TREATISES

ON

PHYSIOLOGY

AND

PHRENOLOGY.

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PHRENOLOGY:

FROM THE SEVENTH EDITION OF

THE ENCYCLOPÆDIA BRITANNICA.

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&c. &c. &c.

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CONTENTS OF VOL. II.

CHAPTER VIII.

CHAPTER IX.

CHAPTER X.

CHAPTER XI.

CHAPTER XII.

CHAPTER XIII.

CHAPTER XIV.

CHAPTER XV.

CHAPTER XVI.

CHAPTER XVII.

CHAPTER XVIII.

CHAPTER XIX.

vision made for bringing the blood to the lungs, and exposing it to the action of the air; and, lastly, the chemical changes which are produced on the blood by the action of the air in that organ. The means of fulfilling the second of these objects has already been sufficiently explained in the account we have just given of the circulation. It remains, therefore, that we consider the first and third branches of the inquiry.

SECT. I.—MECHANISM OF RESPIRATION.

(470.) The anatomical structure of the organs of respiration, namely, the lungs with its air passages, including the trachea, bronchiæ, and air cells, together with the general conical cavity of the thorax, bounded by the sternum in front, the spine behind, and the ribs on every other side, while its lower side, or basis of the cone, is closed by the diaphragm, have already been fully detailed in the treatise on ANATOMY, to which it is only necessary here to refer.

(471.) The mechanical act of respiration is divisible into two periods, that of *inspiration*, during which air is drawn into the lungs, so as to distend their vesicles, and *expiration*, during which the air which had been so received is expelled.

(472.) Inspiration is accomplished by enlarging the capacity of the thorax in all its dimensions. This is effected by the action of different sets of muscles. The principal muscle of inspiration is the diaphragm, which has an arched form, the convexity being towards the chest. Its attachments by radiating fibres arising from a central tendinous portion, and inserted into the ribs which form the lower margin of the chest, are such, that when they contract they draw down the middle tendon, and render the diaphragm more flat than it was before. Hence the space above is enlarged. The flattening of the diaphragm takes place chiefly in the fleshy lateral portions, but the middle tendon is also slightly depressed.

(473.) The second set of muscles employed in inspiration are those which elevate the ribs ; and the principal of these are the two layers of intercostal muscles. Each rib is capable of a small degree of motion on the extremity by which it is articulated with the vertebræ. This motion is chiefly an upward and a downward motion. But since the ribs, as they advance from the spine towards the sternum, bend downwards in their course, the effect of the vertical motion just described will be that of raising the sternum, and increasing its distance from the spine; enlarging, consequently, the capacity of the chest. The intercostal muscles are disposed in two layers, each passing obliquely, but with opposite inclinations, from one rib to the adjacent rib. Hence they act with the advantage of oblique muscles on the principles formerly explained.

(474.) Thus there are two ways in which the chest may be dilated ; first, by the diaphragm, and, secondly, by the muscles which elevate the ribs. In general, when the respiration is natural and unconstrained, we chiefly breathe by means of the diaphragm ; but we also employ the intercostal muscles when the respiration is quickened or impeded by any cause. If respiration should be rendered difficult several other muscles are called into play in aid of the intercostals ; namely, the great muscles situated in the back and sides, which connect the ribs to the spine and to the scapula ; and several of the muscles of the neck are also thrown into action as auxiliaries on these occasions, when the respiration becomes laborious.

(475.) The glottis is kept open, during inspiration, by the muscles of the larynx which perform that office; and when a forcible inspiration is made, the nostrils are expanded, the lower jaw depressed, and every action which can in the remotest degree concur in the effect of removing all obstruction to the passage of the air into the trachea, is exerted.

(476.) Having thus shown how the cavity of the thorax is dilated, let us next trace the effect of this expansion upon the lungs. It is obvious, that if when, by the descent of the diaphragm and elevation of the ribs, the cavity of the chest is enlarged, the lungs were to remain in their original situation, an empty space would be left between them and the sides of the chest. But no vacuum can ever take place in the living body; the air already present in the air-cells of the lungs must, by its elasticity, expand these organs; and the external air, having access to them by means of the trachea, will rush in through that tube in order to restore the equilibrium. This, then, is *inspiration.*

(477.) The expulsion of the air from the lungs constitutes *expiration.* This takes place as soon as the air which had been inspired has lost a certain portion of its oxygen, and received in return a certain quantity of carbonic acid gas and of watery vapour, by having had communication with the blood in the pulmonary capillaries. When thus contaminated it excites an uneasy sensation in the chest, and the intercostal muscles relaxing, the ribs fall into their original situation, and the relaxed diaphragm is pushed upwards by the action of the abdominal muscles. The lungs, being compressed, expel the air they had received, and this air escapes through the trachea. The movements of inspiration are in like manner prompted by an uneasy sensation consequent upon the presence of venous blood in the pulmonary system.

(478.) Thus the lungs are merely passive agents in the mechanism of respiration; for it does not appear that they have, as was at one time supposed, any inherent power of extension or contraction, if we except only that arising from the elasticity which they possess in common with all membranous textures. Hence, if an opening be made in the sides of the chest, the lung on that side immediately collapses, in consequence of the internal pressure of the air against its air-cells, which kept the lung expanded, being balanced by the external pressure of the atmosphere which has been admitted on the outer surface of the lung.

(479.) The alternations of inspiration and expiration, which together constitute one act of breathing, take place, in ordinary health, about once for every four pulsations of the heart; and as both are generally accelerated in the same proportion, the same rule usually holds good in states of disease.

(480.) The quantity of air taken into the lungs at each inspiration has been very variously estimated by different experimentalists. It differs, indeed, considerably in different persons, and in different states of the system; but from the concurrent testimony of the most accurate experimentalists, the average quantity appears to be about forty cubic inches. By a forcible expiration there may be expelled, in addition to this quantity, about a hundred and seventy inches more. But even after this effort has been made, there still remain about a hundred and twenty cubic inches in the lungs; so that, adding all these quantities together, it will appear that the lungs are capable of containing, while in their most expanded state, after ordinary inspiration, about three hundred and thirty cubic inches of air. One-eighth of the whole contents of the lungs, therefore, is changed at each respiration. If we suppose that we respire twenty times each minute, the quantity of air respired during twenty-four hours will amount to six hundred and sixty-six cubic feet.[1]

SECT. II.—CHEMICAL EFFECTS OF RESPIRATION.

(481.) Before we inquire into the changes produced on the blood by its exposure to the air in the lungs, it will be proper to notice the changes which the air undergoes by this process. The air of the atmosphere is found by chemical analysis to consist of seventy-nine per cent of nitrogen, twenty of oxygen, and one of carbonic acid.[2] When expired, the principal change which has taken place in it is the substitution of a certain quantity, which, on an average, is about seven and a half per cent, of carbonic acid gas for a nearly equal quantity of oxygen gas, and the addition of a quantity of aqueous vapour. Air which has passed through the lungs only once is incapable of supporting the combustion of a taper, which is accordingly extinguished the moment it is immersed in the air. The weight of the oxygen consumed in the air respired in the course of a day, will be found to amount to about two pounds and a quarter avoirdupois, or nearly 15,500 grains, occupying in its gaseous state a volume of 45,000 cubic inches, or a little more than 26 cubic feet. The quantity of carbonic acid expelled from the lungs is somewhat less than this; its

[1] See Bostock on *Respiration*, and also his *Physiology*, 3d edition, pages 321 and 361.

[2] The recent experiments of De Saussure tend to show that the proportional quantity of carbonic acid gas in atmospheric air is even less than this. He estimates it at only four parts by volume in a million volumes of air.

total bulk in the twenty-four hours amounting on an average only to 40,000 cubic inches, or 23·2 cubic feet. Its total weight is 18,600 grains, or 2·86 pounds avoirdupois. The weight of the quantity of carbon contained in this amount of carbonic acid is 5,208 grains, or very nearly three quarters of a pound; and that of the quantity of oxygen is 13,392 grains. Hence the quantity of oxygen which disappears from the air respired, over and above that which enters into the composition of the carbonic acid gas, is 2,108 grains, and had occupied, while in a gaseous state, 5000 cubic inches. The only way in which we account for the disappearance of this oxygen is, by supposing it to have been absorbed by the blood.

(482.) The numbers given above are, of course, to be taken as imperfect approximations to the truth, being deduced as the mean of the best authenticated observations, in which, however, there exist such great discrepancies as to render any accurate appreciations nearly hopeless. An excellent summary of the results which have been arrived at by different experimentalists, with critical remarks on their respective values, will be found in *Dr. Bostock's Elementary System of Physiology.*[1]

(483.) Much difference of opinion has prevailed with respect to the absorption or evolution of nitrogen during respiration. From the accurate experiments on this subject made by Dr. Edwards, it appears that on some occasions there is a small increase, and in others a diminution of the nitrogen of the air respired. But the limits within which we must confine ourselves in this treatise, forbid our entering into the experimental details from which this conclusion is deduced.

[1] We refer particularly to the 3d section of chap. vii. p. 336—362.

(484.) The quantity of water exhaled from the lungs in the course of a day, has been estimated by Dr. Thomson at nineteen ounces, and by Dr. Dalton at twenty-four.

(485.) It should be observed, however, that the quantity of carbonic acid thrown off from the lungs, is liable to great variation from several causes; it has been found by Dr. Prout to be greatest at noon, and least at midnight. It has also been ascertained that it is less in youth than in middle age; and that it is diminished by causes which induce fatigue or lessen the vital energies.

(486.) We have next to inquire what changes have, in the meanwhile, been effected in the blood by the action of the air to which it has been subjected in the lungs. A visible alteration in the first place, is produced in its colour, which, from being of a dark purple, nearly approaching to black, when it arrives at the air cells by the pulmonary arteries, has acquired the bright intensely scarlet hue of arterial blood when brought back to the heart by the pulmonary veins. In other respects, however, its sensible qualities do not appear to have undergone any material change. Judging from the changes produced on the air which has been in contact with it, we are warranted in the inference that it has parted with a certain quantity of carbonic acid and of water, and that it has in return acquired a certain proportion of oxygen. Since it has been found that the quantity of oxygen absorbed, is greater than that which enters into the composition of the carbonic acid evolved, it is obvious that at least the excess of oxygen is directly absorbed by the blood; and this absorption, constitutes, no doubt, an essential part of its arterialization.

(487.) It has been much disputed whether the combination which seems to be effected between the oxygen of the air and the carbon furnished by the blood, occurs during the act of respiration, and takes place in the air cells of the lungs, or whether it takes place in the course of circulation. On the first hypothesis, the chemical process would be very analogous to the simple combustion of charcoal, which may be conceived to be contained in the venous blood in a free state, exceedingly divided and ready to combine with the oxygen of the air; and imparting to that venous blood its characteristic dark colour; while arterial blood, from which the carbon had been eliminated, would exhibit the red colour natural to blood. On the second hypothesis, we must suppose that the whole of the oxygen which disappears from the air respired, is absorbed by the blood in the pulmonary capillaries, and passes on with it into the systemic circulation. The blood becoming venous in the course of the circulation, by the different processes to which it is subjected for supplying the organs with the materials required in the exercise of their respective functions, the proportion of carbon which it contains is increased, both by the abstraction of the other elements, and by the addition of nutritive materials prepared by the organs of digestion. The oxygen which had been absorbed by the blood in the lungs, now combines with the redundant carbon, and forms with it either oxide of carbon, or carbonic acid, which is exhaled during a subsequent exposure to the air in the lungs. Many facts tend strongly to confirm our belief in the latter of these hypotheses.

(488.) It appears from a multitude of experiments, as well as from observations of the phenomena which take place in asphyxia, (that is, in the suspension of the vital actions from an interruption to respiration, as in hanging or drowning, or immersion in any gas not fitted for respiration,) that if the blood be not arterialized, and if, retaining its venous character, it be circulated in that state through the arteries of the system, it will act as a poison to the organs to which it is sent, destroying both the nervous and sensorial powers, and impairing the irritability of the muscles; and that this is the cause of the rapidity with which death ensues under these circumstances. It thus appears that respiration requires to be constantly kept up in order to free the blood from the continual additions of carbon which are made to it by the various processes of assimilation and absorption. It is also a principal agent in perfecting the animalization of the chyle, which is added to the blood, and in converting it into fibrin.

SECT. III.—ANIMAL TEMPERATURE.

(489.) Since we find that the human body, as well as those of all warm-blooded animals, is constantly maintained during life at a temperature higher than that of the surrounding medium, at least in temperate climates, it becomes interesting to inquire into the sources whence this heat is evolved. The union of carbon and oxygen which takes place in consequence of respiration, is the most obvious of these sources; and suggests that the evolution of animal heat takes place in a manner somewhat analogous to the ordinary combustion of carbonaceous fuel. The circumstance of the equable heat of every part of the body, excepting the immediate surface where it is cooled by the contact of the air, and by cutaneous perspiration, would be in perfect accordance with the theory of Dr. Crawford already explained; for if the combination of oxygen with carbon take place gradually in the course of the circulation, it will follow that the evolution of heat will also take place at the same time, and in the vessels employed in the circulation. Or even if the combination took place in the lungs, if it could be shewn, as Dr. Crawford endeavoured to prove, that arterial blood has a greater capacity for caloric than venous blood, all the heat that would have been evolved in the pulmonary vessels would be absorbed by the arterial blood, and given out in the course of its circulation, during its gradual conversion into venous blood, which has a less capacity for caloric.

(490.) It would appear, however, from some recent experiments of Dulong and Despretz,[1] that only three-fourths of the whole quantity of caloric produced by the living system can be explained by the combination of oxygen with carbon in respiration. Probably, therefore, several of the other chemical changes induced on the blood by the processes of secretion and nutrition, contribute to the further evolution of caloric, and to the maintenance of the animal temperature. This evolution appears, although primarily dependent on respiration, to be in a great measure controlled by the action of the nervous powers; and to be regulated by a variety of circumstances in the condition of the other functions, especially that of the circulation, which are very imperfectly known; and the inquiry into which would lead us into a field of discussion far too extensive for the limits within which we must confine ourselves in the present treatise. We must content ourselves, therefore, with again referring to the work of Dr. Bostock for more ample information on these subjects.

[1] See *Müller's Physiology*, by Baly, p. 83.

CHAPTER IX.

SECRETION.

(491.) Seeretion is that function by which various substanees are either separated from the blood or formed from it, in order to be applied to some useful purpose in the economy. We have noticcd, in the eourse of the preceding inquiries, sevcral instances of fluids prepared from the blood, and rendered subservient to different uses in the economy. The saliva, the gastrie and panereatic juices, the bile, and the mucus lubricating the surface of the alimentary canal, are all examples of secretions subservient to digestion and assimilation.

(492.) Such being the general purpose answered by this function, we have first to examine the apparatus provided for its performanee; seeondly, the nature of the effects obtained; and, thirdly, the peeuliar powers which are coneerned in their produetion.

SECT. I.—APPARATUS FOR SECRETION.

(493.) The apparatus employed by naturc for the performance of secretion varies considerably in its structure, in different instances, according to the nature of the product which is to result from the operation; and aceording as that product is merely separated from the blood, in which it may already have existed, or is formed by the combination of certain elements and proximate principles furnished by that fluid. In the simplest cases, where that product is principally aqueous, and apparently consists of nothing more than the serous portion of the blood separated from it by mere transudation, we find no other organs requisite than those smooth membranous surfaces which we have already described under the name of the *serous membranes*. The mucous secretions proceed, in like manner, from the modified, yet still simple action of a membranous surface, of a rather more refined structure, namely, the *mucous membranes*. The more elaborate products of secretion, on the other hand, which are apparently formed by combinations of pre-existing elements, are obtained by the agency of organs of a more complicated structure, which are denominated *glands*.

SECT. II.—GLANDULAR APPARATUS.

(494.) The essential part of the structure of a gland consists in a collection of tubes, more or less convoluted, united by cellular substance into masses of a rounded form, constituting a *lobule*. Each lobule has a separate investment of membrane; and the whole aggregate of lobules is furnished with a general membranous envelope, or capsule. In every gland we meet with a complex arrangement of numerous arteries, veins, nerves, and lymphatics, provided with ramified excretory ducts, which conduct away the secreted matter that has been prepared in the substance of the gland.

