a part corresponding to that at which the first spiracles are to appear in the perfect insect. The true *Libellulidæ* have neither lateral nor anal branchiæ, but, according to Suckow and others, breathe by means of branchiæ in the colon. But in these insects, as in the *Ephemeridæ* with lateral branchiæ, the acts of respiration are also those of progression; since, although the imbibition and expulsion of water at the anal extremity are regular and constant, even when the insect is remaining perfectly quiet, they are increased both in number and force at every act of locomotion, and carry the body forward by darts or sudden impulses. The water is received at the anal orifice by an inspiratory or sucking action, as proved by the circumstance that small particles of substances floating in the water are drawn in with the stream at the anus at each inspiration, and again expelled from it when the water is ejected, and this occurs with the greatest regularity. The cavity into which the water is received is a *cloaca* distinct from the proper alimentary canal, analogous to the respiratory cloaca of the Holothuria and other lower invertebrata.

These external organs of respiration all communicate with elongated tracheæ, from which are distributed other branches over the internal structures. In the larvæ of all insects these internal respiratory organs are simply ramified tubes, but in perfect insects, and more particularly in volant species, these tubes are dilated into an immense number of minute vesicles, which not only allow of the most extensive respiration, but also render the body lighter, by enabling the insect to alter its specific gravity during flight. In all insects the vesicles are only dilated tracheæ, the structure of which is the same throughout the class. In the larva of the Sphinx and other insects the tracheal vessels consist of two elongated tubes, extended one on each side of the body, and which on their external side communicate by very short tubes with the spiracles, and on their opposite, towards the middle line of the body, give off near each spiracle a large tuft of vessels, about twelve in number, which extending inwards are distributed over the different organs within the body. The chief of these are distributed to the alimentary canal, while others pass upwards among the muscles, and ramify most extensively between them, and are given in great abundance to the dorsal vessel. In every segment other branches are extended to the median line above the vessel, and anastomose with corresponding branches from the opposite side of the segment. In the head one large branch passes forwards from the prothoracic spiracle, and anastomoses with its fellow from the opposite side above the œsophagus, behind the brain, and the two thus united then give off four branches, which passing forwards over the brain give off branches that ramify on the surface, and even in the substance of that organ and of the optic nerves. Other branches are given to the muscles of the head, the future antennæ, and the organs of manducation. On the under surface of the body the tracheal vessels distribute themselves among the muscles, as on the dorsal surface, some passing beneath the nervous cord to anastomose with those from the opposite side, while others are distributed to, and ramify extensively over the surface of each gangliated portion of the cord, giving off the most minute branches which penetrate the very substance of the ganglia (*fig.* 415, *i*, *i*), and also that of the nerves themselves, along which other minute branches are extended, so that even the most important and delicate organs of the body are plentifully supplied with tracheal vessels. Other branches of tracheæ also pass

* Id. vol. i, pl. xxxvii.

† Burmeister, p. 167.

between the fibres of the muscular coat of the alimentary canal, and ramify extensively between the mucous coat and a structure which we have described* as the *adipose coat*, which lies between the mucous and muscular, as is well seen in the colon and cœcum of the puss-moth, *Cerura vinula*, in the perfect state. It is in this layer that the ramifications of tracheæ anastomose very freely, but do not enter the mucous or internal coat. Besides these parts all the secretory and generative organs are supplied with anastomosing branches in abundance, and tracheæ are extended even to the very last joints of the tarsi in the limbs. The only parts into which we have not observed tracheæ penetrate are the adipose vesicles, upon which we have not often observed ramifications, although branches of tracheæ are distributed very extensively among them. In the larva state the tracheæ are always smaller than in the perfect, compared with the size of the individual, and they are smallest in those apodal larvæ of Hymenoptera which reside long in closed cells, as the *Anthophora retusa*, in which insect the communications of the tracheæ across the body are very distinct, as was shewn long ago by Swammerdam in the larva of the hive-bee.

The *structure* of the tracheæ has been described by Swammerdam, Sprengel, and others. Sprengel has described the structure as consisting of an external serous and an internal mucous membrane, inclosing between them a spirally convoluted fibre (*fig*. 435, *a*), which is elastic, and gives to the tracheæ the appearance exhibited by the tracheæ in other animals. The external or serous membrane (*b*) very loosely surrounds the spiral fibre (*a*). The mucous or internal lining, as we formerly remarked, and as noticed by Swammerdam, De Geer, Lyonet, and Bonnet, is continuous with, and is thrown off at the change with the external covering of the larva, and certainly is a distinct membrane, renewed at those periods, although Sprengel believes that it is only a means of connexion between the coils of the spiral fibre, and not a distinct structure.

The *vesicles*, or dilated tracheæ, exist in the greatest abundance in volant insects, although they also exist in a much less developed form in the saltatorial. These vesicles exhibit an appearance which was formerly noticed by Swammerdam in *Oryctes nasicornis*, and subsequently by Sprengel in other insects. It consists of an amazing number of punctured spots, discoverable only under a good microscope, but which, when attentively examined, exhibit somewhat the appearance of perforations. The precise nature of these spots is not well understood. Burmeister conceives that they are occasioned by the rupture of the spiral fibre during development, and that the spots are the spaces between the broken fibres. But Marcel de Serres and Straus Durckheim deny the existence of spiral fibre in the vesicles, while Suckow and Burmeister contend that it certainly does exist, and we also are of this opinion. Indeed, when it is remembered that the vesicles exist only in the perfect insect, and are only dilated tracheæ, and that the existence of spiral fibre in the tracheæ is undoubted, surely its existence can scarcely be questioned in the vesicles, although, probably, it is in an almost atrophied condition. Now the fact that the spots are not observed on the vesicles until the insect has entered the perfect state, was, perhaps, one of the circumstances that led Burmeister to his opinion respecting them; but that they are not caused by ruptured spiral fibre is proved by the existence of these spots in some of the tracheæ that communicate directly with the vesicles, and have not been dilated, and in which the spiral fibre is unbroken. It is also shewn by the circumstance of their not being in a regular series, over the course of the fibres, but distributed thickly and irregularly over the surface of the vesicles, and by their existing in the space between two parallel fibres in the tracheæ, and even in the substance of the fibre, as we have seen them in the vesicles of the male of *Bombus terrestris*. Besides this, they are sometimes seen to terminate in an abrupt and remarkable manner in the dilatations of the larger tracheæ in the same insect. The results of our own observations lead us to conclude that these spots are not ruptures of the spiral fibre, but are partial perforations of the vesicles,—that they do not pass through the internal or lining coat, and probably are little cells in the coats of the vesicles, through which the circulatory fluid can be freely submitted to the action of the air in the vesicles, as in the minute terminal cells in the lungs of vertebrata.

The use of the vesicles, as above remarked, and as formerly suggested by Hunter, appears to be to enable the insect to alter its specific gravity at pleasure, by enlarging its bulk, and thus rendering it better able to support itself on the wing with little muscular effort. That this is the use of the sacs may be inferred from their non-existence in the larva state, or in insects that constantly reside on the ground, more particularly in creeping insects; and it seems further confirmed by the fact that, among volant insects, those have the largest and greatest number of vesicles which sustain the longest and most powerful flight. Thus the vesicles are found most developed in the Hymenoptera, Lepidoptera, Diptera, and some Coleoptera and Hemiptera, in all which, in the larva state, there is not the slightest trace of them. A still further proof that they are for lightening the body is found in *Lucanus cervus*. In the male of this insect the large and heavy mandibles and head, but more especially the mandibles, are not filled with solid muscle, as in the *Hydröus* and others in which these parts are more in proportion to the size of other parts of the body, but with an immense number of vesicles, which in the mandibles are developed in the greatest abundance in rows from long tracheæ, that are extended from one end of the organ to the other, so that the interior is almost entirely filled with vesicles. By this beautiful provision these pro-

* Phil. Trans. 1836.

jecting and apparently unwieldy structures are rendered exceedingly light, while their solid exterior fits them for all the purposes of strength required by the insect. The large and apparently heavy body of the humble-bee is lightened in a similar manner. In this insect and others of the same order, the vesicles are fewer but very much larger than in Coleoptera. The lateral tracheæ in the abdomen form one continuous chain of dilatations, which are larger in the males of the species (*fig.* 436)

Fig. 436.

The lateral and inferior series of vesicular respiratory organs in the abdomen of a male individual of Bombus terrestris. (*Newport, Phil. Trans.*)

than in the females. The longitudinal tracheæ (*a*), that pass backwards from the thoracic region, are connected just as they pass through the petiole or thoracico-abdominal segment into the abdomen, by a very short transverse branch (*b*), which gives off two pairs of minute branches into the abdomen. The longitudinal tracheæ (*c*) pursuing their course onwards are dilated, soon after they enter the large first segment of the abdomen, into two enormously expanded vesicles (*f*), above which is placed transversely a third and much larger one, which is formed from the anastomosing branches of the opposite sides of the segment, and is also connected with the little branches given off from the transverse branch (*b*). Beneath this large vesicle passes the dorsal vessel, and between the two lateral ones (*f*) the alimentary canal. Besides the branches from the transverse tracheæ (*b*) there are two others from the large tracheæ (*c*), which pass longitudinally backwards, one on each side of the œsophagus. That on the left side (*c, e*) passes as far as the posterior part of the proventriculus, and then turning forwards distributes its branches to that organ. The other on the right (*d, d*) extends no farther than the anterior part of the proventriculus, immediately behind the crop or honey-bag, upon which it is chiefly distributed. The large vesicle (*f*) is connected with the dilated tracheæ in the succeeding segments, and the whole form one continuous irregularly-shaped vesicular cavity, which, along its under surface in each segment, is dilated into a funnel-shaped transverse trachea (*g*), that anastomoses with its fellow of the opposite side, passing beneath the muscles as in the larva. From the upper surface of the longitudinal canals similar funnel-shaped dilatations (*i, k*) pass over the dorsal surface of the abdomen and anastomose in like manner with those of the opposite side, besides which single undilated ramifications of tracheæ (*h*) pass inwards on each side and are distributed over the alimentary canal. At the posterior part of the body the vesicular canals communicate directly by a large branch (*l*), from which large trunks are given to the colon and organs of generation. Thus, then, the use of the vesicles is distinctly indicated, even in the peculiar distribution of undilated tracheæ to the whole of the organs of nutrition. The distribution of single ramified tracheæ from large vesicles appears to be constant in this order; it was formerly shown by Leon Dufour* in *Scolia hortorum*, and we have always found it in the *Ichneumonidæ* and other families. Burmeister states that he has been unable to ascertain whether this is also the case in Diptera, in which order the vesicles are both large and numerous. According to Marcel de Serres† the *Asilidæ* have an immense number of small elongated vesicles on each side. In one species they amount to so many as sixty. Burmeister remarks‡ that, in Lepidoptera, the vesicles in the *Sphingidæ* and moths are chiefly found in the males, which agrees with our own observations in Hymenoptera. In *Acherontia Atropos* he states also that the existence of spiral fibre in the vesicles is so distinct as not to be doubted.

This is the structure of the respiratory organs in volant insects, but throughout the class, whether in volant or creeping insects, there is always a complete anastomosis of the tracheæ on one side of the body with those on the opposite, as has been well exemplified by almost all insect anatomists, Swammerdam, Lyonet, Marcel de Serres, Dufour, Straus, and others.