(495.) The above description of a gland does not include those organs, which, although resembling the proper glands in their general appearance, perform no distinct office of secretion, and are therefore unprovided with any excretory duct.

This is the case with those bodies belonging to the absorbent system, which bear improperly the title of *lymphatic* or *conglobate glands.* The spleen, the renal capsules, the pineal gland, the thyroid gland, and the thymus, are, in like manner, improperly included in the class of glands; for we have no evidence of their secreting any fluid, and indeed know nothing of their real functions.

(496.) The catalogue of glands, strictly answering to the definition, will comprise the following organs, namely, the liver, pancreas, and kidneys; the salivary, lacrymal, and meibomian glands; the tonsils, the ceruminous glands of the ear, and the sebaceous glands of the face; the mammæ, the prostate, the testicle, Cowper's glands, the glandulæ odoriferæ, and the extensive system of mucous glands about the head and trunk. These parts, although differing widely from each other in many respects, agree in a sufficient number of particulars to allow of being classed together in one organic system, which Bichat has termed the *glandular system.*

(497.) Most of the glands are arranged in pairs, as the kidneys, testicles, salivary and lacrymal glands, while others are single, as the liver and the pancreas.

(498.) The organization of the glandular system is exceedingly complex, and cannot be unravelled without great difficulty. The tissue of which they are composed presents us with no regular arrangement of fibres, such as we see in the muscles, ligaments, nerves, or bones; but the whole structure is made up of a congeries of vessels and cells, having no very firm cohesion amongst themselves, and hence admitting very readily of being separated by slight mechanical causes. Whilst organs which have a more extensive fibrous organization possess considerable powers of resistance, a very moderate degree of violence is sufficient to tear asunder the texture of a gland. The resistance in the latter case is owing solely to the cohesion of the cellular tissue which connects their parts, and which differs in its density and strength in different glands.

(499.) There are three different ways in which the glandular tissue, or *parenchyma* of glands, as it has been generally termed, is disposed. In those glands which have been called *conglomerate*, a term which, as we have seen, has been used in contradistinction to the *conglobate*, or lymphatic glands, the organ is made up of distinct portions, connected together by a large quantity of loose cellular tissue, in the intervals of which the vessels and nerves are situated. These larger lobes are again made up of smaller lobes united in the same way. By successive divisions we obtain smaller and smaller component portions, till we arrive at last at very small bodies still visible to the naked eye, and which are called by anatomists *glandular acini.* These successive lobules are firmer in proportion as they are smaller, being surrounded and connected with the adjoining portions by shorter and denser cellular substance. The second, third, and even the fourth subdivisions of these lobes may easily be followed with the scalpel. The acini themselves are of a roundish figure and pale colour, and readily distinguishable from other parts by the absence of fibres. The microscope shows them, however, to be still farther divisible into smaller portions, between which are seen plates of cellular substance, and if we attempt to pursue these subdivisions with successively greater magnifying powers, we do not find that we can reach their limit. The above description is particularly applicable to the salivary, lacrymal, and pancreatic glands.

(500.) The second modification of glandular structure occurs in the liver and the kidneys, in which it is impossible to trace these successive divisions into lobules, after we have distinguished the primary lobes which they present. Their structure exhibits an uniform and even tissue, made up of glandular acini, closely united together into one substance. The connecting cellular substance, if any such exist, is very short and small in quantity; and hence these organs may be torn asunder with great ease, and their ruptured surfaces present the appearance of granulations.

(501.) The third description of glands applies to the prostate, to the tonsils, and in general to all the mucous glands.

(502.) On examining the course of the blood-vessels, the small arteries which enter into a gland are found to ramify in various ways through a mass of cellular texture. But it is a matter of great uncertainty what specific structure intervenes between the secreting arteries and the commencement of the excretory ducts. Two opinions have long divided anatomists on this subject. Malpighi, who was one of the first who investigated the minute anatomy of glands, asserted that the acini invariably contain a central cavity, or *follicle*, as it was termed, on the inner surface of which the arteries are distributed, while the secreted fluid is collected in the follicle, and conveyed away by the branch of the excretory duct which arises from the follicle. He considered the mucous glands of the alimentary canal, which undoubtedly present a structure of this kind, as the most simple forms of glandular structure; the larger glands being only aggregations of these simpler structures.

(503.) The theory of Ruysch, who also bestowed extraordinary care in the examination of glandular structures, is founded on the supposed continuity of the extremities of the arteries with the commencements of the excretory duct. This theory is so far opposed to that of Malpighi, that it pre-supposes all the glands to consist merely of an assemblage of vessels and of cellular substance, without any membranous cavities interposed between the arteries and excretory ducts. The opportunities of dissection which Ruysch enjoyed, and his unrivalled skill in the arts of injecting the vessels, and tracing their modes of distribution, gave great weight to his opinions, which seemed to be immediate deductions from what he saw, and had established as matters of fact. Fluids could be made by injection to pass very readily from the blood-vessels into the excretory ducts, both in the kidneys and liver. After these organs have been accurately injected, they may be resolved, by subsequent maceration, into small clusters of blood-vessels; what Malpighi had represented as hollow acini, seemed to be in reality composed of a congeries of these minute vessels. This appeal to the evidence of the senses, and the admirable preparations which supported it, brought over almost all the anatomists of that time to the opinion of Ruysch; and Boerhaave himself, who had been a zealous defender of the doctrine of Malpighi, and written in support of it, was at length induced to adopt the views of Ruysch.

(504.) This controversy was sustained for a great many years in the schools of medicine; and the opinions of anatomists continue even at the present time to be divided upon this subject. Probably both these opinions may in part be correct, as applied to different glands, though not universally true; and secretion may perhaps be in some cases performed by continuous vessels, and in others by an interposed parenchyma, of a cellular or more intricate organic apparatus.

(505.) As the structure of the secreting organs admits of great variety, it may be useful to advert to some of the terms by which these minute parts have been designated. The terms *acini*, *cotulæ*, *cryptæ*, *folliculi*, *glandulæ*, *lacunæ*, *loculi*, *utriculi*, have been almost promiscuously used; being, as Bell humorously observes, " so many names for bundles, bags, bottles, holes, and partitions." The term *acinus* has been already explained, (§ 499). *Cotulæ* are merely superficial hollows, from the surface of which the secretion is poured forth. A *crypta* is a soft body, consisting of vessels not completely surrounded with a membrane, but resolvable by boiling or maceration. *Follicles* are little bags appended to the extremity of the ducts, into which the secretion is made, and from which it is carried off by the ducts. *Lacunæ* are little sacs, opening largely into certain passages, and into which generally mucus is secreted.

(506.) The *excretory ducts*, whatever may be their exact origin, consist at first of an infinite number of capillary tubes, which, like the veins, soon unite together into more considerable tubes. These generally pursue a straight course through the glandular tissue, unite with one another, and form at last one or more large tubes. The only exception to this general proposition occurs in the excretory ducts of the testicle, which pursue a singularly tortuous course before they unite into the vas deferens on each side.

(507.) There are three varieties in the mode of termination, with regard to the excretory ducts of glands. In the first case, the ducts unite into several distinct tubes, which open separately, and without any previous communication. Sometimes these separate apertures are met with in a more or less distinct prominence, as in the breasts, the prostate, and the sublingual glands. At other times, the orifices are found in a depression, or kind of cul-de-sac, as in the tonsils, and in the foramen cœcum of the tongue. In the second case, which includes the greater number of glands, their fluids are poured out by a single tube, having a simple orifice. In the third case, some glands deposit the produce of their secretion in a reservoir, where it is retained, in order to be expelled at particular times: as is exemplified in the kidneys, liver, and testicles. In this case there must be two excretory tubes; one to convey the secretion from the gland to the reservoir, and the other to transmit it to its final destination. The size of the excretory ducts will, of course, be regulated very much by their number: when several are produced from one gland, they are very small, and sometimes scarcely perceptible. Those which are single are longer with reference to the size of the gland, and generally pass for some distance, after quitting the gland. In the pancreas, however, this is not the case, the common duct being concealed in the substance of the gland.

(508.) Whatever the arrangement of the excretory ducts may be, they all pour their fluids, either on the surface of the body, or on the surface of some of the mucous membranes. In no instance whatever do they terminate on serous or synovial surfaces, or in the common cellular membrane. All the excretory ducts are themselves, indeed, provided with an internal mucous membrane, which is a continuation of the cutaneous, or mucous surface on which they terminate. In addition to this they are furnished with an exterior coat, formed of a dense and compact membranous and fibrous substance. Every excretory duct may therefore be considered as made up of these two coats, namely the external one, which is membranous, and the internal one, which is mucous.

(509.) Amongst the latest theories relating to the structure of the organs of secretion, is that adopted by Müller,[1] who conceives that the glandular organization consists essentially of a modification of the excretory duct, the remote extremity of which, or that most distant from the discharging orifice, is closed; and the particles of which exhibit a fine net-work, or plexus of minute blood-vessels, whence the secretion is in the first place derived, and afterwards conveyed away by the duct, into the cavity of which it is poured. The duct itself may be variously divided and subdivided; and its trunk and ramifications may be variously contorted and convoluted in different cases, without, however, constituting any material difference in its essential structure.

SECT. III.—ARRANGEMENT AND PROPERTIES OF THE SECRETIONS.

(510.) The classification of the various secretions which are met with in the system has been attempted by different physiologists, but great difficulty has presented itself in fixing on a principle susceptible of being practically applied to substances of such different chemical and mechanical properties, as are those which are to be the subjects of this arrangement. Haller,[2] adopting for his basis their chemical qualities, distributed them under the four classes of aqueous, mucous, gelatinous, and oily. Fourcroy arranged them under eight heads; namely, the hydrogenated, the oxygenated, the carbonated, the azotated, the acid, the saline, the phosphated, and the mixed.[3] Richerand adopts the six classes of lacteous, aqueous, salivary, mucous, adipose, and serous;[4]

[1] *De Glandularum Secernentium Structura*, &c. Lipsiæ, 1830.
[2] *Elementa Physiologiæ*, v. *b.* 2.
[3] *Système des Connaiss. Chym.* ix. 159. [4] *Physiologie*, § 88, p. 235.

and Dr. Young those of aqueous, urinary, milky, albuminous, mucous, unctuous, and sebaceous.[1]

(511.) Dr. Bostock[2] distributes the secretions under the eight heads of the aqueous, the albuminous, the mucous, the gelatinous, the fibrinous, the oleaginous, the resinous, and the saline; an arrangement which, in a chemical point of view, is the clearest and most natural that has yet been devised. We shall briefly notice these several classes in the order above stated.

1. *The Aqueous Secretions.*

(512.) The aqueous secretions are those which consist almost entirely of water, and of which the properties depend principally on its watery part; any other ingredient it may contain being in too small a quantity to give it any specific characters. The two secretions which are referable to this class are the cutaneous perspiration, and the exhalation from the lungs.

(513.) With regard to the fluid of perspiration, it seems doubtful whether it contains any ingredients that are constantly present in it, or that are essential to its nature. It appears to differ, indeed, considerably in different individuals; and varies even in the same individual, according to the state of the system. Its analysis was attempted by Berthollet, and afterwards by Fourcroy; but the most complete examination into its properties is that of Thénard, who considers it to be essentially acid, and that acid to be the acetic. He found in it, also, an appreciable quantity of the muriates of soda and of potass, with traces of the earthy phosphates and of oxide of iron, together with a

[1] *Med. Lit.* p. 109. [2] *Physiology*, p. 480.

very minute quantity of animal matter. Berzelius, on the other hand, who has examined this fluid still more recently, finds the free acid to be the lactic, accompanied with the lactate of soda. An elaborate analysis of the fluid of perspiration in a person labouring under disease, has also been made by Dr. Bostock.[1] The aqueous exhalations from the lungs appears to be so perfectly similar to that from the skin, as not to require further notice.

2. *The Albuminous Secretions.*

(514.) The albuminous class of secretions are numerous, and comprehend both solid and fluid substances. We have already seen that all membranous and fibrous textures, but especially the latter, are composed principally of a material corresponding in its chemical properties to coagulated albumen, (see § 165). But there are many fluid secretions which contain large proportions of this ingredient in an uncoagulated, or liquid state; such as the secretion which exudes from serous membranes, and also occupies the interstices of the cellular texture, and which has been termed the *liquid of surfaces,* (see § 135). This fluid also contains, besides coagulable albumen, an animal matter similar to that which is found in the serosity of the blood, and a small quantity of the usual saline matters which enter into the composition of almost all animal products.

3. *Mucous Secretions.*

(515.) The mucous secretions are characterised by the presence of a substance which does not pre-exist in the blood, but which is prepared by a proper secretory or glan-

[1] *Medico-Chirurgical Transactions,* xiv. 424.

dular action. The properties of this substance, or *mucus*, have been already noticed, (§ 301). To the head of the mucous secretions, Dr. Bostock is inclined to refer also the saliva, the gastric and pancreatic juices, the tears, and the semen.

4. *The Gelatinous Secretions.*

(516.) The gelatinous secretions derive their essential character from the predominance of gelatin in their composition. This substance is found in great abundance in most of the solids, and particularly in the membranous structures. It is strictly a product of secretion; for it is not met with in the blood, and must therefore be formed by some chemical change in the elements of the blood, from which the materials for its prĕparation are derived. There is reason to believe, from the discovery of Mr. Hatchett of the possibility of converting albumen into gelatin by digestion in diluted nitric acid, during which the albumen combines with an additional quantity of oxygen, that some change analogous to this is effected in the living body during the process of its secretion. The characteristic properties of gelatin have already been noticed, (§ 279.)

5. *The Fibrinous Secretions.*

(517.) The fibrinous secretions compose the fifth class, and are so named from their correspondence in chemical properties to the fibrin of the blood, which fibrin is probably the source from whence these secretions derive this ingredient. They constitute the organic products most completely animalized in their chemical constitution; and they at the same time retain, in their physical properties, the peculiar cohesive tendency and fibrous character of the substance from which they are produced. The muscular fibre is the principal, if not the only substance which comes under this head.

6. *The Oleaginous Secretions.*

(518.) The oleaginous secretions derive their essential character from the presence of an oily ingredient. They compose a numerous and varied class, comprehending those in which the oil forms the greatest part of the substance, and those in which it is more or less mixed with a large proportion of other animal principles. The fat is the principal secretion included in the first division ; a substance which, from its being extensively deposited in various parts of the body, must evidently be formed by some peculiar action of the capillary system of vessels. As it consists almost wholly of hydrogen and carbon, we must conclude that its formation is effected by the exclusion of nitrogen and oxygen from the proximate elements of the blood, and the consequent intimate combinations of their carbon and hydrogen. It is well known that the formation of fat, by whatever chemical operation it may be effected, often proceeds with great rapidity, whenever circumstances favour its production. The marrow, as was formerly observed, belongs also to this class of secretions. Dr. Bostock is disposed to refer to the same head the substance termed *cholesterine*, which forms the basis of biliary calculi.

(519.) Milk is a secretion owing its principal characters to the oil which it contains, and which is combined with albumen, so as to form a kind of natural emulsion. When collected in a separate mass, it forms the well-known substance termed *butter*. The oily particles are, however, in the original state of milk, merely diffused by mechanical mixture throughout the watery fluid, as is evident from the ap pearance of milk under the microscope, when it exhibits a multitude of extremely minute globules, swimming in a transparent liquor. The size of these globules has been variously estimated by different observers, and indeed appears to be by no means uniform, varying in different instances from the 10,000th to the 5000th of an inch in diameter. These oily globules have a tendency to adhere together when the milk is allowed to rest, and in the course of a few hours collect at the surface in the form of cream, and by further coalescence they compose *butter*. The albumen may be obtained from the remaining fluid by the ordinary means of coagulation, and constitutes curd, which, as is well known, is the basis of *cheese*. The clarified liquor which remains, yields, by evaporation, a saccharine substance capable of being crystallized, and which is known under the name of *sugar of milk*. It differs from common sugar by being less soluble in water, and by its total insolubility in alcohol. Milk contains, besides these ingredients, several saline substances, as the muriate and sulphate of potass, the phosphates of lime and of iron, and also a peculiar animal matter, which yields a precipitate with infusion of galls. Milk is found to differ from the blood, and from most of the animal fluids, by the base of its salts being potass instead of soda. A peculiar acid, called the *lactic*, is formed by the fermentation of milk, and even alcohol may be obtained during this process. By the action of nitric acid on the lactic acid, a new acid is produced, termed the *saccholactic* or *mucic acid*, which unites readily with alkaline or earthy bases, and forms a peculiar class of salts.

(520.) The substance of the brain bears a considerable analogy to the oleaginous secretions, more especially to that of milk; for it consists of albumen intimately combined with a peculiar oily ingredient. Rather more than one-fourth of its solid substanee eonsists, aeeording to Vauquelin,[1] of a fatty substanee, and nearly one-third of albumen; the remainder being eomposed of osmazome, phosphorus, acids, salts, and sulphur.

7. *The Resinous Secretions.*

(521.) The resinous seeretions, whieh eompose the seventh elass, derive their speeifie eharaeters from an ingredient which is soluble in aleohol, and is analogous to resin. Of these the most remarkable is the substanee whieh eonstitutes the basis, or speeifie ingredient, of bile. (See § 366.)

(522.) In eonnexion with the proeess of seeretion whieh takes plaee in the liver, we have here to notiee the remarkable peeuliarity whieh oecurs in the mode in whieh the blood is eireulated through that organ. The liver is supplied, like the other organs, with arterial blood, by the hepatie arteries, which are branches from the aorta. But it likewise reeeives a still larger quantity of venous blood, whieh is distributed through its substanee by a separate set of vessels derived from the venous system. The veins whieh eolleet the blood that has eireulated in the usual manner through the abdominal viscera unite together into a large trunk, termed the *vena portæ;* and this vein, on entering the liver, ramifies like an artery, and ultimately terminates in the branehes of the hepatie veins, whieh transmit the blood in the ordinary eourse of eireulation to the venæ eavæ.

(523.) This complex arrangement of the vessels which eompose the hepatie system has lately been unravelled with singular felicity by Mr. Kiernan, who in a paper eontained in the *Philosophical Transactions*, gives an aeeount of his

[1] *Annales de Chimie*, lxxxi. p. 37.

valuable discoveries, of which we shall present the following abstract. The hepatic veins, together with the lobules which surround them, resemble in their arrangement the branches and leaves of a tree, the substance of the lobules being disposed around the minute branches of the veins like the parenchyma of a leaf around its fibres. The hepatic veins may be divided into two classes, namely, those contained in the lobules, and those contained in canals formed by the lobules. The first class is composed of interlobular branches, one of which occupies the centre of each lobule, and receives the blood from a plexus formed in the lobule by the portal vein; and the second class of hepatic veins is composed of all those vessels contained in canals formed by the lobules, and including numerous small branches, as well as the large trunks terminating in the inferior cava. The external surface of every lobule is covered by an expansion of Glisson's capsule, by which it is connected to, as well as separated from, the contiguous lobules, and in which branches of the hepatic duct, portal veins, and hepatic artery, ramify. The ultimate branches of the hepatic artery terminate in the branches of the portal vein, where the blood they respectively contain is mixed together, and from which mixed blood the bile is secreted by the lobules, and conveyed away by the hepatic ducts which accompany the portal veins in their principal ramifications. The remaining blood is returned to the heart by the hepatic veins, the beginnings of which occupy the centre of each lobule, and when collected into trunks, pour their contents into the inferior cava. Hence the blood which has circulated through the liver, and has thereby lost its arterial character, is, in common with that which is returning from the other abdominal viscera, poured into the vena portæ, and contributes its share in furnishing materials for the biliary secretion.

(524.) The general conclusion which Mr. Kiernan draws from his anatomical researches is, that the hepatic artery is destined solely for the nutrition of the liver, and has no direct connexions, except with the branches of the vena portæ, after its own blood has become venalized.

(525.) Urea is another substance of a resinous nature, which may be ranked among the secretions, and which constitutes the peculiar or specific ingredient in urine. It is remarkable for containing a very large proportion of nitrogen, which is by this channel discharged from the system. This substance has been found in the blood of animals from whom the kidneys had been removed.

(526.) The peculiar proximate animal principle, termed by Thénard *osmazome*, is referred by Dr. Bostock to the class of resinous secretions. It was procured originally from the muscular fibre, of which it forms one of the component parts; and it appears to be the ingredient in which the peculiar flavour and odour of the flesh of animals principally depends. It is found, however, in most of the component parts of the body, as well solids as fluids. The *cerumen*, or ear-wax, appears also from the analysis of Vauquelin, to have a relation to the resinous secretions.

8. *The Saline Secretions.*

(527.) This class comprehends all those fluids in which saline ingredients predominate; they are very numerous, are dispersed over every part of the system, and are more or less mixed with its constituents. They consist of acids, alkalies, and neutral and earthy salts. The following are the acids entering into the composition of animal substances, and which are, for the most part, united with alkaline or earthy bases; namely, the phosphoric, muriatic, sulphuric, fluoric, lithic, lactic, benzoic, carbonic, and oxalic acids; and perhaps also the rosacic and the amniotic. Soda, potass, and ammonia, are found in almost all animal fluids; but only the first of these is met with in an uncombined state. Of the earths, lime is by far the most abundant; magnesia is found in small quantity, and also silex.

(428.) With reference to their saline qualities, Dr. Bostock proposes a division of the secretions into four classes. 1. Those which are nearly without any admixture of salts. 2. Those which possess a definite quantity of salts, and these salts different from those which exist in the blood. 3. Those containing salts similar both in their nature and quantity to those of the blood. And, 4. Such as contain salts different from those in the blood, and which are also variable in quantity. The fat, the saliva, the liquor of surfaces, and the urine, may be given as examples of each of these divisions.

SECT. IV.—THEORY OF SECRETION.

(529.) The nature of the powers and processes by which the products of secretion are prepared, is a subject involved in the greatest obscurity. There is scarcely any question in physiology, indeed, the investigation of which presents greater difficulties. At the very outset of the inquiry we are embarrassed by the very imperfect state in which the science of organized chemistry still remains; and it follows as a necessary consequence, that the precise nature of the chemical changes effected during secretion cannot be properly understood. That the operations themselves are of a chemical nature, must be inferred from their results, consisting of substanees which differ in most instances very considerably from the eonstituents of the blood, whenee their elements are obtained. The blood is evidently the great reservoir of nutriment, and the fountain whence all the materials of the secretions are derived. In a few instanees, as we have seen, the proeess of secretion appears to eonsist simply of the separation of some of the proximate principles of the blood. The operation is, in that ease, more of a meehanieal than of a ehemieal nature, and is analogous to mere transudation or filtration, subjeet, however, to a eertain power of seleetion exereised by the seereting organ. In the greater number of instanecs, however, the produet of secretion appears to be a new formation, differing entirely from any of the proximate prineiples eontained in the blood, and resulting therefore from a new eombination of its elements.

(530.) Seareely any light has been thrown on this mysterious subjeet by the anatomical investigation of the organs of seeretion. Their intimate strueture is generally so minute and eomplicated, as to elude the severest serutiny of the anatomist, even when assisted by the best optieal instruments. What inereases the diffieulty of finding any elue to the labyrinth, is, that we often see parts having apparently very different struetures giving rise to seeretions whieh are nearly identieal in their qualities ; and eonversely, we see substanees having very different properties produeed by organs very closely resembling each other in their strueture.

(531.) Sometimes we find no distinct seeretory apparatus, the whole proeess appearing to be eonducted in the eapillary vessels, out of the sides of whieh the produet seems to transude. In other instanees, the seereted fluid exudes from the smooth surface of a membrane, as is the case with the serous secretions in all the closed cavities of the body, such as those of the peritoneum, pleura, pericardium, and pia mater. The matter of perspiration finds its way through the skin and cuticle without any visible ducts or even pores, appearing simply to transude through the bibulous substance of the latter.

(532.) In other cases we find the secreting membrane furnished with minute processes, or *villi*, from the extended surface of which the secretion is produced. At other times, there are *follicles*, or *crypts*, as they are called, into which the secreted fluid is poured, and where it is collected previously to its discharge by its appropriate channels. These minute cavities are occasionally grouped together, and covered with a denser investing membrane common to the whole assemblage, constituting the masses which are called *glands*. But no practical advantage has arisen from the technical or anatomical classification of glands, neither has any information of value been gathered from the examination of the mode in which the blood-vessels are distributed in those organs; although this mode of distribution is apparently very different in different cases, each seeming to be intended for the application of some definite but unknown principle of action. Being wholly in the dark with regard to the specific objects intended to be answered, we can form no rational conjecture as to the designs of nature in the contrivances she has adopted. We see, in some instances, the smaller arteries divide suddenly, as soon as they have reached the gland, into very numerous minuter branches, like the fibres of a hair pencil. This has been called the *pencillated structure*. The arrangement in other cases is somewhat different, though similar in its principle; the minuter branches spreading out from their origin, like rays from a centre, and forming a *stellated structure.* Sometimes we observe the arteries of the secreting organ much twisted and contracted in their course, and collected into spiral coils, before they terminate. All the varieties of secreting organs, as Mr. Mayo observes, appear to be only contrivances for conveniently packing a large extent of vascular surface into a small compass. So intricate, indeed, are those complex arrangements, that it is impossible to attempt to unravel them with any prospect of success. In a word, nothing hitherto known relative to the structure of glands has explained the mode in which they act, or has thrown any light upon the nature of the substances they produce.

(533.) In this, as in other subjects, where facts are wanting for its elucidation, we find numberless hypotheses proposed in their stead. Secretion was formerly pronounced to be a species of fermentation, by those who could attach no definite idea to the term they employed. Others sought to explain secretion by various mechanical hypotheses, supposing it to be the result of a mere organic filtration of particles already existing in the blood; they racked their imaginations for the invention of forms of apertures and channels capable of admitting particles having corresponding figures, and of refusing a passage to the rest. Leibnitz compared the glands to filters, of which the pores were originally impregnated with a particular fluid, which fluid would therefore be allowed to pass, to the exclusion of all other fluids, in the same manner as a paper impregnated with oil prevents the passage of water, but allows oil to be transmitted. This unchemical theory proceeded on the hypothesis that all the secreted matters pre-exist ready formed in the blood, and require only to be separated by the glands; a supposition of which the later improvements in animal chemistry have sufficiently exposed the falsehood.

(534.) But even admitting the operation of the secretory organs to be wholly of a chemical nature, we are still completely in the dark as to the means which nature employs in the hidden laboratories of organization; nor do they appear in any way reconcileable to the ordinary laws of chemical affinities to which inorganic substances are obedient. The means employed are superior to mere chemical agency, in the same degree as the operations of chemical affinities transcend those of mechanism. All that we can conceive to be the office of the different series of vessels, which, by ramifying into smaller and smaller tubes, have the effect of subdividing the blood, as by a strainer, to certain degrees of tenuity, is that merely of preparing it for the changes it is to undergo in that stage of the process in which the essential conversion consists. Farther than this we cannot venture to speculate, knowing, as we do, so imperfectly either the changes produced, or the means by which these changes can be effected; unless, indeed, we endeavour to call to our assistance the power of galvanism, which has been, in modern times, proved to be so important and powerful an agent in effecting changes of chemical composition. But the analogy is yet too vague to serve as the basis of any solid theory.

(535.) There is no doubt that in many cases the process of secretion is considerably influenced by the condition of the nervous powers. Thus the section of the par vagum is invariably followed by the diminution or total suppression of the gastric juice, and by the increase of the secretion of bronchial mucus. Under these circumstances, the secretions of the stomach are restored by directing a stream of galvanic electricity through the nerves that have been divided; a fact which is explicable only in one of two ways, namely, either by supposing that the galvanic influence is the same as the influence derived from the nerves, or that galvanism excites a fresh exertion of the nervous influence, in the portion of the nerve on which its action is directed.

(536.) On the whole, as it appears impossible to refer the phenomena of secretion to any of the other known laws of matter, whether chemical or mechanical, it becomes us to acknowledge our ignorance of the real causes that produce them, and to ascribe them to the agency of those powers to which we have given the name of the *organic affinities;* by which term, however, we are far from wishing to imply that these affinities essentially differ in their kind from the ordinary chemical affinities which regulate the combinations of the same elements in unorganized bodies; but only that their operation is modified by the peculiarity of the circumstances in which they are placed. One of the principal causes of this peculiarity appears to be the influence of the *nervous power;* a power carefully to be distinguished from the sensorial powers, hereafter to be considered, and wholly of a physical character, exercised by the nervous system, and controlling the actions of the blood-vessels, and more especially of the capillaries, and also those chemical changes which produce the evolution of animal heat, regulating in a particular manner the processes of secretion, and in some instances producing the contractions of the muscles in a way directed to some beneficial purpose, and in cases where the interference of the mind does not take place. But of this latter exercise of the nervous power we shall have to speak more at large when we come to treat of the involuntary motions.

CHAPTER X.

ABSORPTION.

(537.) The objects of the function of absorption are, first, the removal of those materials which have become unserviceable and noxious from the situations where their presence is injurious; and, secondly, their transmission into the general mass of circulating fluids. The lymphatic vessels are appropriated to this office, and form, with the lacteals, which perform a similar service with respect to the chyle, one extensive system of vessels denominated the *absorbents*.

SECT. I.—STRUCTURE OF THE ABSORBENT SYSTEM.

(538.) The absorbent system, then, is understood to comprehend two sets of vessels, distinguished only by a certain difference in the office which they perform, but agreeing in their structure and general functions. The first are the *lacteals*, which, as we have seen, are appropriated to the conveyance of the chyle, or nutritious fluid prepared in the intestines, into the general reservoir of nutriment, the sanguiferous system. The second are the *lymphatics*, which perform a similar office with regard to the materials of the body itself, that have become either useless or noxious, or with respect to foreign substances applied to the external surface, or introdueed into any part of the body. The same general description, as to strueture, will apply to both these systems of vessels.

(539.) Absorbent vessels are met with in almost every part of the body. They may be regarded as analogous, or even supplementary in their offiee, to the veins; and aceordingly, their strueture and mode of distribution are very similar to that portion of the sanguiferous system. The absorbents arise from the various surfaees of the body, external as well as internal, by very minute branehes; but whether these branehes eommenee by open orifiees, or imbibe the fluids they reeeive through the medium of their eoats, we have hitherto no eertain knowledge. The lesser branehes of the lymphaties, like those of the veins, join together to form larger branehes; while these again sueeessively unite into larger and larger trunks, till they eonduet their eontents into the veins, into whieh they open. They eommunieate with one another freely in their eourse; and these eonnexions are frequently so numerous and intrieate, as to form an extensive net-work, or plexus of lymphatie vessels. They are furnished with numerous valves, whieh, like those of the veins, are of a semilunar or parabolie form, disposed in pairs, and plaeed so as to prevent any retrograde motion of the contents of the vessels.

(540.) Like the veins, the absorbents have thin and transparent coats, which are possessed of eonsiderable strength, so as to admit of being distended mueh beyond their natural size without being ruptured, by injeeted fluids urged into them with eonsiderable force. When they are thus enlarged by injeetion, they resemble a string of beads; an appearanee arising from the numerous valves they eontain, and which occur at short, but generally unequal intervals.

(541.) The absorbent vessels are formed of two coats, which in the principal trunks are very distinct from each other. The external coat is the one which constitutes the chief bulk of the vessel, and gives it its general form. It is of a membranous structure, and is connected with the surrounding parts by a loose tissue of cellular substance. It exhibits, where it joins the inner coat, more or less of a fibrous structure; and some anatomists have pretended even to have perceived traces of muscular fibres at this part. The interior membrane which lines the former, is more thin and delicate; and it is by duplicatures of this membrane that the valves are formed. These valves are remarkable for their strength, not being ruptured without the greatest difficulty.