The *development of the vesicles* begins to take place at about the period when the larva ceases to feed, preparatory to changing into the pupa state. At the time when the larva of the *Sphinx* enters the earth, and is forming the cell in which it is to undergo its transformation, the longitudinal tracheæ of the second, third, fourth, and fifth segments become a little enlarged. In the butterfly, *Vanessa urticæ*, which does not enter the earth, but suspends

* Journal de Physique, Sept. 1830.
† Mémoires des Muséum, tom. iv. p. 362.
‡ Op. cit. p. 181.

itself vertically to undergo its change, the dilatation commences while the insect is spinning the silken hangings from which it suspends itself; so that the changes commence at a corresponding period in both insects. It is in the butterfly that we have most closely watched the development of the vesicles. During the period that the insect remains suspended it makes several powerful respiratory efforts, accompanied by much muscular exertion, and these efforts are continued at intervals until the old skin is fissured and thrown off. It is at this period that the tracheæ become much enlarged, as we have found at about *two hours* after the insect has suspended itself. Meckel observed the sacs soon after the insect has entered the pupa state, but it will thus be seen that the expansion of the tracheæ in the formation of these sacs commences very much earlier. At about *half an hour* before the insect becomes a pupa we have found the whole of the tracheæ more distended, particularly those on the under surface of the thorax, from which branches are given to the legs, so that the elongation of these tracheæ is probably connected with the subsequent rapid development and extension of those organs. At this period the tracheæ of the abdomen have experienced but little alteration. It is at the actual period of transformation that all the changes take place most rapidly. At that time the laborious respiratory efforts made by the insect appear greatly to affect the condition of all the organs. When the skin is thrown off, these efforts cease for a few minutes, after which the abdominal segments become shortened, and the circulatory fluid is propelled forwards, and the wings, then scarcely so large as hemp-seeds, are gradually distended at their base, and at each respiration are perceptibly enlarged, and carried downwards over the under surface of the thorax and first abdominal segments. Carus* attributes the development of the sacs, and dilatation of the tracheæ, to the entire closing of the spiracles, and expansion of the air contained within them, which he thinks is *increased in quantity* during the development of the insect. But from the circumstance that all the tracheæ are enlarged immediately after the insect has entered the pupa state, it seems probable that this enlargement is occasioned simply by the closing of the spiracles, and the expansion of the air within the tracheæ, during the powerful respiratory efforts, aided by the receding of the circulatory fluid from the abdomen into the partially developed wings, suddenly removing pressure from the tracheal tubes, which then become distended by the natural elasticity of the air contained within them; and further, that the subsequent enlargement of these tracheæ into distinct bags is occasioned, not by an increased quantity of air in the vesicles, as Carus imagines, but simply by a continuance of the same cause that effects the first dilatation of the tracheæ, the elasticity of the contained air, since the dilatation appears to keep pace with the gradually decreasing size of the digestive organs, and the spiracles are not permanently closed during the pupa state, respiration being continued at intervals, excepting perhaps in the most complete state of hybernation. In accordance with this opinion we find that, at about *half an hour* after the change, the pro-thoracic tracheæ that ramified over the œsophagus are enlarged to double their original diameter, and have begun to be detached from that organ. At *seven* hours these changes have been carried much farther. At *twelve* hours they are still further enlarged, and the principal alteration observed is the diagonal direction of those from the seventh spiracles, which supply the posterior extremity of the digestive stomach, owing to that organ having now become shorter, previously to its subsequent change. At *eighteen* hours all the tracheæ of the head and thorax are still further enlarged, and those from the third spiracle are detached from the cardiac extremity of the stomach, and are more enlarged than the others, and those from the ninth spiracle, in the twelfth segment, which supply the colon, are beginning to be distinctly vesicular. At *thirty-six* hours not only have the longitudinal tracheæ and their many branches become dilated, but those distributed to the different viscera have also become vesicular. At *forty-eight* hours the development of these parts is so far advanced that the whole have assumed the vesicular form, and those at the anterior part of the abdomen occupy a great proportion of that region, and the dilatation of others proceeds until within a few days before the perfect insect is developed, before it is completed. The only difference we have observed between the development of these organs in the Sphinx and the butterfly is in the rapidity with which the changes are effected. The Sphinx remains many months in the pupa state, during a great part of which time the changes are almost or entirely suspended. The butterfly remains but a few days, and in consequence all the changes proceed with rapidity, which is either greater or less in proportion to the season of the year and temperature of the atmosphere.

Function of respiration.—Having dwelt so long upon the *structure* of the parts concerned in respiration we cannot venture at any length upon the phenomena connected with the *function*, which properly belong to a distinct subject. (See RESPIRATION.) We would remark, however, that the circumstances connected with it are in many respects particularly interesting, while the results are similar to those of the respiration in other air-breathing animals. Thus the *acts* of respiration consist of alternate dilatations and contractions of the abdominal segments, the air entering the body chiefly at the thoracic spiracles, and partly also at the abdominal, during which the dorsal and ventral arches of the abdomen are alternately elevated and depressed, like the ribs of Vertebrata. The number and frequency of these

* Introduction to Comparative Anatomy, translated by Gore, 1827, vol. ii. p. 167.

respirations vary, as in Vertebrata, according to the degree of activity and state of excitement of the insect. Thus when an insect has been subject to long-continued exertion, the acts of respiration are quick and laborious, as every one must have observed in the larger *Bombi*, when alighting after a long-continued flight. The contractions and extensions of the abdominal segments are then short and quick, and sometimes so labored that the whole abdomen is shortened and extended like the flanks and ribs of the race-horse, after a long and severely contested race. The number of respirations, when the insect is in a state of moderate excitement, varies also in different species as well as in the different states of the same insect, and at different periods. Thus in the green grasshopper we have noticed from thirty to forty regular contractions in a minute, alternating, at irregular periods, with others more long and deep than the rest. When this insect was much excited the intervals between the long inspirations were longer, and the inspirations when they occurred were more deep and laborious. When an insect is preparing itself for flight the act of respiration resembles that of birds under similar circumstances. At the moment of elevating its elytra and expanding its wings, which are, indeed, acts of respiration, the anterior pairs of spiracles are opened, and the air rushing into them is extended over the whole body, which, by the expansion of the air-bags, is enlarged in bulk, and rendered of less specific gravity, so that when the spiracles are closed at the instant the insect endeavours to make the first stroke with and raise itself upon its wings, it is enabled to rise in the air, and sustain a long and powerful flight with but little muscular exertion. In the pupa and larva state respiration is performed more equally by all the spiracles, and less especially by the thoracic ones.

The frequency of the acts of respiration seem to bear some relation to the expenditure of muscular energy by the insect in a state of activity. All volant insects respire a greater quantity of air in a given time than terrestrial, and both these in their perfect than in their larva state. Thus in the common hive-bee we have noticed from one hundred and ten to one hundred and sixty contractions of the abdominal segments in a minute, while in a less active state, when the insect was entirely undisturbed, the acts of respiration seldom amounted to one-half that number. In an exceedingly wild and irritable little bee, *Anthophora retusa*, which dies exhausted from the most violent excitement and exertion, in the course of an hour or two, after being captured and confined during summer, the acts of respiration are often performed so rapidly that, on one occasion on which we observed them, they amounted to two hundred and forty in a minute, and of course it was only by the closest attention that their number could be ascertained.

Next to the pupa state, a state of common repose is that in which insects respire with the least frequency. When a perfect insect or a pupa has remained for some time undisturbed, its respiration becomes gradually slower and slower, until at last it is scarcely perceptible. Thus, in the midst of winter, at a temperature of the atmosphere a little below freezing, we were unable to detect more than the very slightest trace of respiration during two or three days, and even at the expiration of fourteen days the quantity of carbonic acid gas formed was very small. But when the insect was removed into a much warmer atmosphere it began again to respire more freely, and the quantity of carbonic acid produced in a given time was considerably increased. In a specimen of *Bombus terrestris*, which had remained at rest for about half an hour, the respirations had become deep and laboured, and were continued regularly at about fifty-eight per minute. At the expiration of one hundred and forty minutes, during which time the insect remained in a state of repose, the respirations were only forty-six per minute, and at the expiration of one hundred and eighty minutes they were no longer perceptible. This same insect, when first captured, and in a state of moderate excitement, respired at the rate of one hundred and twenty-five inspirations per minute. We have noticed the like circumstances in a female *Sphinx ligustri*, which after it had been excited for a short time in flight breathed at the rate of forty-two respirations per minute, while after it had remained at rest about seventy-five minutes respired at the rate of only fifteen per minute. Hence the quantity of air deteriorated by an insect in a given time depends upon the state of activity and condition of life of the individual. In accordance with the frequency, and consequently the quantity of respiration, such are the results. In accelerated respiration the circulation of the fluids is increased, and in those conditions, noticed in another part of this paper, in which the circulation is accelerated, the acts of respiration are at the same time more frequent.

The *development of heat*, which is now found to take place in all insects as in the air-breathing vertebrata, depends mainly upon the quantity and activity of respiration, and the volume and velocity of the circulation. In Hymenoptera, in which, as we have seen, the capacity of the respiratory organs is greater than in other insects, and consequently the quantity of air deteriorated in a given time is also greater, the quantity of heat evolved during the process is proportionate to the quantity of respiration. In the larva, in which, in relation to its size, the quantity and energy of respiration are less than in the perfect insect, the quantity of heat developed is also less, so that in the larvæ of Hymenoptera it does not exceed from two to four degrees that of the medium in which the insect is placed; while in the perfect insect, in a state of little activity, the quantity of heat developed is apparently at its minimum amount at three or four degrees above the temperature of the surrounding medium. But when the same insect is in a state of moderate activity, and consequently is respiring more frequently, it amounts to even fifteen or twenty degrees. In all cases the amount of temperature depends chiefly upon the quantity of respiration.

We have seen that in a state of repose the acts of respiration become less and less frequent, and that at last they are scarcely perceptible. In like manner the amount of heat generated is proportionate to the diminished number of respirations, and continues to be lessened until the temperature of the insect has very nearly sunk down to a level with that of the atmosphere. There are also other circumstances which moderate the production of heat. When the insect is fasting less heat is generated, even during a state of activity, than when the insect is not deprived of its proper quantity of food. The cause of this deficiency seems readily to be accounted for on the consideration that no new material, the product of digestion, is taken into the general circulation, and requires to be assimilated with the circulatory fluids, and, consequently, there is less change in the chemical condition of the fluids at each respiration, than when the animal is taking its full amount of food. Other circumstances also tend to regulate the amount of heat. When the insect is respiring rapidly, the power and frequency of its circulation are augmented, and not only is there a greater quantity of gaseous expenditure from the respiratory organs, but there is also a greater amount of cutaneous expenditure, which tends to cool down the insect by evaporation from the surface of its body, and diminish the amount of heat developed. This expenditure is so enormous, as we have elsewhere shown,* that it is more than equal to the quantity of solid matter excreted from the alimentary canal in a given time, and, consequently, is a powerful means of reducing the temperature of the insect. One very marked difference which exists, in respect to the function of respiration and the evolution of heat, between these air-breathing invertebrata and the vertebrated animals is, not in their different powers of generating, but of maintaining their temperature. Insects in their low power of maintaining heat closely resemble the true hybernating animals. Any great or sudden change of temperature in the surrounding medium rapidly reduces the temperature of the insect. It is thus seen that a reduction of temperature takes place not only at the period of true hybernation, which insects undergo either in their pupa or perfect state, but also during vicissitudes of the season, as well as during natural repose. On the other hand, it is remarkable that the evolution of heat in insects takes place as rapidly as it becomes reduced. Its increase is perceptible by the thermometer within a very few moments after the insect has begun to respire more rapidly. The explanation of this circumstance must be sought for in the peculiar distribution of the respiratory organs, which are extended over the whole body, and aerate the blood in every part of it at the same instant, the result of which is the immediate evolution of a large amount of heat, from the changes that occur in the fluids in vessels that partake both of the venous and arterial character. Consequently a large amount of heat is liberated instantaneously, whether the oxygen of the atmosphere be absorbed into the circulatory system, or whether the whole of the changes take place, and carbonic acid be formed in the respiratory structures. The same rapidity with which the heat is evolved from the body accompanies its diminution when the quantity of air inspired is lessened. In confirmation of this view with regard to the production of heat being the result of the chemical changes in the air inspired, there is one remarkable circumstance that cannot be passed over. It is the *voluntary power* which we have found is possessed by some species of generating heat by means of accelerating their respiration. We observed this fact in the individuals of a nest of Humble-bees, *Bombus terrestris*, which were confined by us for the purpose of watching their habits. Huber formerly noticed that bees are in the habit of incubating on the cells of their pupæ, before the perfect insects are developed, and we have had ample opportunities of confirming his observations. It was during the time that we were engaged in watching these habits that we discovered that bees possess this voluntary power of increasing their temperature. The manner in which the bee performs her incubatory office is by placing herself upon the cell of a nymph that is soon to be developed, and then beginning to respire at first very gradually. In a short time the respirations become more and more frequent, until at length they are increased to one hundred and twenty or one hundred and thirty per minute. The body of the insect soon becomes of a high temperature, and on close inspection is often found to be bathed with perspiration. When this is the case the temperature of the insect soon becomes reduced, and the insect leaves the cell, and another bee almost immediately takes her place. When respiration is performed less violently, and consequently less heat is evolved, the same bee will often continue on a cell for many hours in succession. During these observations we have, in some instances, found the temperature of a single bee exceed that of the atmosphere more than twenty degrees. Thus when the temperature of the atmosphere was 73° 5 Fahr. that of four female bees, in the act of incubation, was 94° 1. On another occasion when the atmosphere was 72° 5, a single bee, nursing on a single cell, from which a perfect insect was developed about eight hours afterwards, afforded a temperature of 92° 3, the bulb of the thermometer being placed between the abdomen of the bee and the cell. The insect was then breathing at the rate of one hundred and twenty respirations per minute. In another instance, the temperature of the atmosphere being the same, that of another bee in the act of nursing was 94° 5. This extreme amount of heat was evolved entirely by an act of the will in accelerating the respiratory efforts, a strong indication of the relation which subsists between the function of respiration and the development of animal

* Phil. Trans. 1837, p. 2.

heat. These curious facts tend much to confirm the opinion as to the chief origin of animal heat, but for farther illustration of this interesting subject we must refer our readers to the article RESPIRATION.