(542.) The continuity of the course of the absorbents is interrupted in a variety of places, by small rounded bodies, which have been called *lymphatic* or *conglobate* glands, and which are situated on the track both of the lacteals and lymphatics. They seem to have a similar relation to the absorbents which the ganglia have to the nerves; and they have, on that account, been sometimes called the *lymphatic ganglia*. They are of various sizes; the smaller being placed near the origin, and the larger on the more considerable trunks of these vessels. Those of greatest magnitude are situated at the root of the mesentery, in the course of the lacteals, and are denominated the *mesenteric glands*. These glands are sometimes detached, and sometimes in groups or clusters, and commonly of an oblong rounded shape, and somewhat flattened, bearing some general resemblance to an almond. Their colour is a whitish red, of more or less intensity, according as they are situated more externally. Those of the mesentery are nearly white; those of the spleen brown; and those belonging to the lungs are of a very dark, or almost black hue. Each gland is enveloped in a thin, fibrous, and very vascular membrane, surrounded with dense cellular tissue, which sends down processes into the substance of the gland, dividing it into numerous compartments.

(543.) It would appear from the extensive researches of Mascagni, that every absorbent vessel, during its course, passes through one or more of these glands. Previous to their penetrating into the gland, each absorbent trunk branches out suddenly into numerous subdivisions, distinguished by the name of *vasa inferentia*. These vessels are distributed on the surface of the gland in a radiating form, so as to surround it with a kind of net-work. After they have entered the gland, their course becomes extremely difficult to unravel, from their numerous and minute ramifications, their tortuous course, and their frequent communications. It would appear, however, that while some acquire and retain an extreme degree of tenuity, others become dilated, and form cells, somewhat resembling the erectile tissue formerly described. That portion of the vessels which is destined again to collect the fluid, and conduct it forwards on its course, appears to have a similar structure, presenting a congeries of minute ramifications, and of dilatations or cells.

(544.) By the successive reunion of these branches, they are all collected into a certain number of trunks which emerge from the gland, under the name of the *vasa efferentia*. The total capacity of the vasa efferentia is, in general, less than that of the vasa inferentia. Large clusters of lymphatic glands exist in the neck, the groin, the axilla, as well as in the course of the greater trunks, not far from their termination in the thoracic duct.

(545.) The great trunks of the lymphatics occupy two principal situations; the one near the surface, and the other more deeply seated; and for the most part they follow the course of the veins. The main branches are finally reduced to three or four great trunks, which terminate for the most part in the thoracic duct. This is a vessel of considerable size, passing upwards close to the spine, in a somewhat tortuous course, to about half an inch above the trunk of the left subclavian vein. It then bends downwards, and opens into that vein, nearly at its junction with the jugular vein. Another similar, but shorter trunk, is found on the opposite side, which pours its contents into the right subclavian vein.

(546.) The nature of the lymph, or fluid contained in the lymphatic vessels, is but imperfectly known, in consequence of the difficulty of collecting it in sufficient quantity for examination. When viewed under the microscope it is seen to contain a number of colourless globules, much smaller and less numerous than the red particles of the blood.[1] Mr. Brande separated a small quantity of albumen from it by the application of voltaic electricity: he found that it also contained some muriate of soda. Berzelius states that the lactates are likewise present in it, derived, as he supposes, from the decomposed substance of different parts of the body, which is taken up by the absorbents. Reuss, Emmert, and Lassaigne obtained fibrin from the lymph of the horse, and Nasse and Müller[2] obtained some also from human lymph. When removed from the body, this fluid fibrin coagulates in less than ten minutes. Besides the above

[1] *Müller's Elements of Physiology*, by Baly, p. 258.
[2] Ibid. p. 259.

ingredients, Tiedemann and Gmelin state that the lymph contains salivary matter, osmazome, carbonates, sulphates, muriates, and acetates of soda and potass, with phosphate of potass.

SECT. II.—FUNCTION OF THE ABSORBENTS.

(547.) Whilst the office of the lacteals is confined to the absorption of a particular kind of fluid, namely, the chyle, the power of the lymphatics extends to the removal of every species of matter which enters into the composition of the body, as occasion may require, as also various extraneous substances that may happen to be placed in contact with their mouths. Whether the lymphatics have the power of taking up solid materials of the body without their being previously liquified, is a point which is yet far from being determined. We are certain that the hardest and densest structures, such as the bones, are liable to absorption, in various instances, not only during the natural processes of their formation and growth, but also on occasions when they are subjected to extraneous pressure. We find that the bones are modelled by the pressure even of soft living parts, during their natural growth, or morbid enlargement. The rapid disappearance of the red tinge which the use of madder in the food had communicated to the bones, when that food is discontinued, has been supposed to warrant the conclusion that the particles of bones are at all times undergoing a quick periodical renovation. But it appears from more recent inquiries, that this inference has been too hastily drawn: the change of colour being the result of the disappearance of the colouring particles of the madder only, without its being at all necessary to suppose that the earthy particles of the bone are themselves changed, or successively absorbed and deposited along with the madder.[1]

(548.) The nature of the process by which the particles to be absorbed are prepared for being taken up by the lymphatics; the mode in which they are conveyed to the orifices of these vessels, if indeed they take their rise like the lacteals, by open orifices; and the power by which they find their way into these vessels, and are conveyed onwards to their termination in the thoracic duct; are all subjects involved in the greatest obscurity. Capillary attraction is the only power to which the rise of the lymph in the lymphatic vessels appears to bear any near resemblance; but the analogy is far too vague and remote to be of much assistance to us in the solution of the difficulty. How far the powers recently discovered, and which have been termed *endosmose* and *exosmose*, whereby membranous substances allow the transmission in a certain direction, of particular fluids only, to the exclusion of others, are concerned in the phenomena, remains a subject for future investigation. It seems likely, however, to throw some light on the processes both of secretion and absorption; and perhaps may furnish an explanation of the selection evinced by the lymphatics in absorbing certain materials in preference to others. Absorption takes place with great facility from the mucous surfaces, and also from those formed by ulceration. It also takes place from the surface of serous membranes, though with less activity. From the external surface of the skin, absorption takes place with great difficulty, and only under particular circumstances, as when substances are forcibly

[1] See a paper on this subject by Mr. Gibson, in the *Memoirs of the Literary and Philosophical Society of Manchester*. Second series, i. 146.

pressed through the cuticle. Considerable absorption often occurs from the interior of the pulmonary air-cells. Absorption from the surface of the body is diminished, or even suspended, by greatly diminishing the pressure of the atmosphere on the part, as by the application of a cupping-glass.

SECT. III.—VENOUS ABSORPTION.

(549.) Soon after the discovery of the lymphatic absorbents, a keen controversy arose as to whether absorption was performed exclusively by these vessels: for it was contended by many that the veins assisted in this process, and occasionally acted as absorbing vessels. The arguments and reasonings of Hunter and Monro, founded on numerous experiments, appeared to have completely decided the question, and established the exclusive agency of the lymphatics in the performance of this function. Of late years, however, the ancient opinion has been revived by Magendie and others, who seem to have satisfactorily proved that absorption is occasionally carried on by the veins themselves; and that many of the lesser lymphatic vessels terminate in the small veins, instead of proceeding to the thoracic duct. It has been ascertained, for instance, that where the great lymphatic trunks are tied in animals, substances injected into the stomach quickly find their way into the general mass of circulating blood, and may be detected in the urine. Poison introduced into a portion of intestine, completely isolated from the rest of the body, with the exception only of the artery and the vein, produces its effect upon the system nearly in the same time as if the natural connexions had been preserved. The same result takes place when a limb is separated from the body, by dividing every part excepting the artery and the vein, and the poison is introduced under the skin. It proves fatal in the usual time, although the only medium through which its influence can be supposed to be transmitted is the circulating blood, which must therefore, it is concluded, have received the poison by venous absorption.

(550.) The subject of venous absorption, and of the connexion between the lymphatic and sanguiferous systems, has of late years much occupied the attention of physiologists. Great labour has been bestowed on its investigation by Fohmann, Lauth, and Panizza, on the continent ; and recently in this country by Dr. Hodgkin, who was appointed, with others, to form a committee for conducting this inquiry, by the British Association for the advancement of science. A short provisional report by this gentleman is published in the report of the sixth meeting of that association, in vol. v. p. 289, to which we must refer our readers, as containing the latest information on this important branch of physiology. Many facts render it exceedingly probable that the contents, both of the lacteals and of the lymphatics, are intermixed with that of the veins in the lymphatic glands.

SECT. IV.—EFFECTS OF ABSORPTION.

(551.) The absorbents have a powerful influence in modifying the fluid secretions, as well as the solid materials of the body. Their agency in assisting the arteries and capillaries which effect the growth and nutrition of the body is beautifully exemplified in the processes of ossification and of dentition, where the changes can more easily be followed than in the progressive modifications of softer organs. All these facts lead to the conclusion that the absorbent vessels possess very extensive powers in modelling the organization of the body in all its parts. In the progress of life, various changes are effected in the size and form of different parts, either in the natural course, or from the effects of disease. We see various organs diminish in size, sometimes with great rapidity, from the general absorption of their substance, or, as it has been termed, from *interstitial absorption;* and in other instances from causes external to the organ affected, such as pressure or ulceration; in which cases the process is denominated *progressive absorption.* In some structures, especially those which are but scantily furnished with vessels, the renewal of particles is much slower than in more vascular parts; but even these are in a certain degree subject to a constant absorption and renewal of their particles.

SECT. V.—FUNCTION OF THE LYMPHATIC GLANDS.

(552.) Of the offices performed by the lymphatic glands, which are so numerously interspersed in the course of the vessels, we are still in profound ignorance; an ignorance which is little to be wondered at, when it is considered that we are but imperfectly acquainted with their structure, and the course which the branches of the absorbents take in the interior of those bodies, and that we are also very much in the dark with regard to the nature of glandular action, and of the changes which it induces on the fluids subjected to its influence. These glands may either be proper secreting organs, intended to prepare a peculiar substance, which is to be mixed with the chyle and lymph, in order to assimilate them more and more to the nature of the blood with which they are to be united; or they may, by their tortuous passages, offer a mechanical obstruction to the progress of these fluids, and thus occasion in them spontaneous changes in the arrangement of their constituent parts. This latter view of the uses of the glands was taken by Mascagni, and he endeavoured to confirm it by pointing out differences in the nature of the lymph before and after it had passed through a gland; but this fact, if established, would be equally explicable on either hypothesis. The greater size and vascularity of these glands in youth, when the growth of the organs is most rapid, would lead to the belief that their functions are of importance in the elaboration of nutritive matter to meet the greater demand for the materials of growth at that period of life.

CHAPTER XI.

EXCRETION.

(553.) The expulsion from the system of those materials which are useless or noxious, is the office of *excretion;* and the organs or channels by which it is performed are called the *excretory organs.* They consist of the lungs, the skin, the kidneys, and probably also the liver.

SECT. I.—EXCRETORY FUNCTION OF THE LUNGS.

(554.) Of the office of the lungs in purifying the blood from its redundant carbonaceous matter, we have already fully treated. Besides carbon, or rather carbonic acid, a large quantity of water is also exhaled by means of the lungs. As, however, there is reason to believe that considerable absorption of water also takes place from the same surface, the amount of loss sustained by the united operation of these two functions is only the excess of the exhalation over the absorption.

SECT. II.—EXCRETORY FUNCTION OF THE SKIN.

(555.) We have already given the results of the chemical analysis of the matter of perspiration, in our account of the aqueous secretions, (§ 514). The chief ingredient is unquestionably water; and the average amount of water which escapes from the body through the channel of the skin, has been very variously estimated by different physiologists; for, indeed, it is hardly possible to arrive at any definite conclusion on this subject, from the great variations that occur even in the same individual at different times, especially according to the variable states of atmospheric temperature and humidity, and also according to differences in the activity of the circulation. The only satisfactory information we can hope to attain is, as to the aggregate loss by exhalation from the skin and the lungs. The daily loss of weight from these two sources taken together is stated by Haller[1] to vary from thirty ounces in the colder climates of Europe, to sixty in the warmer, and is estimated by Lavoisier and Seguin[2] at forty-five ounces in the climate of Paris. But this quantity is, of course, from the causes already mentioned, liable to extreme variation. It has been estimated that, of the whole quantity thus exhaled from the skin and from the lungs, about two-thirds are derived from the former source, and one-third from the latter.

SECT. III.—EXCRETORY FUNCTION OF THE KIDNEYS.

(556.) A considerable proportion of fluid is also carried off from the system by the kidneys; the peculiar office of which, however, appears to be to eliminate more especially the saline materials, which are to be thrown off; and, in particular, the peculiar substance termed *urea*, which, as we have already remarked, partakes much of the character of resinous bodies. As urea contains a very large proportion of nitrogen, it is probable that the kidneys are the channels

[1] *Elementa Physiologie*, xii. 2, 11.

[2] *Mémoires de l'Académie des Sciences*, pour 1790, p. 601.

provided in the economy for the removal of any excess of this element which takes place in the system.

(557.) The chemical analysis of the urine has engaged the attention of a great number of physicians and philosophers, not only from its supposed connexion with various states of the body in health and disease, but also from its containing a great multitude of constituents, some of which have very peculiar properties. Above twenty different substances have been detected as entering into its composition; and almost every year is adding to the list of newly discovered ingredients. The existence of phosphorus in this fluid has long been known; and the urine was, till lately, the only source whence this elementary substance could be procured in any quantity. Scheele discovered the uric or lithic acid, which is one of the most remarkable of the animal products. The labours of Fourcroy and Vauquelin led to the knowledge of the exact composition of many of the neutral salts contained in the urine. This analysis was carried still farther by Cruickshank in England, and by Proust in Spain, but has been brought to its present state of perfection chiefly by the labours of Berzelius[1] in Sweden.

(558.) The daily quantity voided, as well as the sensible qualities of this secretion, is greatly modified by circumstances. The former has been estimated at an average as being about two pounds avoirdupois. Its mean specific gravity has been fixed at 1·03. In a healthy state it generally exhibits acid properties, arising from the presence of uncombined phosphoric, lactic, uric, benzoic, and carbonic acids. These acids, together with the muriatic and fluoric acids, also exist in combination with several earthy and al-

[1] *Annals of Physiology*, ii. 428.

kaline bases, comprising ammonia, lime, magnesia, potass, and soda; the principal compounds thus formed being the phosphates of lime and magnesia, ammonia and soda, the sulphates of potass and of soda, the lactate of ammonia, the muriate of soda, and the fluate of lime. There exist, besides, a large proportion of urea, (composing nearly one-thirteenth of the whole quantity of urine, and about one half of its solid ingredients), mucus, gelatin, albumen, and a small portion of unacidified sulphur. The presence of a minute quantity of silica has also been detected by Berzelius, amounting to about the 220th part of the solid matter contained in the urine. The weight of the solid ingredients obtained by evaporation, is one-fifteenth of the whole fluid, the rest being water. The several ingredients above mentioned may each be rendered evident by the application of appropriate tests.

(559.) Urea is a peculiar animal product, which is procured from urine evaporated to the consistence of a syrup and allowed to crystallize; after which alcohol is added, which dissolves the urea, whence that substance is obtained by evaporation. It then appears in the form of crystalline plates, and has a light yellow colour, a smell resembling garlic, and a strong acrid taste. It is chiefly characterised by the bulky flaky compound which it forms with nitric acid. By distillation it yields about two-thirds of its weight of carbonate of ammonia; and by spontaneous decomposition it is resolved into ammonia and acetic acid. It possesses the very remarkable property of changing the form of the crystals of common salt or muriate of soda, which, as is well known, usually crystallize in cubical crystals; but which, when mixed with a small quantity of urea, assume the form of octohedrons. What adds to the singularity of this effect is, that its operation is precisely the reverse on muriate of ammonia, or sal ammoniac ; the ordinary form of the crystals of this salt are octohedrons, but when urea is present, they take the form of cubes. Urea contains a much larger proportion of nitrogen than any other animal principle. This substance has been found in the blood, after its separation by the kidneys has been prevented, by the extirpation of those glands. Berzelius has advanced an opinion, that urea is furnished by the animal matter of the serosity of the blood, from the similarity of some of its properties, and also from the circumstance, that after the kidneys have been removed, the animal matter of the serosity is first increased in quantity, and afterwards assumes the character of urea. It appears probable that the principal function of the kidney is the separation from the blood of the excess of nitrogen which it may contain, and its excretion in the form of urea ; thus performing an operation with respect to this element analogous to that of the lungs with regard to the superfluous carbon of the blood.[1]

SECT. IV.—EXCRETORY FUNCTION OF THE LIVER.

(560.) Cholesterine, or the peculiar matter found in the bile, and which composes about eight per cent. of that fluid, contains a large proportion of nitrogen. Whatever may be its uses in contributing to the formation of chyle, it is ultimately rejected from the body, and may therefore be classed among the excrementitious substances. We have already noticed the singular circumstance regarding the mode of its preparation, in being formed from venous instead of arterial blood, as is the case with all the other known secretions.

[1] See Berard, *Annales de Chémie et de Physique*, v. 296.

(561.) It is doubtful how far these two peculiar substances, urea and cholesterine, may be considered as pre-existing in the blood, or as formed by the organs which respectively secrete them. It has been ascertained by the experiments of Prévost and Dumas, that in animals in whom the secretion of urine is suppressed by the removal of the kidneys, urea may, after some time, be detected in the blood; and Dr. Bostock ascertained that a similar substance makes its appearance in the human blood, in cases where the secretion of urine had been much obstructed by disease of the kidneys. The secretion from the liver is not liable to so much variation in its amount, as that from the other excernent organs; it is, however, diminished during febrile excitement and inflammatory conditions of the circulation, and increased by moderate exercise, and by external warmth. Both the liver and the kidneys, accordingly, may be ranked among the compensating organs, or those which have their actions occasionally increased in order to supply deficiencies in the functions of others. The excretion of watery fluid from the skin and lungs is evidently made to alternate with that from the kidneys, each of these organs being capable of occasionally supplying the office of the others. The chemical properties of the urine are very much influenced by the condition of the digestive functions. But the necessity of the excretion of urea is apparent from the rapidly fatal consequences which ensue from its accumlation in the system, when the secretion from the kidneys is suppressed, and which would lead to the conclusion, that this substance, when present in sufficient quantity, speedily acts on the nervous system as a virulent poison.

CHAPTER XII.

NUTRITION.

(562.) Nutrition consists in the appropriation of the materials furnished by the blood in the course of circulation, and modified by the processes of secretion, to the purposes of growth, and to the repair of that waste which is continually experienced by the solid structures of the body, in consequence of the exercise of their respective offices. We understand as little what are the particular processes by which these purposes are accomplished as we do respecting those of secretion. No mechanical or chemical hypothesis which can be devised appears at all adequate to the solution of this mysterious problem. The analogy of crystallization, implied in the celebrated definitions of Linnæus, in which the three kingdoms of nature are contrasted, is, in a philosophical point of view, utterly fallacious. According to this great naturalist, " minerals grow, vegetables grow and live, animals grow, live, and feel." It requires no lengthened argument to show that the growth of an animal, or of a plant, is a phenomenon belonging to a class entirely different from the increase of a mineral body. The latter is effected by the successive accretion of new layers of materials, which merely augment the volume of the body, without adding to it any new property ; so that the separation of its parts destroys only the form of the aggregate, and not any of its essential qualities. But organized bodies are nourished from internal resources, and the materials which are incorporated with their substance have undergone a slow and gradual elaboration in the organs themselves, and have been assimilated to the qualities of the body of which they are to form a component part. We may consider them as the result of the operation of the organic affinities, to which we have already referred the phenomena of secretion.

(563.) The only general fact of importance which has been established with regard to the succession of phenomena in this function, is, that the enlargement of any organ appears to depend essentially on the state of the circulation in that part, and on the supply of blood by its arteries. The increased growth of a part at any period, compared with that of neighbouring parts, is always preceded and accompanied by a marked enlargement of the arteries which furnish it with blood; and this is invariably observed, whether that growth be natural or morbid. A theory has been advanced, that nutrition is effected by the direct union of the red particles of the blood, or of their nuclei, with the tissues. This theory is successfully combated by Müller.[1]

(564.) Although we are unable to trace the exact nature of the processes of nutrition, yet much curious information may be collected by observing the succession of phenomena in the case of the formation of particular structures. Those which we shall select for the purpose of illustration are the bones and the teeth, in which the several stages of growth admit of being observed.

[1] *Elements of Physiology*, translated by Baly, p. 359.

SECT. I.—OSSIFICATION.

(565.) The process of ossification is particularly interesting, from its exhibiting the operations of nature in the completion of an elaborate structure of such great importanec in its mechanieal relations to the system, as the osseous fabric. In the early periods of the fœtal state, we can but just traee the figures of some of the larger bones, which appear to be modelled in a soft gelatinous matter contained in a dclicate membrane. This substance, as well as its membrane, aequires greater dcnsity, and the former assumes more the appearance of cartilage. In process of timc, opaque white spots are perceived on different parts of its surfaee, which, when examined by the microscope, exhibit a fibrous appearance. These lines increase in number and extent; and aftcr a timc, red points are secn dispersed throughout the future bone, in consequenee of the enlargement of the vessels which now admit the red globules of the blood. Soon after this, we find the earthy matter deposited in great abundance, imparting hardness and rigidity to the structure. In the long bones of thc extremities, thc osseous substance forms at first a short hollow cylindcr, as if it werc deposited from the vessels of the investing membrane, or periosteum. In the flat bones of the cranium, ossification commences from a few central points, and spreads on all sides, the fibres taking a radiating direetion. In proportion as the bony material extends, the cartilage is removed by the absorbent vessels, in order to make room for the extension of the bone. After a certain time, in thc cylindrical bones, a cavity is formed in the middlc, in consequence of the absorption of ccntral portions of cartilagc and of bone which had occupied that situation. These two oppositc proccsses of absorption and deposition continue during the whole of the future growth of the bone, the interior parts being removed in proportion as fresh bony layers are added at the exterior surface. Thus, when the outer part of the bone is compact and hard, the interior is either formed into a complete cavity, or into the cancellated structure formerly described.

(566.) Such are the few well ascertained known facts relative to ossification; but numberless have been the speculations to which they have given rise. Most of the opinions of the ancients on this subject were extremely vague and hypothetical, and have been fully refuted by modern physiologists. Many of the hypotheses of the latter have undergone a similar fate. The one which has acquired most celebrity is that of Duhamel, who, following the analogy of the growth of trees, conceived that the bones were formed of concentric rings, or laminæ, deposited from the periosteum. He endeavoured to adduce in support of his theory the results of experiments in which bones acquired a red tinge, when madder was given with the food. He alleged that when the madder was occasionally intermitted, and again resumed, many times in succession, the bones of the animal exhibited alternate rings of a red and white colour, corresponding to the periods when the animal had taken madder, and had intermitted it. It has since been shown, however, that his imagination in this instance must have misled him; for no such result takes place under the circumstances he describes.

(567.) The reparation of fractured bones by the powers of the constitution is a striking instance of the beautiful provisions of nature for remedying injuries accidentally occurring to the body. The fractured ends are quickly united by a bony substance called *callus*, formed in a manner very similar to that by which the bone itself is originally constructed. The arteries near the seat of the injury pour out a kind of lymph, which coagulates, and is either gradually converted into cartilage, or replaced by cartilage after it has itself been absorbed. The deposition of phosphate of lime then takes place within this cartilage, which is either removed or adapted to its reception, and thus the ends of the bone are cemented together, and the limb rendered as firm as before the accident.

SECT. II.—DENTITION.

(568.) No less curious and interesting is the process employed in the formation of the teeth. The rudiments of every tooth, when examined in the fœtus, consists of a gelatinous pulp, which is extremely vascular, enclosed in a double investment of membrane. The outer membrane is soft and spongy, and is apparently destitute of vessels; while the inner one is firmer, and extremely vascular. The first depositions are those of bony matter, which take place on the exterior surface of the vascular pulp, and chiefly on the upper part, but within the membranous coverings already noticed. The shell of bone thus formed has the shape of the future tooth, and acquires thickness from successive deposits of bone in its inner surface, which are still made by the outer surface of the vascular pulp. When the ossification is sufficiently advanced, the pulp which has thus served as a mould for the tooth, divides itself into two or more parts, corresponding to the intended number of fangs, so that the ossific matter is now deposited in the form of as many tubes round these portions of the pulp, and growing in a direction towards the jaw, forces the tooth in the contrary direction; thus in the lower jaw the tooth rises, and in the upper jaw it descends. The enamel is deposited after the body of the tooth is considerably advanced in its formation. It is the product of a secretion from the inner surface of the outermost of the two membranes, which form the capsule of the tooth, and the materials deposited from it adhere strongly to the bony crown of the tooth which they surround. This secreting capsule has been called the *chorion* by Hérissant, who has given an accurate description of the process of dentition. Layer after layer of enamel is thus deposited, till the growth of that part of the tooth has been completed; then the chorion shrivels and is absorbed, and the tooth still continuing to grow at the root, pierces the gum, the resistance of which has been gradually diminishing by the absorption of its substance.

SECT. III.—NUTRITION OF THE SOFTER TEXTURES.

(569.) Greater difficulty exists in following the succession of changes which attend the growth and nutrition of the softer textures, than of those we have now considered, because the materials employed in their construction are less distinguishable by the eye from the other animal substances, and their changes are less easily traced, than those exhibited by the calcareous deposits of the osseous fabric.

A question here presents itself, of great importance with relation to our knowledge of the nature of the vital powers, but of which the solution is attended with the greatest difficulties. It is this: how far, it may be asked, are the powers of secretion exerted in merely separating from the blood those organic products which are already contained as ingredients of that fluid, and how far do they also extend to the actual formation of new proximate elements; and next, what reason is there to believe that the vital powers are capable of producing, from the materials presented to them, originally derived from the food, or the atmosphere, any quantity of those chemical substances, which, never having hitherto been decomposed, must, in the present state of the science, be regarded as elementary?

The consideration of the chemical analysis of the blood, and of the substances prepared from it will suffice to shew that most, if not all the secretions, may very possibly be produced solely by the operation of ordinary chemical affinities. It has been found, indeed, that we are able by certain chemical processes, to form from the blood, out of the body, substances similar to many of the secretions; and we are therefore warranted in the supposition that operations of the same kind are carried on by the secreting organs within the body. It is interesting, however, to trace the origin of many of the products of secretion, from the ingredients contained in the blood itself. On this subject Müller[1] remarks, that some of the proximate elements of the tissues exist in part ready formed in the blood. The albumen which enters into the composition of the brain and glands, and of many other structures, in a more or less modified state, is contained in the blood; the fibrin of the muscles and muscular structures is the coagulable matter dissolved in the lymph and blood; the fatty matter, which contains no nitrogen, exists in a free state in the chyle; the azotised and phosphoretted fatty matter of the brain and nerves exists in the blood combined with the fibrin, albumen, and cruorin. The iron of the hair, pigmentum nigrum, and crystalline lens, is also contained in the blood; the silica and manganese of the hair, and the fluor and calci-

[1] *Physiology, &c.* p. 361.

um of the bones and of the teeth, have not hitherto been detected in the blood, probably from their existing in it in but very small proportion. The matters here enumerated are attracted from the blood by particles of the organs analogous to themselves, partly in the state in which they afterwards exist in the organs ; in other instances, their ultimate elements are newly combined in them, so as to form new proximate principles ; for the opinion that all the component elements of the organs exist previously in the blood in their perfect state, cannot possibly be adopted ; the components of most tissues in fact present, besides many modifications of fibrin, albumen, fat, and osmazome, other perfectly peculiar matters, such as the gelatin of the bones, tendons, and cartilages, nothing analogous to which is contained in the blood. The substance of the vascular tissue, and also the different glandular substances, cannot be referred to any of the simple components of the blood. Even the fibrin of muscle cannot be considered as exactly identical with the fibrin of the liquor sanguinis. Between coagulated fibrin and coagulated albumen, there is scarcely any chemical difference, except in their action on peroxide of hydrogen ; the only very important distinction between the fibrin dissolved in the blood and the albumen is, that the former coagulates as soon as it is withdrawn from the animal body, while the latter does not coagulate spontaneously, but requires a heat of from 158° to 167° Fahr., or some chemical agents, such as acids, concentrated solutions of fixed alkali, or metallic salts ; and the fibrin of muscle in its chemical characters has scarcely a greater analogy with coagulated fibrin, than with coagulated albumen. In its vital properties the fibrin of muscle differs from both. The comparison of nervous substance, again, with the fatty matter containing nitrogen and phosphorus, is only justified by the present imperfect state of organic chemistry.

The blood, as Dr. Bostock[1] observes, is a substance, the composition of which is peculiarly well adapted to undergo the changes necessary for the processes both of secretion and of nutrition, as it consists of a number of ingredients, which are held together by a weak affinity, liable to be disturbed by a variety even of what might appear the slightest causes. As examples of the facility with which these changes may be effected, we may cite the numerous reagents which have the power of coagulating albumen ; the action upon it and upon fibrin of dilute nitric acid, which converts these substances respectively into adipose matter and jelly, changes which are probably the result of the addition of oxygen to the fibrin and to the albumen ; and there is some reason to believe that by applying the same reagent to the red particles, we may obtain a substance nearly resembling bile.

With regard to the formation of the saline secretions,[2] and of those substances, the elements of which are not to be found in the blood, or at least not in sufficient quantity to account for the great accumulation that takes place in certain parts of the system, and of which the source is not apparent, we must confess that the present state of the science affords no means of explaining the phenomena. "To suppose," as Dr. Bostock justly remarks, "that we are affording any real explanation by ascribing it to the operation of the vital principle, or to any vital affinities, which is merely a less simple mode of expressing the fact, is one of those delusive attempts to substitute words for ideas, which

[1] *Elementary System of Physiology*, p. 518. [2] *Ibid.* p. 532.

have so much tended to retard the progress of physiological science."

SECT. IV.—GENERAL PHENOMENA OF NUTRITION.

(570.) The instances we have above given of the processes employed in ossification and dentition, together with the varied operations concerned in the formation and nutrition of all the softer textures of the body, forcibly illustrate the beneficent care displayed in the construction of every part of the frame, and the admirable adjustment of the long series of means which have been provided for the attainment of these diversified and frequently remote objects of the animal economy. Every part undergoes a continued and progressive change of the particles which compose it, even though it remain to all outward appearance the same. The materials which had been united together by the powers of nutrition, and fashioned into the several organs, are themselves severally and successively removed and replaced by others, which again are in their turn discarded, and new ones substituted in their place, until, in process of time, scarcely any portion of the substance originally constituting the organs remains as their component part.

(571.) We see from the examples of the bones, that this continual renovation of the materials of the body takes place in the most solid, as well as in the softest textures; and so great is the total amount of these changes, that doubts may reasonably be entertained as to the identity of any part of the body at different epochs of its existence. The ancients assigned a period of seven years as the time required for the complete renovation of all the materials of the system, but perhaps this entire change may take place during a shorter interval.[1]

(572.) The two functions we have been considering, namely, nutrition and absorption, may be regarded as antagonist powers, each continually counteracting the effects of the other. In the early periods of life, though both are in full activity, the former predominates; all the organs enlarging in their dimensions by the addition of fresh materials in greater quantity than the losses by absorption, the whole body is in a state of growth. In the course of time, the frame having attained its prescribed dimensions, these opposite processes of reparation and decay approach nearer to an equality; and at length are exactly balanced. The parts then cease to grow, and the system may be said to have reached its state of maturity. This is the condition of the adult, in which the equilibrium of the functions is maintained for a great number of years. At length, however, the period arrives when the balance, hitherto so evenly kept, begins to incline, the renovating powers of the system are less equal to the demands made upon them, and the waste of the body exceeds the supply. It contracts in its dimensions; it has attained its period of declension, which marks the progress of age, and ultimately leads to decrepitude. The fabric then betrays unequivocal symptoms of decay, the functions are imperfectly performed, the vigour of the circulation flags, the flame flickers in the socket, and is finally extinguished in death. Thus is the whole duration of life, from the first developement of the germ to the period of its dissolution, occupied by a series of actions and

[1] See the article AGE, in the *Cyclopædia of Practical Medicine*, vol. i. p. 34.

reactions, perpetually varying, yet constantly tending to definite and salutary ends.