Organs of generation.—These parts have already been treated of to some extent in a preceding article, (GENERATION, ORGANS OF,) and the forms which they assume in different orders, more particularly those of the male organs, having in part been described, we shall only briefly allude to them on the present occasion, in consequence partly of the great length to which this paper has already been extended, and partly that we shall necessarily return to this subject, more especially with reference to the functions of these parts, in describing that class of Articulata, which in every respect are so closely related to insects, the Myriapoda, to which we must refer.

In our observations on the skeleton we have shown that the terminal segments of the body invariably form part of the external organs of generation. The long ovipositor of the *Chrysididæ*, composed of four distinct annuli, retractile within one another, and even within the proper abdomen itself, are only the terminal segments of the body, which is thus made to consist of fewer, but proportionately larger annuli than the abdomen of those in which so many segments are not employed in the formation of the generative organs. A corresponding structure is also seen in the *Panorpidæ*, in which the separate annuli, not retractile to so great an extent as in the *Chrysididæ*, but capable of being extended to as great a length, are distinctly shown to form part of the abdomen, while the corresponding parts in the male, the terminal segments, are developed into a claw-shaped prehensile organ. A similar modification of structure exists in all other insects. In some species one or more of these parts becomes atrophied, or is developed to a greater extent than the others, and the result is that in some instances we find long, exsertile, and apparently new organs, while in others some parts, even of the annuli themselves, appear to be absent. But the normal number is almost every where present, either simply as terminal plates of the abdomen, between which the proper excretory portion of the organs of generation is concealed, or more highly developed, and forming a separate sheath for that structure.

In the *male* insect (*fig.* 437) the organs consist of an external portion, the *penis* (*h*), or "organ of intromission," in which is inclosed the termination of the *ductus ejaculatorius*, which extends backwards, and is connected with the *vesiculæ seminales* (*e*) and *vasa deferentia*, which are connected with the *epididymis* and the proper *testes* (*a*) These parts are found in a large number of insects, in some developed to a great extent, but in others almost entirely atrophied. This is the order in which the parts are met with when passing from without inwards.

The *penis* of the male, like the ovipositor of the female, assumes a variety of forms. It is usually inclosed between two lateral plates, the analogues of the sheath of the ovipositor, and which are derived from the terminal or penultimate segment of the body. Within this is a corrugated soft membrane, the *preputium*, which is continuous with, and is reflected inwards from the inferior margin of the anal aperture, and separates the organs of generation from the alimentary canal. When the penis is retracted it is covered by this membrane, which is corrugated upon it (*fig.* 402, s). In Coleoptera, as in the *Carabidæ* and *Melolonthidæ*, the penis is a long horny tube, retractile within the abdomen on the under surface as far as the anterior segments. The strong horny covering of this organ is simply a consolidated state of parts of the tissues which in other instances are soft and flexible. It contains within it the excretory portion of the ejaculatory duct. In most of the Coleoptera, and in many other species, it has this strong hardened exterior, necessary apparently for its employment by certain species, in which there is little flexibility of the abdominal segments, as an organ of intromission. In *Carabus monilis*, as noticed also in *C. clathratus* by Burmeister, the hardened case of the penis is gently curved downwards to facilitate its introduction into the vulva of the female. At its extremity on the under surface it is a little elongated, and it is terminated by a soft corrugated glandiform structure, which is perforated in its centre, and represents a *glans penis*, the perforation in its centre being the orifice of the excretory duct. In other Coleoptera the penis is also inclosed in a horny sheath, and presents a great variety of forms in different species. In many instances it is furnished at its extremity with short hooked spines, by means of which the male effectually retains his connexion with the female. The external sheath of the male organs, which incloses the penis, is analogous to that of the ovipositor of the female, and is employed when it is well developed to open the vulva of the female. In many species it is scarcely at all developed, being like the sheath of the ovipositor only a highly developed portion of the lateral plates of the terminal abdominal segments. The circumstances above referred to will not allow us to describe in detail the forms of these organs of generation in many species, we shall therefore content ourselves with a brief notice of some of those of the Hymenoptera (*fig.* 437). The general form of the penis in this Order is similar to that of Athalia, and consists of a

Fig. 437.

Male organs of generation of Athalia centifoliæ. (*Prize Essay.*)

short valvular projectile organ, covered externally by two pointed horny plates (*i*), clothed with soft hairs. Above these are two other irregular double-jointed plates (*l*), convex on their outer and concave on their inner surface, and surrounded at their base by a bony ring (*k*). They are half corneous half membranous, and folded together like a closed fan, and are furnished at their posterior margin with horny hooks (*i*), which are used as organs of prehension. Between these in the middle line are two elongated muscular parts (*m*), which when applied together form a pointed structure, and inclose between them in its retracted state the proper intromittent organ (*h*). These perhaps assist to dilate the vulva of the female, like the plates above noticed in the Coleoptera. In many instances, as in *Anthidium manicatum*, the posterior margin of the last true abdominal segment is armed with spines that are curved downwards, and serve to retain the female, and this is also the case in the *Chrysididæ*. In *Anthophora retusa* the horny penis formed of the last two segments of the larva has also two external plates developed into hooked prehensile organs, with which the insect grasps the abdomen of the female at the moment of actual connexion. In the Sphinx (*fig.* 391) and other Lepidoptera the appendages of the anal segment appear to be analogous to the sheath of the ovipositor in the preceding orders. On each side of these parts at their inner surface are two horny plates, which form the lateral boundary of the male organs. Within these is a cloaca, in which the anal aperture terminates, and immediately beneath it are situated the male organs. These consist of an extensile bifid, ejaculatory organ included between two soft valvular parts. They form the virile organ. In the Sphinx the posterior margin of the dorsal plate of the terminal segment is armed with a slender curved hook, bifid at its apex, and bent downwards, like the hooks in the body of Hymenoptera, for retaining connexion with the female. Among the Diptera the *Asilidæ* have the male organ formed in a somewhat similar manner. The terminal segment of the body forms a pair of broad horny plates, which inclose between them the double stiliform excretory canal.

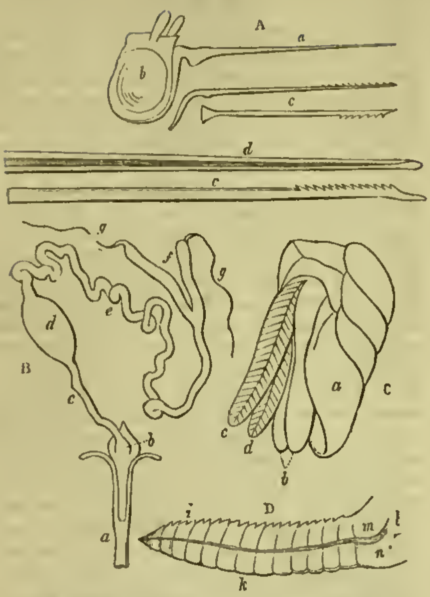
The *ductus ejaculatorius* passes backwards from the penis as a single canal, which either is exceedingly short, as in *Athalia*, (*fig.* 437, *f*), or is a very long tube, forming many convolutions in its course, as in many of the Coleoptera. Into this canal open the *vesiculæ seminales* and the *vasa deferentia*. The *vesiculæ seminales* are usually long convoluted cœcal tubes, which assume a variety of forms, sometimes branched sometimes simple. They are two, and sometimes four in number. In some species, as in *Athalia* (*e*), they are exceedingly short, and very much dilated, serving evidently as receptacles for the semen as it is secreted by the testes, and conveyed towards the ejaculatory duct by the vasa deferentia (*d*). These, like the seminal vessels, vary in number according to the number of the testes. When the whole of the testes are aggregated together, the vasa deferentia that proceed from them are united from each set of testes into a single tube on each side (*b*), but when the testes remain distinct from each other, each deferential vessel passes at first separately from each testis for a short distance, and the whole are then collected together, and form on each side a single tube, which, after many convolutions, either is inserted into the extremity of the seminal vessel, or is inserted along with it into the commencement of the ejaculatory duct. The length of the common deferential vessels is sometimes so great, and they are so much convoluted, as to be readily mistaken for testes, much larger than the proper testicles. This is the case in Athalia (*d*). The proper testes are usually several rounded glandular bodies, in some instances, as in *Melolontha** and *Lucanus*, amounting to as many as six on each side, and in a few instances, as in *Athalia*, even to as many as thirteen. In form they are sometimes rounded, and sometimes are elongated cœciform tubes. They are usually regarded as cœcal organs, but in some instances we have distinctly traced minute vessels connected with them, but whether these vessels passed by open mouths directly into the cœca, or whether distributed over their surface, is perhaps still a question; our impression certainly is that they enter the testes. Besides these parts, there are in some instances structures that resemble an *epididymis*, as in *Hydrous*,† but these are generally absent.

These organs lie within the abdominal cavity, in general on each side of the alimentary canal, and sometimes above it, as in the instance of the Lepidoptera, in which the two separate testes of the larva (*fig.* 364, *i*) are united in the perfect insect into one mass, which is situated immediately beneath the dorsal vessel (*fig.* 366, *i*). In each of these cases the connexion with the vessel, as formerly noticed, is distinctly traced. Besides these parts we ought also to notice some which are appendages of the organs similar to appendages found in the female, but the function of which is not distinctly understood.

In the *female* the organs of generation are more simple than in the male. Of these we have first to notice those external parts which form, as we have stated, either the long extended *ovipositor* of the *Gryllidæ*, the sheath of the *sting* of the bee (*fig.* 438, A, *a*, *d*), or the sheath or valves of the ovipositor of the *Terebrantia* (C, *b*). The condensed description of these parts that has been given by Mr. Westwood‡ clearly explains their structure. He remarks that, " from the centre of the under side of the abdomen, near its extremity, arise two plates, each consisting of two joints, sometimes valvular and together forming a scabbard, sometimes more slender, and resembling palpi, and sometimes very long; between these plates, as they exist in the bee (A, *b*), under the form of two flattened plates, with a pair of terminal lobes, arise two other pieces which are very slender, serrated

* Straus.
† Dufour.
‡ Entomologist's Text Book, p. 375.

Fig. 438.



A, *lateral view of the sting of the Bee.* (*Westwood.*) *a*, the sheath; *b*, terminal segment of the abdomen; *c*, the barbs or proper sting; *d*, the channeled surface of the sheath of the sting in which the barbs are concealed.

B, the *poison-bag* and vessels of the sting of the *Anthophora retusa* (Newport); *a*, sheath of the sting; *b*, the dilated extremity of the poison duct; *c, d*, the bag; *e*, efferential vessel; *f*, the secretory organs; *g*, their vessels.

C, terminal segment of the abdomen of a saw-fly, *Trichosoma* (Lyonet); *a*, dorsal end of the terminal segment; *b*, sheath of ovipositor or terminal ventral arch; *c, d*, the inner plates or saws, analogous to the barbs, *c*, of the sting of the bee.