(573.) We have now concluded the account we proposed to give of the long series of functions which maintain the various organs of the system in that mechanical condition and chemical composition fitting them for the exercise of their several offices in the economy. We have next to enter into the consideration of the higher order of functions connected with the nervous system.

CHAPTER XIII.

THE SENSORIAL FUNCTIONS.

SECT. I.—GENERAL VIEWS.

(574.) The functions we have hitherto considered, however admirably contrived, and beautifully adjusted, are calculated only for the maintenance of a simply vital existence. All that is obtained by their means is a mass of organized materials, which lives, which is nourished, which grows, which declines, and which perishes in a certain definite period, by its mere internal mechanism. But these can never be the real ends of animal existence. Sensation, voluntary motion, pleasure and pain, together with all the intellectual operations to which they lead, these must be the proper objects of animal life; these the purposes for which the animal was created. In man we find the extension of these latter faculties to an extraordinary degree, and the addition of moral attributes which elevate him so far above the brute creation, and place him one step nearer to that divine essence after whose likeness he was made.

(575.) The functions of sensation, of voluntary motion, and of thought, are those which establish our mental connexions with the external world; which enable us to acquire a knowledge of the existence and properties of the material objects that surround us; which awaken in us the operations of our own minds; which bring us in communication with other intellectual and sentient beings, and which enables us to react on matter, to exercise over it the dominion of the will, and to influence the condition of those other beings which like us have received the gift of life, of sensation, and of intellect.

(576.) Throughout the whole of the inquiries in which we are about to engage it is important to keep steadily in view the essential and fundamental distinction between mind and matter. Of the existence of our own sensations, ideas, thoughts, and volitions, we have the highest degree of evidence that human knowledge can admit of, that of our own consciousness. Of the existence of matter, that is, of causes foreign to our own mind, but acting on it, and giving rise to sensations, which are strictly mental affections, we have merely a strong presumption; still, however, the belief in the existence of those causes, however irresistibly it may operate in producing in us convictions, and influencing our actions, is yet but an inference from the regularity in the succession of our sensations. We are not justified in saying that it is impossible we can be deceived in this belief; whereas in the consciousness of our mental existence we cannot possibly be mistaken, because that consciousness implies the very fact of our existence.

(577.) It is, however, most true, that notwithstanding our ideas of mind and matter are such as wholly to exclude our conceiving any property to belong to both of them in common; yet some inscrutable link of connexion has, in our present state of existence, been established between them, so that each may, under certain circumstances, be affected by the other. External matter acts on our bodily organs, which are still mere matter; but our bodily organs act on our minds; and our minds in turn react on our bodily organs, and occasion movements which enable us to act on extraneous objects. Moreover, it is impossible for us in our present state to carry on any intellectual operation, but by the instrumentality of our material organs; we can neither feel, nor think, nor will, without the healthy condition of the brain, and all the other physical conditions which such a state implies. Disturbance of the physiological functions of the brain is invariably attended by a disturbance of the mental operations connected with those functions. Both are excited by certain states of the circulation in the brain; both are instantly suspended by pressure upon that organ; both are restored by the removal of the pressure, or other disturbing cause.

(578.) The *nervous system* is the name given to that assemblage of organs which perform the important functions of which we are now speaking. The primary office of the fibres composing that system appears to be to transmit certain affections, which we may call *impressions*, from one part of that system to another; and more particularly to convey them both to and from that particular part of the brain, the affections of which give rise to sensation, and accompany our mental operations. In the one case, the impression made on one extremity of a nervous fibril, adapted to receive such impression, in a part called an *organ of sense*, is propagated to the part of the brain above described, and to which the name of *sensorium* has been given, and thereby producing a certain physical effect, the nature of which is wholly unknown; *sensation*, which is a mental effect, ensues. In another case, the fibres of the brain are by their action instrumental in retracing, in combining, in modifying these impressions, and forming them into ideas, which are linked together by the laws of association. Again, the mental act we term *volition*, and of which we are always conscious, affects some particular fibres or portion of the sensorium, the impression made upon which is followed by an affection of certain nervous filaments proceeding from those parts of the brain, and conveying an influence, (which for want of a more specific term we may also call *irritation)*, to the muscles in which these nerves terminate; and this is immediately followed by the contraction of those muscles. This constitutes *voluntary motion*.

(579.) But the office of the nerves extends yet farther. Various muscles subservient to many of the vital functions, such as the heart, the stomach, and the intestines, act without any interference, or even control of the will. They compose the class of *involuntary muscles;* yet these muscles are supplied with nerves, and have a certain dependence on the nervous system, which is of a very peculiar kind, and will be considered afterwards. These nerves supplying the involuntary muscles, appear to have the office of establishing connexions between the actions of these muscles, and of uniting the various organs of the different functions into one connected harmonious whole.

(580.) Thus the various phenomena which relate to the nervous system in the performance of the functions we are considering, will arrange themselves under the following heads, according to the natural order of their sequence:

First, the impressions made by external objects on the sentient extremities of the nerves distributed to the organs of sense, through the medium of those organs.

Secondly, the transmission of the impressions so made to the sensorium, through the medium of the nerves of sensation.

Thirdly, the physical changes made on the sensorium.

Fourthly, the mental change consequent on this physical change in the sensorium; which mental change is termed *sensation;* and in experiencing which the mind is wholly passive.

Fifthly, the recurrence, associations, and combinations of the physical changes originally induced in the sensorium, but probably extended through various parts of the substance of the brain, and simultaneous with various mental operations, in exercising which the mind is partly passive and partly active.

Sixthly, the mental act denominated *volition*, which is accompanied with consciousness, and in which the mind is wholly active.

Seventhly, the corresponding change induced by volition on the sensorium, or origin of the nerves of voluntary motion.

Eighthly, the transmission of the impression so received by the nerves of voluntary motion, to the muscles on which they are distributed.

Ninthly, the contractions of these muscles, constituting voluntary motion.

Tenthly, the influence of the nerves on the muscles of involuntary motion, and on various functions apparently depending on involuntary actions.[1]

SECT. II.—ORGANIZATION OF THE NERVOUS SYSTEM.

(581.) The nervous system comprises organs of a curious and complicated structure, and which are of the highest importance in the animal economy. Their study is exceed-

[1] See Bridgewater Treatise on *Animal and Vegetable Physiology*, vol. ii. p. 535, note.

ingly interesting, whether they be viewed as instruments of sensation, as sources of action, or as the medium of connexion between the body and the mind. This system is composed of a considerable mass of a soft pulpy substance called the *brain*, which occupies the cavity of the skull; a prolongation of this substance filling the canal of the spine, and called the *spinal cord*, or *spinal marrow;* and of various processes in the form of cords, called *nerves*, which extend from the brain and spinal cord, to almost all parts of the body. There are found also interspersed in various parts along the course of the nerves, small rounded or flattened bodies, called *ganglia*, which also belong to this system of organs. All the parts of this system are intimately related to each other, and although they differ considerably in their general appearance, they possess many characters in common In point of structure they present us with three different modifications; the first comprehending the substance of the central masses, which include the brain and spinal cord; the second, the nerves; and the third, the ganglia. We shall proceed to consider each of these in the above order.

1. *Organization of the Brain and Spinal Cord.*

(582.) *The brain*, or general mass which fills the cavity of the skull, is composed of a number of parts of various shapes, the particular forms and dispositions of which belong properly to descriptive anatomy. It will be sufficient for our present purpose to state, that it is divided into three masses, distinguished by the names of *cerebrum*, which is by far the largest portion, and which occupies the whole of the upper and fore part of the cavity of the skull; the *cerebellum*, or lesser brain, which is situated at the hinder and lower part of the cerebrum; and the *medulla oblongata*, which lies at the central part of the base, or inner surface of the cerebrum, and connects it with the cerebellum, and with the spinal cord. All these parts, as well as the spinal cord itself, are formed of two kinds of substance; the *cineritious*, or ash-coloured substance, which has also been called the *cortical* substance; and the white, or *medullary* substance. These two substances are variously intermixed, sometimes forming strata of different thickness, and sometimes the one enveloping separate portions of the other, in different parts of the whole mass. There is a layer of cortical substance placed on the outside of the cerebrum; it does not, however, form a smooth uniform plane, but is moulded into *convolutions*. In the cerebellum there is a similar superficial stratum formed into concentric laminæ. The convolutions are of considerable depth; and if any of them be cut through, it is seen to consist of both cortical and medullary substance. The cortical forms a layer of considerable thickness; and on looking attentively on its divided edge, a very narrow lamina of medullary substance will be perceived passing through it, and following it through all its windings. This fact has been particulary noticed by Dr. Baillie. The concentric laminæ on the surface of the cerebellum, are composed also of cortical and medullary matter. By this arrangement, the quantity of cortical substance, as well as the extent of its surface on the outer part of the brain, is very much increased.

(583.) In the interior of the brain we find cavities of considerable size, termed *ventricles*, and bodies of regular, but various shapes, presenting many different mixtures of two species of matter. Where these bodies appear, from their outside, to be formed of cortical substance only, on cutting into this, there is found a considerable mixture of medullary matter; and where they seem, from their outside, to be formed of medullary matter alone, they are discovered, on dividing them, to contain some cortical substance in the interior. Thus, there is no particular part of the brain composed purely of the one kind of substance or the other; although the proportions of each in the various parts may be very different. A similar intermixture of cortical and medullary matter exists in the spinal cord; but contrary to what takes place in the large mass of the brain, the cortical part is placed in the interior, and is enveloped by the medullary.

(584.) The medullary substance has generally been considered as constituting the most perfect state of nervous matter, or that which more especially exercises the functions of the nervous system. Some physiologists, on the contrary, consider the grey substance as the seat or origin of nervous power; whilst the fibres of the white substance act merely the part of conductors of nervous influence from one part to another. This medullary portion is obviously of a firmer consistence than the cortical part, and contains fewer blood-vessels interspersed throughout its substance. Both the one and the other are almost perfectly homogeneous in their appearance. Ruysch had fancied that the cortical substance was entirely composed of blood-vessels, connected by cellular membrane; and in this opinion he was for a long time generally followed, although the pulpy consistence it exhibits is scarcely compatible with such a notion. Malpighi supposed that he had detected in it a glandular structure; but this must also be regarded as a mere hypothesis, unsupported by any substantial evidence. The medullary matter presents traces of a fibrous structure; a fact which was first observed by Malpighi, and which is particularly insisted on by Drs. Gall and Spurzheim; and notwithstanding the existence of such a structure is denied by other eminent anatomists, it appears to have been sufficiently established by the elaborate researches of Reil, a detailed account of which has been given by Mr. Mayo.[1]

(585.) Anatomists are far from being agreed as to the minute and ultimate structure of nervous matter. De la Torré asserts that it consists of a mass of innumerable transparent globules immersed in a transparent fluid; and that these globules are larger in the brain than in the spinal marrow. Prochaska describes the same globular structure, which he represents as united by a transparent elastic cellular membrane disposed in fibres. Monro,[2] in his first inquiries, thought that these fibres were convoluted, but afterwards acknowledged that he had been misled by an optical fallacy, incident to the employment of high magnifying powers. The Wenzells[3] also recognised the globular composition of the nervous substance, and considered the globules themselves to be vesicles filled with a material either of a medullary or cineritious appearance, according to the portion examined. Bauer[4] states that the globules are of about the same diameter as the central particles of the globules of the blood, some, however, being still smaller; and that they are of a gelatinous consistence, and soluble in water. The cineritious substance, he finds, is composed chiefly of the smallest globules, surrounded by a large proportion of a gelatinous and serous fluid. The medullary substance, on the other hand, is formed principally by the larger and more distinct globules which adhere together in

[1] In his *Anatomical and Physical Commentaries*.

[2] On the *Nervous System*.

[3] *De Structura Cerebri*.

[4] *Philosophical Transactions* for 1818, and 1821.

lines, and have a smaller proportion of fluid, that fluid being more viscid than in the cineritious substance. Dr. Edwards[1] has confirmed by his observations, these results, as far as the general globular composition of nervous matter is concerned. He asserts the diameter of the globules to be one three-hundredth of a millimetre, which is equivalent to the seven thousand six hundred part of an inch; and that these globules are arranged in linear series, constituting the primary linear fibres. Béclard states that he has verified these observations.[2]

2. *The Nerves.*

(586.) The *nerves* are white cords extending from different parts of the brain and spinal cord, to different parts of the body, and more especially to the muscles, the integuments, and other organs of sense, and to the viscera and blood-vessels. Their general form is cylindrical; but they divide, in their course, into a great number of branches, many of which again reunite, or are joined with the branches of other nerves, so as to form in many parts a complicated nervous net-work, or *plexus,* as it has been termed by anatomists. The nerves are usually spoken of as originating in the brain or spinal cord, and as proceeding from thence to their termination in other, and generally distant parts. As the united branches would form a cord of much larger diameter than the trunk from which they arise, it is evident that the total quantity of nervous matter they contain is augmented as they proceed in their course. When examined with the microscope, their surface presents a number of transverse lines or wrinkles, which are evidently for the

[1] *Sur la Structure Elémentaire.* [2] See his *Anatomie Générale.*

purpose of admitting of flexion; and thus accommodating them to the different movements of the parts with which they are connected.

(587.) The nerves appear to consist of filaments of medullary substance, enclosed in a tough cellular membrane. At their origin from the central organ, whether it be the brain or the spinal cord, they consist of detached fibrils, sometimes isolated, but in general arranged so as to constitute flat bands. There are two such bands, namely, an anterior and a posterior fasciculus, which unite to form each of the nerves arising from the spinal cord. Some nerves are composed of pure medullary matter, as the optic nerve; but in the greater number this matter is so enveloped in a tough cellular membrane, which has been termed by anatomists the *neurilema*, that it cannot distinctly be perceived. In the olfactory nerves there is an evident junction of cortical with medullary matter, but in most others we find nothing but filaments of medullary matter, each of which is contained in a separate envelope of neurilema, that forms tubes for their reception.

(588.) Many anatomists have attempted the investigation of the minute structure of nervous fibrils by means of the microscope. De la Torré[1] perceived in them globules similar to those of which the matter of the brain is composed. Monro[2] and Fontana describe the nervous filaments as being connected by cellular substance, much in the same way as the muscular fibres, and arranged like them in fasciculi of various sizes. They represent the ultimate fibril as being twelve times greater than the muscular fibre, having a serpentine or tortuous form, and being composed of a cylindri-

[1] *Philosophical Transactions* for 1769. [2] *On the Nervous System.*

cal canal, containing a viscid pulpy matter, evidently diffe-rent from the substance of the canal itself. Reil has pursued this investigation with still greater care and minuteness, and states that the ultimate filaments differ in thickness from that of a hair to the finest fibre of silk. Their arrangement into larger and larger fasciculi is analogous to what we observe in the structure of muscles, but with this difference, that the nervous fibres in their course along the nerve, frequently divide and subdivide, and are again variously united and conjoined, so as to produce an extensive connexion among all the parts of the same nerve. The membranous neurilema, besides giving support to each individual filament of nerve, and uniting them into fasciculi, furnishes also a general covering to the whole nerve.

(589.) What has now been stated must be understood as applicable to nerves in general. Many differences have been pointed out in the structure of different nerves; but it is not necessary to descend into these minute particulars in the general view we are now giving.

3. *Ganglia.*

(590.) *Ganglia* are small rounded nodules, which are placed in different situations in the course of nerves, sometimes in the trunk of a single nerve, and sometimes where two nerves unite. They are most numerous on those nerves which are distributed to the viscera, and to the muscles of involuntary motion. Their appearance is very different from that of a mere dilatation of a nerve, being of a reddish-brown colour, having a minute fibrous texture, a firmer consistence, and a greater number of blood-vessels than ordinary nerves. The nerves which pass out from a ganglion are generally of a larger size than those which entered into it, as if they had received, in their passage through it, an additional quantity of matter. It would appear, from numerous observations, that the filaments of the different nerves which join the ganglion proceed through it individually without interruption, but are, at the same time, involved and twisted together in a very complicated manner; the result being, that filaments from many different nerves are united in the formation of a new nerve; so that the parts to which the nerve is distributed receive a supply of filaments from many different sources, and are in very extensive communication with various parts of the brain, spinal cord, and indeed the whole nervous system.

(591.) Besides this junction and intertexture of nervous filaments, the ganglia contain a soft semi-fluid matter, which appears to be analogous to the proper substance of the brain, and like the latter, may be distinguished into cineritious and medullary portions. It would appear, therefore, that the ganglia have some peculiar office with regard to the nerves which traverse them, and that they do not serve the purpose only of a plexus of filaments, establishing mere mechanical connexions between them, as some anatomists have alleged.

CHAPTER XIV.

THE EXTERNAL SENSES.

(592.) The external senses have usually been reckoned five in number, namely, touch, taste, smell, hearing, and sight ; but this arrangement has reference more to the organs by which they are exercised than to the nature of the sensations they excite in the mind. A variety of sensations have been referred to the sense of touch, which are wholly different in their kind, and which are received by means of impressions made on the skin, and also others which are conveyed by nerves in other parts of the body, without any connexion with the skin. These we shall notice after we have considered the sensations more peculiarly belonging to the sense of touch.

SECT. I.—TOUCH.

1. *Sensation of Pressure.*

(593.) Every part of the surface of the body is exposed to the contact of foreign bodies ; and in most parts of the skin very slight pressure made by those bodies gives occasion to the primary sensation of touch, which is in fact simply that of resistance to the part of the skin on which it presses. This sensation is quite specific, and distinguishable from all other sensations. It may be conveyed, though less perfectly, by several of the internal surfaces of the body, as those of the mouth and pharynx. Certain parts of the skin possess, however, a more peculiar delicacy of nervous sensibility to the impressions of touch, and are therefore to be considered as more especially the organs of this sense. In man the points of the fingers are particularly employed for receiving the finer impressions of touch, and for distinguishing the qualities of external objects, of which this sense is fitted to convey us information. The greater vascularity of the skin of the fingers, and greater developement of its papillary structure, have been assigned as the causes of the apparent increase of sensibility with which they have been endowed. There is no doubt, however, that much depends on the education given to the ends of the fingers, by their constant employment in this office; for we find that the toes and other parts of the body may, by use, be trained to the acquisition of an equal degree of sensibility; of this we see examples in individuals who have been born without hands. Parts where the epidermis is very thin, such as the lips, are also endowed with considerable sensibility to the impressions of touch, and with the power of discriminating differences in those impressions which cannot be felt or appreciated by means of the fingers.

(594) Professor Weber of Leipsig[1] has made a series of very interesting experiments on the relative sensibilities of the skin in different parts of the body, with reference more particularly to its power of conveying to the mind accurate perceptions of mechanical impressions made upon it. He found this power possessed in the highest degree by the

[1] An account of these researches is contained in the *Edinburgh Medical Journal*, xl. p. 83.

tip of the tongue and ends of the fingers, the sensibility of which he estimated at eighty times greater than that of the skin of other parts of the body. He observed, also, that even the skin in different parts of the face, when touched with the points of a pair of compasses opened to a small distance, shewed the greatest diversity in their power of conveying distinct perceptions of touch as to the object in contact being single or double, and as to the distance between the points, when they were perceived to be double.

2. *Sensations of Temperature.*

(595.) The same organs which, when pressed by an external body, convey the impression of resistance, communicate also sensations of heat and cold, and nearly in the same relative proportion. Thus the fingers are more sensible to variations of temperature in the bodies they touch than other parts of the skin less accustomed to discriminate them. The lips are still more sensible than the fingers to the differences of temperature in the bodies to which they are applied. This peculiar sensibility affords a ready mode of distinguishing genuine diamonds and other precious stones from such as are counterfeit; for the former, being better conductors of heat, produce a more lasting impression of coldness when applied to the lips or to the tongue.

The sensations of heat and cold are, however, far from being in exact proportion either to the actual temperatures of the bodies which are in contact with the skin, or even to the differences between their temperature and that of the skin. The actual condition of the sensibility of the skin at the time, which depends on a multitude of causes hereafter to be noticed, has a very considerable influence on the sensations. The difference which is observable in the sensibilities of the same part to the impression of resistance, and to that of heat or cold, suggests a doubt whether a different set of nerves may not be employed to transmit to the brain these different kinds of impressions. We find in certain states of disease, that the general sensibility of the surface of the body may be much impaired, and yet it may preserve its sensitiveness with regard to heat and cold; and it is also certain, that differences of temperature produce sensations in parts, the stomach for instance, which are wholly disqualified from communicating the feeling of resistance.

3. *Anomalous Sensations.*

(596.) Hunger and thirst are sensations referred to the mouth, throat, and stomach, which are also quite specific in their nature, though generally referred to the sense of touch.

(597.) The same observation applies to a variety of peculiar sensations, many of which are common to the whole surface of the body, and may even be felt in some internal parts, but which it would be difficult to class, or even completely enumerate. The sense of tingling and of itching are examples of this species of sensations. The feeling of nausea is an undefinable sensation referred to the stomach.

4. *Sensation of Pain.*

(598.) Every sensation thus referred to the sense of touch, when it rises beyond a certain degree, is accompanied with the additional feeling of pain, which, if considerable, engrosses the whole attention, and effaces all marks of discrimination as to its origin. Pain is generally readily referred to a particular part of the body, as being the origin, or as it is commonly called, the *seat* of pain, especially when the part is external. But in internal parts, this specific reference is often extremely vague and imperfect; and there frequently exists a general feeling of uneasiness, often more intolerable than any other, and to which it is impossible to assign any particular locality. It may also be observed, that in general the actual sensibility bears no relation to the capacity for feeling pain.

(599) A vast number of experiments were made by Haller, with a view to ascertain the comparative sensibilities of the different textures and organs of the body. In general, those which have but a small degree of vascularity, such as the cartilages, tendons, ligaments, fibrous membranes, and bones, and even the simple cellular texture, and serous membranes, in a state of health, have a very obscure degree of sensibility, when cut across, pricked with a pointed instrument, or burned by a hot iron. Yet many of these textures, though deficient in sensibility to these stimuli, are yet extremely sensible to injuries of another kind, namely, forcible stretching, when applied suddenly and in a degree which endangers the integrity of their structure. This is sufficiently illustrated by the acute pain that is attendant on a sprain. Bones, also, though scarcely communicating any feeling of pain when sawn through in the living body, yet feel acutely the concussion produced by violent blows, as any one may be convinced of who has suffered a blow on the knee. It is also remarkable that all those parts, which are apparently so incapable of sensation under ordinary circumstances, become highly sensible when in a state of inflammation.

(600.) The internal parts of most of the glands and other solid organs, have but little sensibility; and the chief source of pain, when they are attacked with inflammation, arises from the affection spreading to the membranes which invest them. Inflammation of the mucous membranes does not oeeasion any proportionate degree of pain. Those parts of the body which reeeive no blood-vessels, as the cuticle and its appendages, the nails and the hair, are absolutely insensible. The cutiele consequently is well adapted to protect the highly sensitive organ which it covers, and to blunt its sensibility.

(601.) Pain often arises from internal eauses; from pressure, or distension, or other mechanical or chemical irritation applied to nerves; or from some changes taking place in the texture of the nerve itself. It will appear evident, on a general review of the sensibility allotted to the different organs of the body, that each has reeeived from nature that particular kind and degree which is most needed, and which best accords with the relative importance of its functions, and the dangers to which, in the ordinary course of events, it is exposed.

5. *The Muscular Sense.*

(602.) A very important class of sensations has been referred to the sense of touch, which require to be particularly distinguished from the rest; they are those attending the contractions of the voluntary museles, which render us sensible of the movements of our limbs, and of other parts which are voluntarily moved. These are the feelings which give rise to the idea of extension, and which, combined with the feeling of resistance, communicate to us a knowledge of the forms, magnitudes, and relative positions of external objects. Thus, by moving the hand over the surfaces of bodies, we gain the ideas of their tangible extension together with most of their mechanical properties, sueh as their roughness, hardness, weight, texture, and dimensions. In these examinations we avail ourselves of the admirable properties of the hand, an instrument which, by the number and variety of its parts, and the motions of which they are capable, is exquisitely fitted for procuring us this useful kind of knowledge. By the perceptions we acquire in infancy from the active employment of the limbs in various kinds of progressive motion, our sphere of knowledge of the material world is prodigiously extended ; and these perceptions are an important source of gratification, in consequence of the feelings of pleasure with which, by the beneficent ordination of nature, the active exercise of the voluntary muscles is accompanied.

(603.) The sense of touch, in the comprehensive view which we have now taken of it, is unquestionably the most important of all our external senses, bringing us more immediately acquainted with the essential qualities of the material world, and laying the great foundations of all the knowledge which the other senses supply, by a reference to the ideas derived from touch.

SECT. II.—TASTE.

(604.) It was the fashion among the French metaphysicians to resolve all the senses into that of touch ; so that in speaking of vision, for instance, they would allege that we see by means of the light which touches the retina. But this is a mere refinement not warranted by facts, and in which the real distinctions existing among the sensations themselves are overlooked.

(605.) If any of the senses could be considered as a finer sense of touch, it would be that of taste, by which we receive impressions of a peculiar kind from the sapid qualities of bodies in contact with the upper surface of the tongue. This sense is manifestly intended to guide us in the choice of our food, and it is accordingly placed at the entrance of the alimentary canal.

1. *Organs of Taste.*

(606.) The principal organ of taste is the *tongue*, but several of the neighbouring organs are auxiliaries in the exercise of this sense. The soft parts of the mouth consist of the lips and cheeks, the gums, the soft palate, the velum, uvula, tongue, the membranous lining of the mouth, and the salivary glands. The osseous parts are the upper and lower maxillary bones, the teeth, and the palate bones.

(607.) The *lips* and *cheeks* are principally composed of muscles; they are covered on the outside by the common integuments, and lined within by the membrane of the mouth, in which are situated numerous mucous glands. The membrane of the mouth is covered with fine villi, which are most conspicuous on the edges of the lips. A small doubling of this membrane is met with in the middle of both the upper and under lips, which fixes them more closely to the jaws. They have been termed the *fræna labiorum*. The union of the lips at the corners of the mouth form what has been called the *commissures* of the lips.

(608.) The *gums*, which surround, and firmly adhere to the collar of the teeth, are very vascular, and composed of a dense and compact cellular substance.

(609.) The *palate* is divided into the *palatum durum*, and *palatum molle*. The former is composed of the palate plates of the upper jaw, covered by periosteum, and by the membrane of the mouth, which here forms numerous rugæ. The *soft palate*, or *velum pendulum palati*, is the name of that membranous curtain which hangs from the posterior edge of the ossa palati, and pterygoid processes, and forms a flexible partition between the mouth and throat. It serves to conduct the fluids of the nose downwards, and at the same time acts as a valve in preventing the passage into the nostrils of what is swallowed. In the middle of the edge of the velum, a conical papilla, termed the *uvula*, is met with, and in the relaxed state hangs pendulous over the root of the tongue.

(610.) The *tongue* is a complex organ, principally consisting of a mass of muscular fibres, irregularly disposed, and crossing each other in a great variety of directions, and being also intermixed with a soft kind of fat. It is invested by a mucous membrane, being a continuation of that which lines the mouth generally, and which here presents large and numerous *papillæ*. These papillæ are distinguished by anatomists into three kinds, according to their size, form, and situation. The first class of these, called *papillæ maximæ*, *lenticulares*, or *capitatæ*, are by much the largest, have a lenticular form, with round heads and short stems. They are placed at the base of the tongue, in superficial fossulæ. They have been regarded as auxiliary salivary glands, and have each a perforation in the middle of their convex surface for the excretion of mucus. The second class, or *papillæ mediæ*, or *semi-lenticulares*, are much smaller than the former, and are scattered over the upper surface of the tongue, at some distance from each other; their form is cylindric, while some are terminated by a round, but not dilated extremity. Others are more or less tuberculated at the summit. The third class, or *papillæ minimæ*, which have also been termed *conicæ*, or *villosæ*, are exceedingly numerous, but of very minute size. They cover almost the whole of the upper surface of the tongue, but are most abundant towards the tip, where the sense of taste is most acute.

(611.) The membrane covering the root of the tongue abounds with *mucous follicles.* At the root of the tongue, and behind the papillæ maximæ, there is a hole or deep depression, called the *foramen cæcum Morgagni,* which penetrates only a small way into the substance of the tongue, and receives the mouths of several excretory ducts that open into it. A line is also observable running forwards along the middle of the tongue, from the foramen cæcum; this is the *linea linguæ mediana.* The tongue is somewhat restrained in its motions by the *frænum linguæ,* which is formed by a duplicature of membrane at its under part, connecting it with the jaw.

(612.) All sapid substances require, in order to produce an impression of taste, to be applied in a state of solution to the nerves of that sense. Nature has accordingly provided a fluid secretion for the purpose of effecting their solution, and diffusing them over a sufficient extent of the surface of the tongue. This secretion, which is the saliva, is prepared by the *salivary glands,* which consist of three large glands on each side of the face, namely, the *parotid,* the *submaxillary,* and the *sublingual.* The parotid is the largest of the three, and occupies the whole space between the ear and the angle of the lower jaw; its excretory duct, called *Steno's salivary duct,* passes off from the upper and fore part of the gland, and perforates the buccinator muscle, so as to open in the inside of the cheeks, opposite to the second or third molar tooth of the upper jaw. The *submaxillary,* or *inferior maxillary* gland, is situated on the inside of the angle of the lower jaw; its duct is called the *ductus Whartonii,* and it terminates by a small orifice on the surface of a papilla on the side of the frænum linguæ. The *sublingual gland* is still smaller, and is under the anterior portion of the tongue above the duct of Wharton, and its ducts open by several orifices arranged in a line near the gums, a little to the outside of the frænum. The smaller salivary glands of the mouth are very numerous, and are named from their situation, *buccales*, *labiales*, *palatinæ*, and *linguales*.

2. *Function of Taste.*

(613.) Attempts have often been made, but with no great success, to establish a classification of tastes. The general characters of the tastes denominated acid, sweet, bitter, saline, alkaline, aromatic, astringent, acrid, and spirituous, are sufficiently known, but their combinations are endless; and there exists besides these, a greater number of other tastes, which it would be impossible to reduce to any of the above classes.

(614.) The principle on which sapid bodies act upon the tongue is probably resolvable in all cases into chemical action. It is observed, accordingly, that substances which are in a solid form, and absolutely insoluble in the saliva, are invariably tasteless; just as in chemistry it is an established axiom that bodies do not act chemically unless they are either in a liquid or gaseous state. Mr. Mayo observes, that the sensations of taste are not perfect until the mouth is closed, and the tongue pressed against the palate, by which means the sapid liquid is brought into more exact contact with the surface of the tongue, and perhaps forced into the texture of its mucous membrane.

(615.) The organ of taste appears to be exclusively the upper and papillated surface of the tongue; for although the impressions of this sense are often referred to the palate, inside of the cheeks and gums, accurate discrimination shows that this reference to the parts against which the sapid body is pressed by the tongue, is deceptive, that the real seat of the sense is confined to the tongue itself, and that its immediate organs are the papillæ, and more particularly those denominated *conicæ* or *villosæ*, which are highly vascular and erectile, being observed to rise above the surface of the tongue when any sapid substance is applied to it. On the other hand, no papillæ are discoverable on the palate.

Some substances, such as peppermint, produce a pungent impression on the back of the fauces; and others, again, such as mezereon, excite in the same part a peculiar sense of irritation, which appears to proceed more from a generally acrimonious property, affecting particularly the nervous surfaces, than from any real sapidity; indeed, if the impressions made on the organs of smell be excluded from consideration, it will be found that the extent of the part of the tongue which really receives impressions of taste, is very limited. Mr. Mayo[1] states that salt, aloes, sugar, or acids, which excite the most acute sensation when applied to the tip or edge of the tongue, produce none at the fore or upper part of the organ, or on the hard palate. But at the back of the tongue they again excite sensation enough to be distinguishable, and they are still more perfectly tasted on the middle of the soft palate and uvula. The participation of the soft palate in the sense of taste has been recently pointed out by MM. Guyot and Admyrauld, and has been carefully verified by Mr. Wheatstone and Mr. Mayo. These

[1] *Outlines of Human Physiology.*

latter gentlemen did not find that one taste was perceived more distinctly than another, at any point of the tongue or soft palate.