D, one of the double lancet-pointed saws of *Athalia centifoliæ.*

at the tip in the bees (*c*) but much broader in the saw-flies (C, *c, d*) and transversely striated, forming the saws with which these insects are provided: moreover these two pieces are received in the bees into a canal (A, *d*), but in the saw-flies this gutter is broad, flattened, and divided into two separated parts, forming the backs of the two saws. In the Ichneumons these various parts are so slender that at the first sight they appear to consist but of a single piece: on more minutely examining the instrument, however, it will be found that it consists of a scabbard, composed of two pieces, inclosing a fine hair-like bristle, which is, in fact, the exact analogue of the stinging part of the bee's sting, consisting of three pieces." This organ constitutes both a means of defence and also of depositing the eggs. There have been some doubts with regard to this fact in the bees, some having questioned whether the sting is at all employed in oviposition by these insects; but a most careful and accurate observer, Dr. Bevan, distinctly states that the ova pass along the sting of the bee to be deposited, and this statement is confirmed by the fact that this is certainly the case in the analogous instrument of the saw-flies, as we ourselves have distinctly witnessed in *Athalia centifoliæ*. The analogy, therefore, of the sting with the ovipositor of the *Gryllidæ*, of the saw-flies, and other insects, is distinctly proved. In *Athalia* the ovipositor is a very interesting organ. It occupies the under surface of the seventh and eighth segment of the body, and is approximated to the posterior margin of the sixth, a part of the seventh having been removed. Four tendons for the insertion of muscles originate from the extremity of the two halves of the ovipositor. In the membrane that unites on the under surface the two halves of the ovipositor, is situated the vaginal orifice between the two saw-shaped organs (C, *c, d*, D). Each of these parts is composed of two plates applied together back to back, and which together form a pointed instrument resembling a lancet (D). The upper one of these plates (*i*) is furnished with small sharp-pointed teeth directed backwards, and the under one (*k*) with fourteen long and slightly convex ones. With the point of this instrument the insect pierces the edges of the leaves of the turnip, separating the cuticle with its saw preparatory to depositing its egg, which is conveyed along its inner surface, which is slightly concave to allow of its safe transit along the plates. Posteriorly and external to these plates are the two sheaths of the ovipositor (C, *b*) analogous to one portion of the ovipositor of the *Gryllidæ*. In all those Hymenoptera furnished with an ovipositor there is also an apparatus for secreting a peculiar fluid, and this apparatus is believed to be analogous to the appendages of the male organs above alluded to, the use of which is not well understood. In the female these parts consist of an *excretory duct*, and *bag*, or receptacle for the fluid, a convoluted efferential vessel, and proper secretory organs. In the wild bee, *Anthophora retusa* (B), at the base of the sheath (*a*) in which the two barbs of the sting (A, *e*) are concealed, is a smooth dilated space, into which the poison is first received at the base of the sting. The poison is conveyed to this space by the efferential duct (*c*) from an oval sac (*d*), in which it is accumulated as secreted, and into which it is poured by a very large and much convoluted efferential vessel (*c*), which receives the fluid from two cœciform glandular organs (*f*), which unite as they enter the efferential vessel. These secretory organs receive at their apparently closed extremity each a minute vessel, which we have distinctly traced to some distance from them, but not to its termination. When the poison is ejected from the bag (*d*) into the base of the sting, it passes along between the two barbs, as in a little gutter, into the wound. Swammerdam delineated these parts in the honey-bee, but did not notice the vessels proceeding from the secretory organs. In another insect of the same class there are similar structures. Thus, in *Athalia* (*fig.* 439), the bag (*g*) is oval, but the efferential vessel is entirely absent, the fluid being poured directly from the secretory vessels (*h*) into the bag without passing along any other tube. The vessel is

Fig. 439.

Female organs of generation of Athalia centifoliæ. (*Prize Essay.*)

also absent between the bag and the base of the ovipositor, so that the fluid is forced directly from the bag at the moment it is employed. There is a somewhat similar structure in the Hornet, although the vessel between the bag and sting is present as in the bee. Burmeister has suggested that the poison-gland may perhaps be an *urinary* organ, but the circumstance of the fluid contained in it being employed by the insect to inject into the cavity in which it deposits its ova, seems opposed to this opinion, although that of its being employed by the bee as a means of defence may be favourable to it. The nature of this fluid is distinctly acid, as remarked by Dr. Bevan in the honey-bee, and as found by ourselves in several instances. The *vaginal aperture* at the base of the ovipositor forms the external orifice of the *common oviduct* or proper laying tube (*e*). This in some instances is simply a dilated orifice, the internal lining of which is continuous with that of the internal part of the ovipositor. This common oviduct is either a simple, straight, uniform tube, or in some instances is a little dilated laterally into pouches, in which are received the lateral appendages of the male organ, as in *Melolontha*. At its termination the common oviduct divides into or rather receives two separate tubes (*d*), one from each side, analogous to the efferential vessels of the male organs. On the upper surface of the common oviduct, there are appendages that vary in number from one to five. The chief of these, the *spermatheca* (*f*), alone exists in *Athalia*. It is into this sac that the fluid of the male is ejected during copulation. Audouin states that the male organ is projected into it. We have invariably found this vesicle, which is exceedingly large in *Meloe*, filled with white, opaque, seminal fluid after connexion with the male, previously to which time we have as invariably found this vesicle empty. This appendage is simple in many of the Orthoptera as well as in Hymenoptera, but in some other species there are also additional vesicular appendages which have been described as secreting a glutinous fluid. In all instances these are attached to and pour their contents into the common oviduct, through which the eggs pass to be deposited. In the middle line, at the union of the oviducts, are situated the terminal ganglia of the nervous cord (10, 11), when the cord is extended to the posterior part of the abdomen. But when this is not the case, and the nerves simply radiate from the thorax into the abdomen, the terminal pair of nerves still pass in a corresponding direction over the union of the oviducts, thus always occupying a position between the organs of generation and the termination of the alimentary canal. From the two oviducts originate the proper *ovarial tubes*. In *Athalia centifoliæ* there are eighteen (*a*, *b*, *c*) attached to each oviduct, but in some other instances, as in *Melöe*, in which the upper part of the oviduct on each side is dilated into an immense bag resembling an uterus, they amount to some hundreds of exceedingly short tubes containing each but one or two ova. In *Melolontha* and *Lucanus* there are six on each side, but in some instances, as in *Lixus*, as shewn by Dufour,* there are only two on each side. These ovarial tubes gradually decrease in size from their base to their apex, and those from each side are collected together at their apices, and are said to terminate each in a dilated cœcal extremity, but we must confess we have never yet traced this structure in any instance. Müller, as above stated, traced a connexion between the extremities and the ovarial tubes and the dorsal vessel in *Phasma*, and many other insects, as we have also done in several instances, but the nature of these connexions is disputed. They certainly appeared to us to be vascular, as supposed by Müller, and we have already stated the reasons that led us to the same opinion.

We shall enter on a consideration of the function of the organs of generation when considering this subject in Myriapoda.

In concluding this lengthened article we have only further to remark that the tegumentary appendages consist of *hair*, *scales*, and *spines*. The first of these serves as a covering for the bodies of many species, more particularly the Hymenoptera, and is also found under the limbs in many Coleoptera. The scales are peculiar appendages and may be considered, according to many, as simply flattened hairs. They entirely cover the bodies of many species, as for instance the Lepidoptera. The curious forms and marking of these parts are sometimes exceedingly beautiful; but the limits of our article will not allow of our entering at present on the consideration of them. The *spines* are found much on the wing of Hymenoptera and are often mistaken for true hairs, between which and spines, and also between these and scales, there is a difference of origin,

* Annales des Sciences Naturelles, tom. vi, pl. 20.

spines being usually developed directly from a trachea or part of a membrane in the immediate vicinity of a trachea.

BIBLIOGRAPHY.—In addition to the foot-notes attached to the article the following are some of the principal works on Insects: De Animalibus Insectis libri septem, Auctore *Ulysse Aldrovandæ*, fol. Bonon. 1602. Experimenta circa Generationem Insectorum, *Francisco Redi*, Florence, 1668. De Bombyce, *M. Malpighi*, 1687? Historia Insectorum, Londini, 1710. Methodus Insectorum, seu Insecta in Methodum aliqualem digesta, *Johannes Ray*. Systema Naturæ, 1735-1770, *Carolus von Linnæus*. Mémoires pour servir à l'Histoire des Insectes, par *Charles De Geer*, 7 tom. 4to. Stockholme, 1752. Traité d'Insectologie, par *Charles Bonnet*, 8vo. Paris, 1748. Biblia Naturæ, fol. by *J. Swammerdam*, translated by Thomas Flloyd, with Notes by J. Hill, London, 1758. Entomologia Carniolica, exhibens Insecta Carnioliæ indigene, &c. 8vo. *Joannis Antonii Scopoli*. Vindobonæ, 1763. Mémoires pour servir à l'Histoire des Insectes, 6 tom. 4to. par *René Antoine Erchhault de Reaumur*. Traité Anatom. de la Chenille, 4to. par *Pierre Lyonet*, 1760. Spicilegia Zoologica, &c. à *Petr. Sim. Pallas, M.D.* 4to. Berlin, 1767-1780. Systema Entomologiæ, &c. 8vo. *Jo. Christ. Fabricii*, Flensburgi et Lipsiæ, 1775. Novæ species Insectorum Centuriæ 1. Auctore *Joanne Rionoldo Fostero*, 8vo. Londini, 1771. Historia Naturalis Curculionum Sueciæ, Auctore *Gabriel Bonsdorf*, 4to. Upsaliæ, 1785. Entomologia Parisiensis, edente *A. F. Fourcroy, M.D.* 2 tom. 12mo. Parisiis, 1785. Exposition of English Insects, arranged according to the Linnean System, 4to. London, by *John Harris*, 1782. Entomologia Helvetique ou Catalogue des Insectes de la Suisse, rangés d'après une nouvelle Méthode, avec Descriptions et Figures, *Clairville*, Zurich, 1798. Tableau elementaire de l'Histoire Naturelle des Animaux, par *G. Cuvier*, 1797. Natural History of British Insects, by *E. Donovan*, 16 vol. 8vo. London. 1792-1818. De antennis Insectorum, 8vo. 1799, *Lehmann*. Vivarium Naturæ, the Naturalist Miscellany, by *G. Shaw*. Lepidoptera Britanniæ, Auctore A. H. Haworth, 8vo. Londini, 1803. Monographia apum Angliæ, by *W. Kirby*, M.A. 2 vol. 8vo. Ipswich, 1802. Introduction to Entomology, by *William Kirby*, M.A. and *William Spence*, vol. iv. 1816-1828. Historia Nat. des Animaux sans Vertebres, &c. par *M. le Chevalier de Lamarck*, 5 tom. 8vo. Paris. Extrait du Cours de Zoologie, &c. par M. de Lamarck, 1812, 8vo. Elements of Natural History, 2 vol. 8vo. London and Edinburgh, 1802, by *Stewart*. Histoire Naturelle des Crustaces et des Insectes, par *P. A. Latreille*. British Entomology, by *John Curtis*, F.L.S. Histoire abregée des Insectes, Paris, 1764, 2 tom. 4to. by Geoffroy. Illustrations of British Entomology, by *James Francis Stephens*, F.L.S. Horæ Entomologiæ, by *W. J. Macleay*. Entomologia Britannica, 1 vol. 8vo. 1802, by *Thomas Marsham*. Considérations Générales sur l'Anatomie comparée des Animaux Articulés, par *Hercules Straus Durckheim*, 4to. Paris, 1828. Modern Classification of Insects, by *J. O. Westwood*, F.L.S.

(G. Newport.)

INSECTIVORA, *(Insecta, voro,)* a group of mammiferous animals, considered by some authors as a distinct order; by others, and particularly by Cuvier, as a family only of the great carnivorous order, named by that great naturalist CARNASSIERS. The peculiarities of structure by which the Insectivora are characterized appear to me to be equally important with those which have led me already to treat of the Cheiroptera as an ordinal group, and I shall therefore consider them in that point of view.

They consist of four very distinct groups, the relations of which are not very clearly fixed. I have ventured to consider them as four families, viz.:—

TALPIDÆ, typified by the mole, *Talpa*.
ERINACEADÆ, by the hedgehog, *Erinaceus*.
SORICIDÆ, by the Shrews, *Sorex*.
TUPAIADÆ, by the genus *Tupaia*.

Such at least appears to me, in the present state of our knowledge, to be a near approach to the natural groups of which the order is composed. In the *Talpidæ* I include the genera *Talpa*, *Condylura*, and *Chrysochloris*; in the *Soricidæ*, the genera *Sorex*, (with the subgenera, so called, into which it has lately been subdivided,) *Mygale* and *Scalops*, the latter genus being clearly osculant between the *Soricidæ* and the *Talpidæ*; in the *Erinaceadæ*, the genera *Erinaceus*, *Echinops*, and *Centenes*; and in the *Tupaiadæ*, the single genus *Tupaia*, or *Cladobates*, as it is named by Fred. Cuvier.

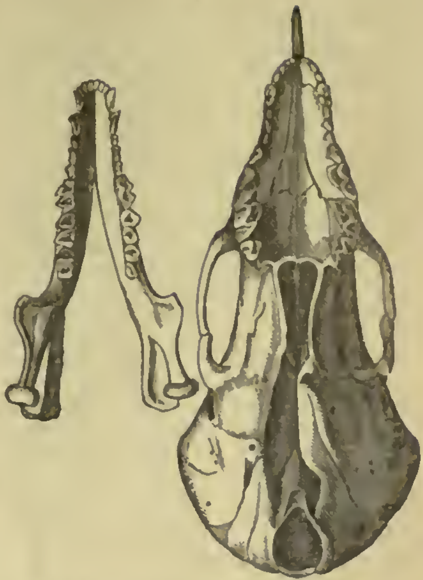
It will at once be seen, by reference to this enumeration of the types of form which occur in this order, that animals, differing greatly in their general structure and habits, are included in it. But it will also be found that they all agree in the general character of their teeth, which are in all instances furnished with elevated and pointed tubercles, for the purpose of breaking down the hard and polished elytra of coleopterous insects, upon which most of them in a greater or less degree subsist. This character has already been exhibited in the insectivorous group of the Cheiroptera, which we have considered as leading towards the present order; and even in the lower forms of the Quadrumana a similar tendency is evident, as in the Maki, the Loris, and others. They agree, also, in being for the most part nocturnal animals, and, with some exceptions, in living under ground, or at least in exhibiting a tendency to such a mode of life; and all those which inhabit the colder countries pass the winter in a state of torpidity. They all possess clavicles; their limbs are generally short, and they are plantigrade. They have ventral mammæ, the stomach is perfectly simple, and they are destitute of a cœcum.

The different families which I have named are as well characterized by their habits as by their external form, and their more intimate structure. The *Talpidæ*, the teeth of which are shewn in the genus Talpa *(fig.* 441,) and Chrysochloris *(fig.* 450), which are pre-eminently subterranean, are distinguished by their extraordinary habits of forming long and complicated burrows underground, passing their whole lives in a subterranean retreat, in which they are born, feed, breed, hibernate, and die; and which retreat, in the case of the common mole, is formed with the utmost art, and a beautifully complicated construction. The *Soricidæ (fig.* 449) are a sort of carnivorous mice; and although they do not actually burrow, retreat during the winter, and in their ordinary repose, into holes, feeding, however, on the surface or in the water, several of them being partially aquatic, diving with facility after aquatic insects, and remaining without difficulty a long time under water. In both these families there is a peculiar character in the structure of the hair, which favours the habits I have mentioned, and which will be presently described. In the *Erinaceadæ* (see *fig.* 451) we still have hibernating animals, but these, instead of burrowing or descending into deep excavations, conceal themselves only under leaves, or in any superficial hollow, and live upon food which they either find upon the surface or dig out of the ground with their hard moveable muzzle; the character of their integument is very peculiar, the hair being modified into spines of a greater or less degree of firmness, and the animals being mostly capable of rolling themselves into a ball, and thus presenting a panoply of sharp spines to their enemies. The last-named group, which I have named *Tupaiadæ*, (*fig.* 452) partake, as before observed, of the character of the Insectivorous Quadrumana; living in trees, which they climb with all the agility of a monkey or a squirrel. They consist but of a single genus, named by the late Sir Stamford Raffles, *Tupaia*, of which three species are well distinguished. They are natives of Java.

I. *Osteology.*—It can scarcely be said that there is any peculiarity of structure in the skeletons of the whole of the insectivora, in which they differ essentially from other groups; but on the other hand, there are many in which they differ from each other, according to the very striking and obvious diversity of their habits. In the family *Talpidæ*, the genus *Talpa* (*fig.* 440) presents itself as the type. In these animals the cranium is greatly elongated, and of a tapering or conical form, a character which it partakes with the *Soricidæ*, but to a still more remarkable degree. The cranium of the *Chrysochloris*, or Cape-mole, the South African representative of this family, presents this character in the most regular form. It is, in fact, a perfect cone, short, pointed at the muzzle, broad behind, where the base of the cone is distinctly circumscribed by a crest, which passes from the root of the zygomatic arch of one side, over the vertex, to the corresponding point on the other; on the sides of the head the zygomatic arches themselves complete the cone, passing obliquely and in a straight line from the maxillary to the temporal bone, and beneath it is completed by the inclination inwards of the symphysis, the rami, and the coracoid processes of the lower jaw. The portion posterior to the base of the cone is rounded.

In the genera *Talpa* (*fig.* 441) and *Condylura* the head is equally but less regularly conical, and the snout is more elongated; the zygomatic

Fig. 441.



arch is extremely slender, and rises obliquely, joining the cranium considerably above the auditory meatus. A similar conformation is seen in the genus *Scalops*, which I have already mentioned as leading from the *Talpidæ* to the *Soricidæ*. This form is admirably suited for their subterranean progression, as they push their way through the soil by their long moveable snout, which acts in some measure as a wedge. Amongst the *Soricidæ*, the *Scalops* approaches in its structure most nearly to the *Talpidæ*, having the almost perfectly conical form of the head which belongs to that family; and all the *Soricidæ* partake of it to a greater or less degree. But the cranium of the *Erinaceadæ* approaches more nearly to that of the Carnivora; and viewed from above, the sides are nearly parallel, the zygomatic arches projecting further than the posterior part of the cranium. The muzzle is shorter, more obtuse, and somewhat narrower than the cranium, which is compressed forwards. In *Centenes* the head is much more elongated and conical. The genus *Tupaia* has the head nearly oval, the muzzle straight, prominent, much smaller than the cranium, the zygomatic arches but slightly prominent, and the circle of the orbit closed posteriorly, a circumstance which is not found in any other of the order Insectivora. In this

Fig. 440.

genus the orbit is therefore circumscribed by being closed posteriorly by the union of the post-orbitar processes of the frontal and jugal bones ; in all the other genera the orbit and the temporal fossa are confounded in one cavity, without the trace of any attempt at forming a division between them. This peculiarity in the genus *Tupaia* shews a marked tendency towards the insectivorous Quadrumana.

The bones of the face are very early united in the *Talpidæ* and the *Soricidæ*. In the genus *Centenes* there is no jugal bone. There is therefore no zygomatic arch, notwithstanding the masseter muscle is of great size. This is attached by a single tendon to a sort of tubercle, which represents the zygomatic process of the maxiliary bone. In *Tupaia* the intermaxillary bones are very large, and their suture descends vertically, nearly half way between the nares and the orbits. The Shrews, like *Centenes*, have no malar bone, and the zygomatic process of the maxillary is even less conspicuous than in the former genus. Most of the subterranean forms have at the extremity of the muzzle, that is to say, around the opening of the nares, a small rim or border, which is especially conspicuous in the *Chrysochloris*, for the attachment of the large and moveable cartilages of the nose, so important to these animals in turning aside the earth as they make their way through the ground, as well as in seizing the worms and insects on which they feed.

The proportions of the spine vary greatly in the different families of Insectivora, as may be anticipated from the great difference in their habits. On this subject it may not be useless to subjoin the following table of the numbers of the separate classes of vertebræ, which is taken from the last edition of the Leçons d'Anatomie Comparée of Cuvier :—

	Dorsal.	Lumbar.	Sacral.	Coccygeal.	Total, including 7 cervical.
Erinaceus Europæus (Hedgehog)	15	6	3	12	43
Centenes ecaudatus (Tenrec).	15	5	3	10	40
C. setosus (Tendrac)	14	7	3?	9	40
Tupaia	13	7	2	25	54
Sorex araneus (Shrew)	14	6	5?	14	46
S. fodiens (Water-shrew) ..	13	6	5	17	48
Chrysochloris Capensis (Cape mole)	19	3	5	5	39
Talpa Europæa (common mole)	13	6	6	11	43
T. cæca (blind mole)	14	5	5	11	42
Condytura cristata (radiated mole	13	6	5	17	48
Scalops (mole-shrew)	12	7	6	10	42

It is worthy of remark, in taking a comparative glance at this list, that the length of the tail in the different species is in exact accordance with their habits, as far at least as we are acquainted with them. Thus, in Tupaia, we observe a tail as long as that of a squirrel, and obviously for the same object, that of balancing the animal when taking leaps from one branch to another ; and in the Water-shrew the tail is lengthened to assist in swimming, for which purpose it is also fringed on each side with stiff hairs. Of the habits of the *Condytura** we know little, and of that little nothing which accounts for the considerable proportion of the tail.

Of the form of the different vertebræ in the various groups of the Insectivora, little need be said, as there are few circumstances connected with these bones which bear materially upon any physiological point. It may be observed, however, that in the *Talpidæ* and the *Soricidæ* the cervical vertebræ form large rings, have strong transverse processes, and, excepting the second, do not possess any spinous processes. In the *Erinaceadæ*, and particularly in the Tenrec (*Centenes*) the transverse processes are particularly large, and the rings smaller than in the former families. The spinous processes are also wanting in the dorsal vertebræ of the mole.

The sternum offers some peculiarities worthy of notice. In the mole the first sternal bone is very large and compressed. To its anterior pointed extremity the thick short clavicles are attached, and further back to the same bone, the first rib is articulated ; to the second bone is fixed the second rib, and there succeed to these three elongated bones of the ordinary form, to each of which two pairs of ribs are articulated ; then a small bone. to which one pair of ribs is fixed, and then the xiphoid bone, which is long and narrow.

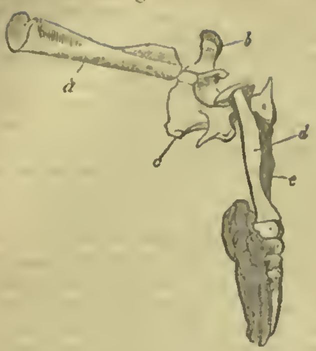
In the *Chrysochloris* the first bone of the sternum is equally compressed but less elevated ; and the anterior half is furnished on the upper part with two small aliform processes, which are concave, and support the first two ribs, which are extremely broad ; the long slender clavicles are attached at its anterior point; and then follow seven other oblong pieces, and an elongated xiphoid bone, which bears at its posterior extremity a semilunar cartilaginous dilatation.

The ribs in the mole and its congeners are nearly all of the same length, giving that peculiar cylindrical form to the body which characterises these animals, and which is so essential to their habits ; and in the *Chrysochloris* the first rib is very much broader than the others.

But it is in the bones constituting the anterior extremities, that the most remarkable and interesting peculiarities exist in some of the families of this group. In the mole especially, the anterior extremity (*fig.* 442) exhibits one of the most extraordinary modifications to be found in the whole of the Mammifera. The clavicle is fully developed in the whole of the Insectivora. In the mole (*b*) it offers the most

* From the name *condytura*, given to this genus by Illiger, it might be inferred that the tail is furnished with knotty tuberosities ; this, however, is only seen in dried specimens, which doubtless furnished to Illiger the characters of the genus, and suggested its name.

Fig. 442



abnormal deviation from the usual construction. It is extremely short and broad, forming in fact nearly a square; about the middle of its anterior margin a strong process rises, which gives origin to the subclavian muscle, which in this animal is greatly developed. It is articulated, as usual, with the sternum by its interior extremity, which may here be more properly called its interior margin; but by its external margin it is connected moveably with the head of the humerus, which connection is rendered more solid towards the anterior part by a strong ligament. Its connexion with the acromion of the scapula is by a ligament merely, which extends from the acromion to the posterior and outer angle of the clavicles. In *Condylura* and even in *Scalops* the construction of this bone is on a similar type; but in *Chrysochloris* it is long and slender as in the other Insectivora.

The scapula (*a*) in the mole is no less singularly formed than the bone just described. It is elongated to an extraordinary degree, being not less than six times as long as it is broad at the broadest part, which is at the superior extremity. Towards the middle it is contracted and almost cylindrical; and the spine, which runs nearly the whole length of the bone, is at this part almost effaced. The acromion, as before observed, has only a ligamentous connexion with the clavicle. In *Condylura* and *Scalops* the construction of this bone is somewhat similar, and in *Chrysochloris* it is also of considerable length.

The humerus in the mole (*figs.* 442, *c*, 443) is of so extraordinary a form, that were it examined alone, isolated from its natural connexions, it would be impossible to detect its true character. It is of a square form, extremely broad at the superior part, where it presents two articular surfaces; the anterior is very broad, slightly convex; the posterior and internal is narrow, but more convex than the former; by the first it is articulated to the clavicle, and by the latter to the scapula. Between the former, which may be considered as appertaining to the greater tuberosity of the bone, and the head, is a deep fossa. The body of the bone is short, thick, and very broad, and is curved upwards, so that its articulation with the forearm is placed actually higher than the shoulder, and the palm of the hand is consequently turned outwards. In *Chrysochloris* the form of this bone is not less remarkable. It is somewhat longer than that of the mole: its articulation with the forearm constitutes half a sphere; and the inner condyle is so elongated and inclined downwards, that the whole bone forms an arch of which the convexity is turned outwards. This condyle is articulated with a bone, which must be considered as a most extraordinary modification of the *os pisiforme*, which is as long as the radius, so that in fact the forearm may be said to be composed of three bones.

The bones of the forearm (*fig.* 442, *d*, *e*) in the extraordinary animal which offers so many deviations from typical structure, the mole, are no less remarkable than those of the shoulder. The *ulna* is very broad and much flattened; its superior extremity is enlarged transversely, the anterior surface concave, the posterior convex. The radius is separated by a considerable interval from the ulna throughout their length, and the two bones are only united at the upper extremity by a capsular ligament. But the articular surfaces of the two bones are flat, and the head of the radius is prolonged into a hook-like process, forming a sort of radial olecranon, so that rotation is impossible. The carpal bones (*fig.* 444) consist of two series of five in each, and an additional bone of a very peculiar construction. This is a large sickle-shaped or falciform bone, having the convex margin outwards; it extends from the carpal extremity of the radius to the first metacarpal bone. It is this bone which gives the great breadth to the hand, which is so important to this animal in its peculiar mode of life.

The phalanges of the fingers are very short, and covered by the integument in such a manner as to appear to belong to the meta-

Fig. 443.

Fig. 444.

carpal portion of the hand; and it is only the long sharp nails which extend beyond the skin, and are externally visible.

The position then of the anterior extremity of the animal is this: the humerus is so placed that the inferior or distal extremity is the most raised, so that the fore-arm is kept in a state between pronation and supination, the elbow raised, the radius and the thumb placed downwards, and the palm of the hand directed outwards. When to this we add the peculiar flexion of the last phalanx of the fingers with the enormous nails, we have a fossorial structure not equalled by any other in the whole of the vertebrated animals, and only imitated by the no less remarkable anomaly amongst insects, the *Gryllotalpa* or mole-cricket.

In *Chrysochloris* the third and fourth fingers are united by one large powerful nail, and are developed to an extraordinary size (*fig*. 445),

Fig. 445.

the fifth finger being reduced to a minute rudiment; and the carpal bones are placed in an abrupt curve, so that the outer side of the fifth finger approaches the first. The *os pisiforme* assumes also a peculiar development, being very much elongated, rises in the direction of the forearm, and is actually articulated with the internal condyle of the humerus.

The pelvis in the *Talpidæ* and *Soricidæ* is extremely long. The *ilia* are narrow and pointed at the anterior part. In the last-named family, the *pubis* and the *ischium* are especially long and narrow. In *Chrysochloris*, on the contrary, the ischium is very broad.

The femur offers but few and unimportant particularities amongst the *Insectivora*, unless it be that there is in the mole and *Chrysochloris* a sort of third trochanter; a process which is also found in some of the lower Quadrumana, and in some other of the Mammifera. The *fibula* is united to the tibia for nearly the inferior third of their length, in the *Talpidæ*, the *Soricidæ*, and the *Erinaceadæ*. In the mole this union is to a greater extent than perhaps in any other animal of the Mammiferous class.

The binder feet in the whole of this order are plantigrade. In the mole, as Daubenton and Meckel have observed, there is an additional tarsal bone, to those which are ordinarily found. It is of considerable size, and seems to answer to the falciform bone of the anterior extremities already described. It is of an uniform shape, of considerable size, and is articulated between the scaphoid and the first cuneiform bone, and extends forwards along the first metatarsal.

II. *Muscles.*—The extraordinary developement of the bones of the anterior extremity in the mole, will, of course, be associated with a no less remarkable structure in the muscles of the same part; and the known habits of the animal will account equally for the necessity of such a structure in both. I give a figure of the muscles of the anterior extremity and of the anterior part of the trunk from Carus. (*Fig*. 446.)

Fig. 446.

The cervical portion of the *serratus magnus* is simple, excessively thick and swelling, and is attached only to the posterior vertebræ. The *trapezius* consists only of two bundles of fleshy fibres, which arise from the lumbar vertebræ, and are inserted into the posterior extremities of the long and narrow scapulæ; and as these fasciculi are nearly parallel, their action would be rather to separate than to approximate the posterior parts of these bones, were it not for a strong transverse ligament which holds them together. Their application consists in moving the anterior part of the body upwards. The scapular attachments of the *rhomboideus* are principally to this transverse ligament of the two scapulæ, and as it is inserted into a sort of ossified modification of a cervical ligament, its office consists in raising the head with great force. The *levator scapulæ* is wanting; its existence would be obviously useless. The *pectoralis minor* is very slender; it is attached to the anterior parts of the first ribs, and to the ligament, already mentioned, which joins the clavicle to the scapula. There are also two muscles arising from the anterior part of the sternum, and inserted into the large head of the clavicles.

The most important muscles of the humerus are the *pectoralis major*, the *latissimus dorsi*, and the *teres major*, all of which are of great size; and it is by means of these muscles that the astonishing efforts of the animal are made in excavating his passages, and throwing the earth behind him. The *pectoralis major* is of extraordinary thickness. It is formed of six portions, which are all of them inserted into the broad quadrate portion of the humerus. Four of these portions arise from the sternum, the fifth from the clavicle; and the sixth passes across transversely from one arm to the other. The *latissimus dorsi* is also of considerable size, and is inserted into the posterior surface of the quadrate portion of the humerus. The *teres major*, which is of enormous thickness, is inserted near the former muscle.

The other muscles of the anterior extremity do not require particular description.

There is one peculiarity in the muscular system which deserves special notice; it is the enormous developement of the *panniculus carnosus* in the hedgehog, by which it is enabled to roll itself up in a ball with such astonishing force as to afford with its spiny covering a complete protection against its most powerful antagonists. I proceed to describe this apparatus and its uses.

As this muscular apparatus has no attachment but to the skin, it changes its position with every movement of the integument; and it is therefore necessary to consider it under the various relations which it assumes in the different positions of the animal. Considering it then, in the first place, as rolled up in a ball (*fig.* 447), either for defence or during repose,

Fig. 447.

the whole body is enveloped beneath the skin by a strong sac or covering, consisting of a mass of fleshy and concentric muscular fibres, of an oval form. All these fibres are attached intimately to the skin, and even to the base of the spines with which it is every where furnished, so that it is even difficult to detach the fibres in dissection. The thickest part of this fleshy sac is at the lower margin or mouth of the sac, at which part it forms a sort of sphincter, composed of orbicular muscular fibres. On the other hand, when the hedge-hog is unrolled, and at its full length (*fig.* 448), the muscle in question totally changes its figure and relations. The muscle now lies over the back, forming an oval covering, the middle of which is very thin,

Fig. 448.

and the circumference exceedingly thick and somewhat raised. To different portions of this circumference of the muscular covering are attached several accessory muscles. Anteriorly there are two pairs; one arising from the median line and inserted into the nasal bone; the other, more external, apparently confounded at its origin with the external orbicular fibres, is inserted into the side of the nose and incisive bones. Posteriorly a pair of broad muscles, of a pyramidal form, arise from the posterior part of the fleshy circumference, and are inserted into the side of the tail towards the extremity.

On the ventral aspect there are also several portions of muscle, belonging to the same apparatus. There is one beneath the throat, arising from the anterior part of the thorax, under the skin, and is inserted about the lateral parts of the head near the ears. Another arises from the median line of the sternum, and passes obliquely forwards over the shoulders, in front of them, to join the margin of the great orbicular muscle before described. There is another ventral portion which has a very extended connexion. It is attached around the anus, to the lateral parts of the tail and neighbouring parts, extends over the whole surface of the abdomen, and then divides into two portions; one internal, and larger than the other, passes under the axilla, and is inserted into the superior and interior part of the humerus; the other, external, passes laterally upwards, to be inserted into the margin of the great orbicular muscle near the neck. The muscles hitherto described lie superficially; but there are others which are seated underneath the great muscle of the back. One arises from the side of the head, being attached to the meatus auditorius on each side, and loses itself in the anterior point of the orbicular muscle. There is also a thin layer of fibres lying beneath the great muscle, of which the anterior are attached to the superior interior portion of the humerus, and the posterior to the third ventral muscle already mentioned.

We have here a very extensive and a very powerful apparatus, and it now becomes necessary to consider its application. When the hedgehog is rolled up in a ball, it is completely enveloped, as regards all the upper and lateral parts of the body, in the great orbicular muscle. When once brought into this position the simple contraction of the thick circumference of the muscle, which forms a true sphincter, is sufficient to retain it. If the animal unrolls itself, the disc of the great muscle contracts whilst the circumference is relaxed, allowing the exit of the feet and the uncovering of the belly and sides: then the whole muscle contracts together, and lies in a mass on the back. By this universal contraction, the necessary muscles become stretched, and in a condition to perform their several offices; by the contraction of the anterior ones the head, and by that of the posterior the tail, is raised, whilst those which lie beneath raise the head and neck together, and the animal is now ready for progression. On the other hand, on the apprehension of danger, or when reposing, it rolls itself into a ball by the following process. The orbicular muscle relaxes, and the muscles extending from it to the head and to the tail extend it in those directions, whilst the deap-seated transverse muscles which are attached to the external lateral portions, and lie on the belly, bring this part of the circumference downwards. At the same time the head is brought downwards towards the breast by the ordinary flexion of the head, and by the cutaneous muscles of the neck already described; the tail and the hinder legs are brought forwards under the belly, and the flexors of the limbs contract. The great orbicular muscle passes downwards over the sides, then contracts at the circumference, and forms a sort of sac or purse, enveloping the whole body and limbs.

III. *Digestive organs.*—It is, of course, in the structure of the digestive organs, and particularly in that of the teeth, that we find the distinguishing characters of the whole order; yet so nearly do these organs in the Insectivora approximate to those in the insectivorous division of the Cheiroptera, that it would not have been possible to separate the two groups, had there been no other important points of distinction. From the insectivorous Quadrumana they are distinguished by the plantigrade character of the posterior extremities; from the bats by the whole structure of the limbs, and from all the true Carnivora by the tuberculated teeth.

There is no inconsiderable difficulty in assigning the various anterior teeth in the Insectivora to their proper classes. In most of the genera, according to the statement of both the Cuviers and others, there are no canine teeth, and the false molares are very numerous; but it is in many cases doubtful whether the anterior false molares, as they are termed by these anatomists, be not theoretically canines modified in their form. On this point, however, there is no possibility of coming to a satisfactory conclusion, as every one will at last form his own opinion on each case; I shall therefore follow the arrangement of Frederic Cuvier as the most generally known, and, upon the whole, by far the best authority on the teeth of the Mammifera.

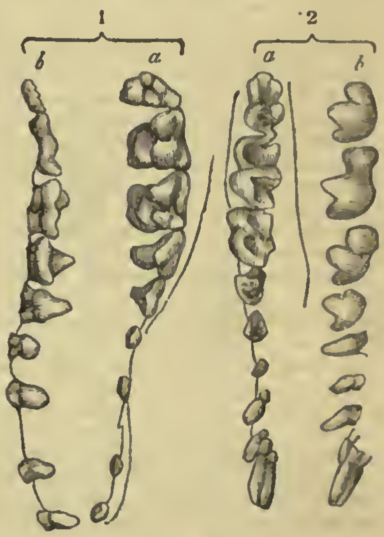
The incisive teeth vary greatly in the different genera. In *Mygale*, in *Scalops*, and in *Condytura*, there is in the upper jaw but a single incisor on each side, which is very strong and of a triangular form. In the first of these genera it is somewhat curved downwards and backwards, and slightly resembles that of some Rodentia. In *Sorex* (*fig.* 449) it is also single, very strong, curved, and similar to the canine tooth in the Carnivora, but furnished with a strong tooth-like process posteriorly, appearing almost like a distinct tooth.

In *Talpa* (*fig.* 441) there are three superior incisores on each side, which are small with cutting edges, like those of the Carnivora. In *Chrysochloris* (*fig.* 450), the single superior incisor is curved, convergent, obliquely truncate and pointed; and in *Erinaceus* (*fig.* 451) there are three pairs, of which the first is large, *Fig.* 449. *Sorex.*

Fig. 451. *Erinaceus.*

Fig. 450. *Chrysochloris.*

Fig. 452. *Tupaia.*



obtuse, and strong, separated by a considerable interval from its fellow, and convergent with it. The others are small and resemble false molares. In *Tupaia (fig.* 452) these teeth are two on each side, distant from each other, and from the first false molar. The inferior incisores also vary greatly in their form and number. In *Scalops* there are two, the first small, the second larger and resembling in form a canine tooth. In *Condytura* there are two, rounded in front, flattened behind. In *Talpa* there are four similar to those of the upper jaw, and in *Sorex* there is one only of a very peculiar form: it is very long from the anterior to the posterior part, somewhat hooked, pointed, and, in some species, the edge is notched or trifid. There are no true canines, according to the opinion of Frederick Cuvier, in any of these animals, excepting *Condytura, Talpa,* (in which they exist in the upper jaw only) *Centenes,* and *Tupaia.* The first tooth beyond the incisores, considered by Fred. Cuvier as the first false molar in the lower jaw in the mole, is by Baron Cuvier termed the canine. In *Centenes* these teeth are of the normal form; and in fact the general arrangement of the teeth in this genus indicates a marked approach towards the Carnivora. In *Condytura* the superior canine is strong and large; the inferior merely rudimentary.

The molares, as in the other Zoophaga, are divided into false and true. Those of the former class are very numerous and of very various form in the different genera, and the great diversity of number in the molar teeth depends in most cases upon these, the true molares being but three on each side both above and below in all the genera, excepting in *Chrysochloris*, in which they are $\frac{6}{5}:\frac{6}{5}$, in *Erinaceus*, in which they are $\frac{4}{3}:\frac{4}{3}$, and in *Centencs* $\frac{4}{4}:\frac{4}{4}$. In *Chrysochloris* the true molares are very curiously and beautifully formed: they are much compressed from before backwards, of a three-sided form, each of the angles terminating in a sharp elevated point; thus, in those of the upper jaw, there are two situated externally and one internally, and in the lower jaw one externally and two internally. The whole of the true molares, in all the Insectivora, are formed of three-sided prisms, either single or double, and surmounted by acute tubercles.

The salivary glands are generally much developed in the Insectivora. In the hedgehog the parotids are larger than the submaxillary; the sublingual are placed in two rows, of which the larger is situate nearest to the lower jaw. In the mole these glands are very large; the parotids are of an oblong shape, and the maxillary are formed of several rounded and detached lobes. In *Sorex* the maxillary glands are of larger size than the parotids, and the latter are situated very low to accommodate the oblique direction of the auditory canal.

The form of the stomach in this Order of animals is perfectly simple, and does not greatly vary in the different genera. It is situated transversely with regard to the axis of the body, is somewhat elongated, and the two orifices are distant from each other, as in many of the Carnivora, and in the insectivorous bats. The cardiac pouch is generally distinct and rounded; the pyloric extremity, on the contrary, is conical and perfectly even. In *Erinaceus* the cardiac point is considerable, the entrance to the œsophagus being at no great distance from the pylorus; and the internal coat forms numerous rugæ and folds. This form of the stomach and the existence of plicæ must be considered as indicating an aberration from the insectivorous type, and a certain degree of aptitude for the digestion of vegetable matters, and we find accordingly that this, with a slight exception or two, is the only family of the Insectivora which can exist upon any but the most exclusive animal aliment. The mole, the *Chrysochloris*, and all their congeners, are in this latter case; but the hedgehog, as is well known, will readily eat various vegetable substances, and often digs under the common plantain for the purpose of obtaining the roots, of which it appears to be very fond. The stomach varies a little in its form in the different genera of the *Soricidæ*. In the great shrew of India it is transverse, the pyloric portion conical, of moderate dimensions, the cardiac pouch small and the two orifices distant; a form which indicates an exclusive aptitude for insect food; but it would appear that the water-shrews (*Hydrosorex*) must occasionally have recourse to some kind of vegetable diet, as the pyloric portion is so much elongated as to resemble in some degree that of the *Pteropidæ* or fruit-eating Cheiroptera, exhibited in *fig.* 287, vol. i. p. 600. In the mole the œsophagus enters at about the middle of its anterior margin, and the lesser curvature is nearly straight to the pylorus. The membranes are extremely delicate and almost transparent. The form is essentially similar in *Chrysochloris* and in *Condyturu*. The stomach of *Tupaia*, according to the Baron Cuvier, is of a globular form.

The intestinal canal is upon the whole remarkably short in the Insectivora. There are some exceptions to this rule, but the only one bearing upon a difference of aliment is that of the hedgehog, which, as has been before observed, lives partially upon vegetable matters. In this animal it is, with regard to the length of the body, as 6.6 to 1. In *Talpa* and *Centenes* this proportion is even exceeded, but it is compensated for by the extreme narrowness of the canal; the diameter of which is to its length, in the mole, as 1 to 82; whilst in the hedgehog it is as 1 to 58. In *Sorex* its length is to its diameter only as about 3 to 1, or a little more. There is no cœcum known to exist in any of the Insectivora. Cuvier queries whether *Tupaia* be not an exception, but this we have at present no means of ascertaining. The liver is in general fully developed in all its parts; there are the principal lobe, to which the gall-bladder is attached, with a notch answering to the suspensory ligament, a right and a left lobe, and two smaller lobes or *lobuli*, a right and a left. The whole of these parts are generally found, but varying without any known law, or any ascertained relation to functional peculiarity. In the hedgehog and in the mole the left lobule is composed of two portions, a cardiac and a pyloric, as in the Rodentia. In Tupaia, according to the statement of Cuvier, the three portions into which the liver is divided belong to the principal lobe; there is no right or left lobe, and the right lobule is also wanting. The gall-bladder is for the most part of considerable size. In the hedgehog its fundus appears beyond the free margin of the liver, and is supported by a process of falciform ligament. In the Tenrec, on the contrary, it is as it were incrusted by the substance of the right portion of the principal lobe.

IV. *Nervous system.*—The form and proportions of the brain in some of the Insectivora exhibit a degree of developement not materially superior to that of the higher Carnivora; whilst others, and especially the mole, have the same higher proportion which are found in the Cheiroptera: thus in the hedgehog the volume of the brain is to that of the body as 1 to 168; whilst in the mole it is as 1 to 36. The proportion of the cerebellum to the cerebrum in the latter animal, however, indicates a considerable developement of the sexual functions, being as 1 to 4½. Supposing the theories of many modern physiologists to be correct, this fact is in perfect accordance with the necessities of the animal, whose means of obtaining access to the opposite sex are extremely difficult, and require intense ardour and perseverance to effect this object.

The most remarkable and interesting peculiarities which are to be met with in the structure of any of the Mammalia are to be found in the eye of the mole, and doubtless of the nearly allied forms of *Chrysochloris* and the other subterranean species. In these, in order to meet the requirements of their habits, the organ of sight is reduced to a mere rudiment, whilst those of hearing and of smell are developed to an extraordinary degree; and the theory of the *balance of organs* can scarcely boast of a stronger support in the whole range of animal organization than in this instance.

The question whether the mole possesses vision has been long and often debated. Without entering into an unnecessary examination of all that has been said on both sides of the question, it may be well to observe that the principal argument which has been urged on the negative is derived from the absence of an optic nerve. That this animal, at least our common species, does possess the faculty of vision to a certain degree cannot, however, be disproved, whatever may be the means by which the sense is communicated, that is to say, whatever the nerve may be which supplies the place of the true optic nerve; and the experiments of Henri le Court and Geoffroi St. Hilaire* would well nigh go to prove the affirmative of the proposition. It has been urged then that an optic nerve is absolutely necessary to the existence of vision; and that, therefore, either the mole has a true optic nerve, or that it does not possess vision. There have indeed been three classes of observers on this point; those who maintain that the mole sees, and that it possesses an optic nerve; those who contend that it is blind, and possesses no such nerve; and others have ventured to agree with the former as to its power of vision, and with the latter in denying the existence of the optic nerve.

The eye of the mole is extremely small, but differs not materially in its structure from that of other animals. The pupil is elliptic and vertical; the cornea even more convex than that of birds; there is a sclerotic and a true choroid. The crystalline lens is perfect, and much more convex than in most of the Mammalia; and the eye-ball, emptied of its contents, exhibits at the base a lining of a whitish colour. "In an injected subject," says Geoffroi, "the central artery of the retina was distinctly seen." Whether there be or not a true retina will be variously solved according to the views of different physiologists. If the nerve, whatever it may be, which takes here the place of the optic nerve, be really the seat of the sense of vision, there seems to be no objection to consider its expansion, upon which the pictures of objects are impressed, as a retina; giving the name rather to the physiological than to the anatomical character of the part; but be this as it may, from the posterior part of this minute eye there passes a distinct branch of a nerve. Perhaps, after all, the name and analogy of this nerve will be viewed differently according to the general views of organic developement entertained by different physiologists. Geoffroy considers it as the optic nerve, notwithstanding it has no connexion with that part of the brain which in all other cases is in immediate communication with it; and he founds this opinion upon the theory that all organs are developed from without. His words are as follow:—"Qu'est ce que ce nerf? La monstruosité et la nouvelle théorie sur le point de départ des développemens organiques assure ma marche: appuyé sur ces deux fanaux, aujourd'hui heureusement importés dans l'histoire encore si obscure des premières formations je ne doute pas que ce ne soit le nerf optique. C'est ce nerf, parceque cet appareil, qui est au complet comme globe oculaire, a du se former de toutes ses dependances jusqu'à l'empêchement qui en arrête le cours. Cette determination ne sauroit être douteuse pour qui reconnait que *les organes naissent à la circonférence de l'être*, d'ou ils envoient leurs rameaux s'embrancher au plus près dans le centre.*

Amongst those who assert that the mole possesses a true optic nerve is Müller. His statement is so brief, and, it may be said, so unsatisfactory, that it can scarcely be considered as sufficient to outweigh the carefully formed opinion of many who differ from him. His statement, as given in Dr. Baly's translation of his admirable book, is as follows:—"Some animals, though provided with eyes—for instance, the mole and the *proteus anguinus*—have been said to want the optic nerves; the sense of vision being then placed in the ophthalmic branch of the fifth nerve. This statement has arisen, in the case of the mole, from inaccuracy in the anatomical examination; and the same is the case probably in the Proteus. The mole has an uncommonly small optic nerve, as Dr. Henle has shewn me."† On the other hand, Serres, Gall, Desmoulins, and others have agreed in delaring that there is no nerve passing from the optic lobes to the eye; and Dr. Todd has recently verified this statement, and traced the nerve which *does* supply this organ, which he finds to be the ophthalmic branch of the fifth pair. I give an enlarged view of a dissection of this nerve, drawn by Mr. Bowman. (*Fig.* 453.)

a is the fifth nerve within the cranium, *b* the Gasserian ganglion, *c* the inferior maxillary nerve, *d* the ophthalmic nerve going to the eye (*e*,) *f* the superior maxillary nerve, *g* branch of the ophthalmic, supplying the side of the nose. Dr. Todd in a letter to me says, "I have been lately looking at the point about the optic nerve in the mole. I can see an optic commissure, but no optic nerve beyond it, and I can very distinctly trace a branch [the ophthalmic] of the fifth to the eye. I carefully searched to see if a second nerve were bound up in the cellular sheath with it, but could find none.

* Geoff. St. Hilaire, Cours d'Hist. Nat. des Mam. leç. 16.

* Cours d'Hist. Nat. des Mammif. 16 leç. p. 27.

† Müller's Phys. by Baly, p. 767.

The chiasma is very distinct, without a trace of a nerve proceeding from it."

Fig. 453.

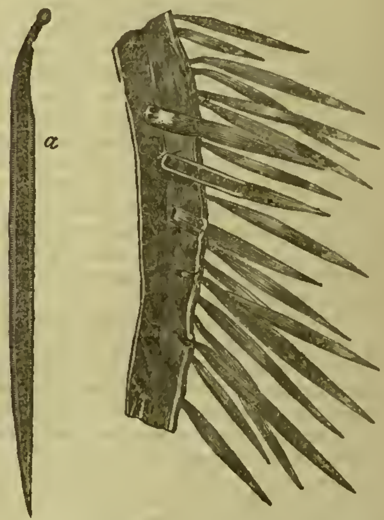
The organ of hearing in the mole is so constructed as to afford the greatest possible delicacy and acuteness of this important sense, and thus to counterbalance the deficiency in that of sight. It would indeed appear that the mass of compact bone constituting the petrous portion of the temporal, which surrounds the labyrinth in most of the Mammalia, must more or less diminish the powers of hearing, for we find it deficient in many animals, which from their habits require this sense to be in the greatest perfection. Thus, in the mole, the semicircular canals are free and visible within the cranium, without any preparation; and the parietes of the cochlea itself are almost as cellular and loose as we find in birds.

The ear of the mole possesses no concha; it is small in the shrews; and in the water-shrews *(Hydrosorex)* the external meatus is closed at the will of the animal by means of the antitragus; a provision obviously essential to its aquatic habits.

When it is considered that the sense of vision is only available on the rare occasions of the appearance of the mole on the surface, and then only for very limited objects, and that all its intimations of danger, and its only guide to the opposite sex, are by means of the sense of hearing, the necessity for this extraordinary developement of that sense at the expense of that of sight becomes obvious. And as, from the nature and situation of its food and its means of procuring it, the sense of smell is equally necessary for effecting this object, we find that the olfactory organ is also of considerable volume. The structure of the nose itself is highly curious and admirably suited to the habits of the animal. The cartilages of the nose are elongated into a tube or trunk, which extends far beyond the osseous basis, and is supported by a very delicate moveable bone, which is represented in the figure of the cranium of the mole at *fig.* 441. It is furnished with a muscular apparatus of considerable complexity (see *fig.* 446), consisting of no less than four pairs of muscles, which arise from above the ears, and passing forwards are inserted by separate tendons into the circumference of the extremity of the cartilaginous snout. This structure is of the utmost advantage to the animal in its subterranean search after worms and insects.

There is no order of Mammalia in which a greater contrast is exhibited in the external covering of the body than in the different groups of the Insectivora. The porcupine and the mouse, amongst the *Rodentia*, do not offer a more remarkable contrast in this respect than do the two families of the *Erinaceadæ* and the *Talpidæ*. The habits of the hedgehog depending for its defence upon the panoply of armour which it presents to its enemies, when rolled up in a compact ball by the muscular apparatus already described, it is furnished on all the upper and lateral parts of the body with hard sharp spines or quills. *Fig.* 454

Fig. 454.



is taken from a drawing by William Bell, engraved in the Hunterian Catalogue, vol. iii. from which also the following description is borrowed:—"On the cut edge of the skin may be seen the roots and sockets of the quills, extending to different depths from the surface, according to the period of their growth: the newly formed ones are lodged deep and terminate in a broad basis, the pulp being large and active, and the cavity containing it of corresponding size; but as the growth of the quill proceeds, the reflected integument forming the socket contracts, and gradually draws the quill nearer the surface; the pulp is at the same time progressively absorbed, and the base of the quill in consequence gradually increases in size, so that it is at last seen to be attached to the surface of the skin by a very narrow neck, below which the remains of the socket and theca are seen in the form of a small bulb." (*Fig.* 454, *a.*) "A completely formed prickle or quill cut longitudinally and magnified, shewing that it is hollow and filled with a pithy substance, which is transversely disposed, so as to divide the cavity into many sections." But the defence of the animal against attack is not the only object of this modification of the hair. I have more than once seen a hedgehog run to the edge of a precipitous descent, and without a moment's hesitation throw itself over, rolling itself up at the same instant, and on reaching the bottom run off perfectly uninjured. It is unnecessary to point out how perfectly this habit is provided for by the elasticity of the spines, dependent upon their structure, as exhibited in the figure. The under parts of the body and the limbs are covered with ordinary hair. The Tenrec and other *Erinaceadæ* resemble the hedgehog in these respects, and in some species the quills and hair are intermixed.

The mole, on the other hand, possesses hair of the softest and most flexible description. In its subterranean galleries, which are not large enough to allow it to turn round, it must often be obliged to retreat backwards; and the hair therefore is so constructed as to lie equally smooth in every direction. This has been supposed to be effected merely by its growing exactly perpendicular to the surface of the body; but it is in fact still more effectually provided for by a remarkable form of the hair itself. Each hair consists of three or four broader portions connected by intervening portions of extreme tenuity; so that there are several points in the length of each hair which present no appreciable resistance. The hair of the shrews is similarly constructed, and in each case it is to this structure that the peculiar and beautiful softness which characterizes it is owing. It is worthy of remark that the colouring matter of the hair exists only in the broader portions, the intermediate parts being wholly colourless.

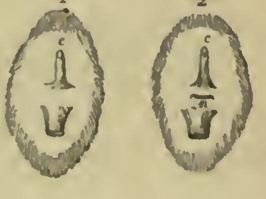
V. *Organs of reproduction.* — The reproductive organs of the Insectivora offer, in several instances, some remarkable peculiarities. The subterranean life of many of these animals renders the meeting of the sexes in their natural haunts a matter of almost fortuitous occurrence; and it is therefore necessary that the sexual desire should in the male be sufficiently powerful to force him as it were to seek and pursue the other sex through all the difficulties and disadvantages occasioned by their peculiar habits. Hence we find that in most of them the male organs are developed to an extraordinary degree; and in the mole the enlargement of the testes as the season of pairing advances is as remarkable as it is in the sparrow or in any other example of this seasonal increase of those organs. Two incompatible statements have been made respecting the testes in the mole. Cuvier asserts that they make their appearance externally during the season of propagation. Blumenbach declares that they belong to the true *testiconda*, with the hedgehog, &c. The truth is, as demonstrated with his usual ingenuity by Geoffroy St. Hilaire, that the testicles of the mole never make their appearance externally, although during the season of their greatest developement they would do so but for the peculiar construction of the parts in which the organs of generation in this animal are contained; for the abdominal cavity extends beyond the pelvis, as far as the first four coccygeal vertebræ, which in fact do not, properly speaking, in any degree constitute the tail, which is formed only of the posterior seven vertebræ, and the testes during the season are protruded so as to lie concealed under this portion of the caudal division of the spine, which forms as it were a continuation of the upper part of the pelvis. In the hedgehog the testes remain within the abdomen excepting during the spring, and even then they are but little protruded. The object of their being thus generally protected is obvious: in the hedgehog these organs, if external, would be exposed to danger from the act of rolling itself up, and in the mole and its congeners they would interfere with the act of excavating their subterranean passages. The penis in the mole possesses a remarkable peculiarity, which doubtless has reference to the condition of the female organ presently to be described. It consists in a small terminal bony appendage, covered but slightly by integument; it was considered by Daubenton as the *os penis*, but from its different situation it may be doubtful perhaps if it be in truth analogous to that part.

The male organs are in the hedgehog developed to an extraordinary degree, more especially the *vesiculæ seminales*. The testes are of an oval form, smooth, and although large in proportion to the size of the animal, are much smaller than the vesiculæ seminales; these are of enormous size, each consisting of four or five fascicles of extremely convoluted tubes, the membranous parietes of which are extremely thin and fragile. Cowper's glands and the prostatic gland are also of considerable size in this animal. The orifices of the *vasa deferentia*, *vesiculæ seminales*, prostatic gland, and Cowper's glands all open within the foramen cœcum of the urethra.

The female organs in the mole offer some peculiarities which deserve more attention than they have hitherto received.

In the first place, it appears that in this animal the urinary and genital orifices are

Fig. 455.



wholly distinct. The clitoris, (*fig.* 455, *c*,) which is of considerable length, and very much resembles the penis of the male, is pierced for the passage of the urine, and thus constitutes a true urinary penis. Beyond this is a transverse slit of a slightly crescentic form, (*fig.* 455, 2), which constitutes the opening of the vagina. There are none of those duplicatures of the integument which in other Mammalia constitute the *labia* and *nymphæ*, but the skin is smooth. But one of the most curious points in the structure of these parts is that in the virgin state this vaginal aperture does not exist, (*fig.* 455, 1,) the skin being perfectly and tightly drawn over the entrance; so that there are in this state but two openings, the urethral and the intestinal. So perfectly is this the case that it is very difficult to know a virgin female mole from the male by mere external examination. As this covering is so tense, the utility of the little bone at the extremity of the penis in the male is very obvious, and its pointed and tapering form is at once accounted for: it is clearly intended to perforate this tense covering to the vagina.

Another peculiarity in this animal is that the abdominal cavity being extended greatly beyond the pelvis, the vagina, the rectum, and the urinary passage terminate considerably further back than in other animals. The opening of the rectum is opposite to the articulation of the fourth with the fifth caudal vertebra.

The uterus is of considerable size in the mole, and its cornua much convoluted.

For Bibliography, see that of Mammalia.

(*T. Bell.*)

ANALYTICAL INDEX

TO THE

SECOND VOLUME.

END OF VOL. II.

ERRATA IN VOLUME II.

Page 153, col. 1, line 13 from bottom, *for* articulated, *read* reticulated.

157, col. 2, line 20 from bottom, *for* supra-spinata, *read* infra-spinata.

174, note, *dele* " and copied into Mr. Mackenzie's work on the eye."

344, line 40, *for* inspection, *read* impaction.

375, col. 2, note, *for* " tarsor," *read* " tensor."

376, col. 2, Bibliography, *insert* Berres.

483, col. 2, line 25 from bottom, *for* " fluid," *read* " blind."

587, col. 1, line 24 from bottom, *for* $45\frac{17}{30}$, *read* $31\frac{13}{61}$.

587, col. 1, line 22 from bottom, *for* $41\frac{1}{3}$, *read* $28\frac{4}{5}$.

587, col. 1, line 20 from bottom, *for* $54\frac{12}{61}$, *read* $32\frac{21}{61}$.

587, col. 1, line 18 from bottom, *for* $48\frac{1}{4}$, *read* $30\frac{7}{60}$.

598, col. 2, line 11 from bottom, *for* " The nerves can be traced," *read* " The nerves have not been traced."

608, col. 2, note, *for* " Prinella," *read* " Prunelle."

617, col. 1, line 32 from bottom, *for* " Enman," *read* " Erman."

849, col. 2, line 5, *for* pecuniary, *read* visceral.

In the article Heart, *for fig.* 272, in references, *read fig.* 274, *passim* and vice versâ.

MARCHANT, PRINTER, INGRAM-COURT, FENCHURCH-STREET.