There is no circumstance more remarkable, with relation to this sense, than its intimate connexion with that of smell, of which we are next to speak.

SECT. III.—SMELL.

(616.) The purpose answered by the sense of smell is apparently to guard against the introduction into the lungs of injurious effluvia, as that of taste is to watch over the qualities of the substances introduced into the stomach. Its seat is the Schneiderian membrane lining the cavity of the nostrils; and more particularly the turbinated bones, which are placed so as to catch the odorous effluvia directly as these enter the nostrils, and which, together with the cavities or sinuses in the contiguous bones, contribute to extend considerably the surfaces on which the impression of these effluvia is made.

1. *Organs of Smell.*

(617.) The organ of smell may be divided into the *external* and *internal parts.*

The external part, or *nose,* properly so called, consists principally of an upper bony portion commonly called the *bridge of the nose,* composed of the ossa nasi, supported by a vertical process from the æthmoid bone, together with the vomer, and an inferior cartilaginous portion, of which the middle prominence is called the *dorsum;* the rounded portions below are the *alæ nasi,* or wings; and the cartilage forming the partition between the nostrils is termed the *columna nasi.* These cartilages have a degree of elasticity which preserves the form of the organ.

The internal parts are contained in the cavities of the nostrils, which are divided by the *septum narium* into two lateral passages. In the upper part of each nostril, a spongy bone of a lengthened but irregular shape, the *os turbinatum superius*, which belongs to the æthmoid bone. Below this extends the *inferior turbinated bone*, so that the general cavity is divided by these bones into three passages for the air, running from before backwards; they have been respectively named by Haller the *meatus narium superior, medius, and inferior.*

(618.) The extent of the cavities belonging to the nose is much increased by their communicating with various sinuses, or cavities in the neighbouring bones, namely, the *frontal*, *sphenoidal*, and *maxillary sinuses.* Posteriorly the nostrils open into the pharynx, by two orifices, termed the *posterior nares.* All these cavities, together with the sinuses with which they communicate, are lined with a sensible and delicate mucous membrane, termed the *pituitary membrane*, or sometimes, from the anatomist who first accurately described it, the *membrana Schneideriana.* The lower part of the lacrymal sac becoming somewhat narrower, but without forming any valve, passes into the nose, under the name of *lacrymal duct*, *canalis nasalis*, or *ductus ad nasum.* At the posterior part of the nares is the opening of the Eustachion tube, leading to the tympanic cavity of the ear.

2. *Function of Smell.*

(619.) The impressions made on the two senses of taste and smell, have not only a great affinity to each other, but also an intimate connexion; inasmuch as many of these referred to the organ of taste are in reality made on the organ of smell, and are not perceived at all if the nostrils be closed, and the odorous effluvia arising from the substance placed on the tongue be consequently prevented from ascending, and acting on the sentient membrane lining their cavity. When the Schneiderian membrane is inflamed, the taste of all those substances, of which the flavour consists in their scent alone, is altogether lost; and as this is the case with by far the greater number of substances employed as food, the sense of taste appears, under these circumstances, to be very imperfect. Both these senses, but particularly that of smell, are possessed by man in a degree very inferior to that in which they exist in the lower animals.

(620.) It is essential to the exercise of this sense, that the membrane of the nostrils should be in a moist state; for when it happens to be dry from a deficiency of secretion, the extremities of the olfactory nerves are unfitted for the reception of the impression of odours. It is also necessary for smelling that the air charged with the odorous effluvia should impinge with some degree of force against the Schneiderian membrane.

The seat of greatest sensibility to odours is the upper part of the nostrils; and the form of the nose and of its apertures are obviously adapted to direct the stream of air towards those parts. It is found, accordingly, that when the nose has been destroyed by disease, the smell is greatly impaired, if not altogether lost.

(621.) Odours as well as tastes have been attempted to be classed. Linnæus distributed them into seven classes: 1. *ambrosial*, of which the smell of the rose and musk are examples; 2. *fragrant*, as the smell of the lily, of the jasmin, and of saffron; these are more evanescent than the former ; 3d. *aromatic*, as the smell of the laurel ; 4. *alliaceous*, partaking of the odour of garlic ; 5. *fœtid*, exemplified in valerian and mushrooms ; 6. *virous*, or narcotic, as in the smell of opium ; 7. *nauseous*, as that of the gourd, melon, and cucumber. But this classification is obviously incomplete, as it omits several very distinct classes of odours, such as that of alcohol, of æther, of camphor, of ammonia, of chlorine, &c.

(622.) Any very acrid or stimulating vapour admitted to the nostrils, instead of producing the sensation of smell, gives rise to mere painful irritation, which excites sneezing, and a copious secretion of mucus.

SECT. IV.—HEARING.

1. *Acoustic Principles.*

(623.) The object of the sense of hearing is to convey to us certain impressions made on the nerves of the ear by the vibrations of the air; which vibrations are the result of some mechanical impulse communicated to it by the motion of a body at a distance. Other media besides air are also capable of transmitting sonorous vibrations to the organ of hearing; thus water is known to convey sounds to great distances; and solid bodies possess the same power in a degree proportioned to their molecular elasticity. If the body which is the source of sound be insulated from any such medium, its vibrations cannot be communicated, and no sound is heard. Thus if a bell be placed in the receiver of an air-pump, in proportion as the air is exhausted the sound it produces when struck becomes more and more faint, till at length, when the rarefaction has been carried a certain length, it is quite inaudible. If the same bell be placed in a vessel of condensed air, the sound it gives out will be louder than in air of the ordinary density.

(624.) The velocity with which sound is transmitted in air of the same density is uniform at all distances, and for all sounds whatsoever. As the air of the atmosphere varies in its density, and also in its degrees of humidity, the velocity of sound is not constantly the same. It may be taken at an average as being 1100 feet in a second, or nearly thirteen miles in a minute.

2. *Organ of Hearing.*

(625.) The organ of hearing is divided into the *external* and the *internal ear.*

(626.) The *external ear,* comprehends the *auricula,* or ear, properly so called, and the *meatus auditorius externus.*

(627.) The auricula is chiefly composed of an *elastic cartilage* bent into various folds and hollows, and covered with a thin layer of common integuments, the lower fold of which, enlarged by the addition of cellular substance, forms the depending part called the *lobe of the ear.* The cartilaginous portion is termed the *pinna,* or *ala.* Its outer circle, or prominent margin, is called, from its winding direction, the *helix.* The semicircular ridge within this is the *antihelix;* and the small protuberance, in which the helix appears to terminate below at its inner edge, is called the *tragus,* from its being frequently covered with hair. Another eminence, nearly opposite to this, below the anterior extremity of the antihelix, and projecting outwards over the hollow of the ear, is called the *antitragus.* Between the helix and antihelix, is the cavity called the *scaphus,* or *fossa navicularis.*

(628.) The *concha* is a large depression under the antihelix, and divided into two parts by the helix. The lower of these leads to the *meatus auditorius*, a passage which at its commencement is composed of cartilage, and farther on is joined to the orifice of the same name in the temporal bone. The cartilaginous tube is lined by a soft membrane, giving rise to hairs, and containing small glands, the *glandulæ ceruminosæ*, which secrete the wax of the ear. This cartilaginous portion of the ear is attached to the temporal bone by several ligaments and muscles; the effects of which in moving the different parts of the external ear are in general very little sensible.

(629.) The membrane lining the meatus is continued along the osseous portion of the canal, which is closed by the *drum* of the ear, or *membrana tympani*. This is a firm, oval, and almost transparent membrane, fixed in an osseous groove at the bottom of the meatus, across which it lies in an oblique position. It is slightly concave on the external side; and is capable of being stretched or relaxed by the action of particular muscles.

(630.) The membrane of the tympanum divides the external from the internal ear. Behind it we find an irregular cavity, called the *tympanic cavity*, or *cavity of the tympanum*, which is filled with air; it is about seven or eight lines wide, and about half that space in breadth; and is every where lined by a fine membrane. It has four openings; the first is the small orifice of a passage of communication with the back of the cavity of the nostrils, which is called the *Eustachian tube*, and is shaped like a trumpet, expanding as it approaches the fauces. The second aperture leads to a number of irregular cells, formed in the mastoid process of the temporal bone, and called the *mastoid cells*. At the back part of the tympanum we find an oval opening, called the *fenestra ovalis*, and below this a round perforation, termed the *fenestra rotunda*. Between these fenestræ, is a bony eminence, called the *promontory*.

(631.) Within the cavity of the tympanum are contained four small bones, the *ossicula auditus*, placed in a series or chain extending across from the membrana tympani to the fenestra ovalis. The *malleus*, or hammer, is the first of these bones ; a long pointed process from which, namely, the *processus brevis*, or handle, is fixed to the membrana tympani. It is articulated by its round head with the next bone, the *incus*, or anvil, which much resembles in its shape a molar tooth, having a body and two unequal crura. With the longest of these processes is articulated the *os orbicularis*, of a rounded figure, and smaller than a grain of mustard seed. It forms the medium of connexion between the incus and the *stapes*, which is the last bone in the series, and is so named from its striking resemblance in form to a stirrup. The base of the stapes is fixed to the margin of the fenestra ovalis, which it accurately closes. The articulations of these minute bones are furnished with capsular ligaments, and all the apparatus of the larger joints ; appropriate muscles being also provided for their movements. Between the malleus and the incus, there passes a small nervous cord, which crosses the tympanum, and is accordingly named the *chorda tympani*.

(632.) The principal cavity of the organ of hearing is situated still more internally, and from the intricacy of its winding sinuosities it has received the general name of *the labyrinth*. All its cavities and passages are lined with a very delicate periosteum, and filled with a watery fluid, and within them is suspended a pulpy membrane of a similar shape, on which are distributed various nervous filaments presently to be described. This saccular-shaped membrane is termed by Breschet the *membranous labyrinth*, in order to distinguish it from the osseous labyrinth, in which it is contained. It forms one continuous closed sac extending within the vestibule and canals, excepting those of the cochlea; and contains a fluid, perfectly similar to the perilymph, and termed by Blainville, *vitrine auditive*, which, intervening between it and the osseous parietes of the labyrinth, surrounds it on all sides, and prevents its coming in contact with those bones.

The central cavity, in which all these passages meet, is termed the *vestibule*; it is of an oval figure, and is situated nearly in the centre of the os petrosum, and at the inner side of the fenestra ovalis. On the side of the vestibule next to the mastoid process, there are five orifices leading to the three *semicircular canals*, as they are called, or passages formed within the substance of the bone. The extremities of two of these canals unite, and terminate by a common opening; hence there appear in the vestibule only five openings, instead of six. These canals are distinguished by the names of the *superior*, or vertical, the *posterior*, or oblique, and the *exterior*, or horizontal. They each form a curvature of more than three-fourths of a circle, and have an enlargement, termed *ampulla*, or *cavitas elliptica*, at one end, the other extremity being nearly of the same size as the rest of the canal.

(633.) The *cochlea*, which is the third division of the labyrinth, has a conical shape, and is situated at the anterior part of the os petrosum, and at the fore-part of the vestibule, with its base towards the meatus auditorius internus, and its apex in the opposite direction; that is, facing outwards. It contains a double spiral passage, winding round like the shell of a snail. This passage begins by a round hole from the vestibule, and after forming two turns and a half, becomes suddenly smaller on arriving at the apex, where it communicates with a similar tube which takes its rise at the base of the cochlea from the fenestra rotunda, formerly noticed as one of the apertures of the cavity of the tympanum; but which is closed by a membrane. The partition which divides these two winding passages is called the *lamina spiralis*, or *septum scalæ;* for the passages themselves are known by the name of the *scalæ cochleæ;* that which communicates with the vestibule being distinguished as the *scala vestibuli*, and the other, from its connexion with the tympanum, the *scala tympani*. The central bony pillar, around which these turns are made has a horizontal direction, and is called the *modiolus*. It has the shape of a cone, at the apex of which is situated another hollow cone in a reverse position termed the *infundibulum*, which, however, is an imperfect funnel, having a common apex with the modiolus, and its base being covered by the apex of the cochlea, which is called the *cupola*.

(634.) It has been supposed that when the fluid in these cavities is in too great a quantity, the superfluous portion is carried off by two minute canals or *aqueducts*, discovered by *Cotunnius*, and bearing his name. One of these opens into the bottom of the vestibule, and the other into the cochlea, near the fenestra rotunda. They bear the names respectively of *aquæductus vestibuli* and *aquæductus cochleæ*. They both pass through the os petrosum, and communicate with the cavity of the cranium.

The form of that part of the membranous labyrinth which occupies the cavity of the vestibule, and which has accordingly received the name of the *membranous vestibule*, though having a general resemblance to that of the cavity itself, yet differs from it in some degree, being composed of two sacs opening into each other. One of these sacs is termed the *utricle;* and the other the *sacculus.* Each sac contains in its interior a small mass of white calcareous matter resembling powdered chalk, and which seems to be suspended in the fluid contents of the sac by means of a number of nervous filaments, derived from the acoustic nerves, and of which they appear to be the ultimate ramifications.[1]

(635.) Through an opening at the base of the modiolus, a branch of the auditory nerve, which has entered by the meatus auditorius internus, passes into the funnel-shaped cavity, and is thence extended through the spiral canals; while another branch passes backwards through the vestibule, and dividing into several branches, enters the orifices of the semicircular canals. The minute branches perforate a part of the bone, which has been termed from its appearance, the *cribriform plate.*

3. *Function of Hearing.*

(636.) We thus see that the ear is an organ extremely complicated in its structure, evidently intended to convey the sonorous undulations of the air, after they are collected by the more external parts of the organ, to the branches of the auditory nerve, which are spread over the membranes lining the different cavities of the labyrinth, and the cretaceous bodies suspended within those membranes. We may therefore distinguish the several parts of the apparatus employed for this purpose, according as they are merely de-

[1] The most accurate and complete description of the anatomy of the ear, is that given by Breschet, *Sur les Organes de l'Ouie,* which first appeared in the *Annales des Sciences Naturelles,* xxix. 129. A compendious account is contained in Dr. Roget's *Bridgewater Treatise,* ii, 420.

signed to collect the aerial undulations, and increase their intensity by concentrating them into a smaller space; or according as they contain the expanded nerves on which the impression is ultimately made. It appears that the medium by which this last effect is produced, is the perilymph, or fluid filling the cavities of the labyrinth, and containing the exquisitely delicate membrane and cretaceous bodies on which the extreme fibrils of the auditory nerve are expanded. This fluid is put in motion by the air in the cavity of the tympanum, and thrown into corresponding undulations.

(637.) The accessory parts of the organ of hearing may therefore be divided into three parts. There is, first, the external ear, which is an elastic cartilaginous appendage to the organ, curiously grooved, so as to form a series of parabolic curves, adapted to receive the undulations of the air, and convey them into the passage of the meatus externus, serving apparently an office similar to that of the expanded part of a trumpet. The sonorous undulations are thus made to strike against the membrane of the tympanum, or ear-drum, which is stretched across, and closes the passage. The cavity behind this membrane is filled with air, which is next thrown into undulations by the medium of the ear-drum, the vibrations of which have been excited by those of the external air. In order to preserve an equilibrium between the air in the cavity of the tympanum and the external air, so that the membrane may not sustain a greater pressure on one side than on the other, a communication is kept open with the back part of the throat by means of the *Eustachian tube*. Hearing is always much impaired, if from any cause the Eustachian tube is obstructed, as it sometimes is by a common cold, which then produces a temporary deafness.

(638.) The cavity of the tympanum is of a very singular form, extending into the mastoid process of the temporal bone, which has a cellular structure. A chain of minute bones, the ossicula auditus, extends, as we have seen, across the cavity, terminating at the fenestra ovalis, or aperture leading to the vestibule; while another aperture, the fenestra rotunda, also closed by membrane, leads to one of the spiral turns of the cochlea. Thus, the fluid in the labyrinth receives from the impulses made on these two membranes, which are situated in two different planes, a double undulation; and these two undulations, the one circulating along the semicircular canals, the other through the spiral turns of the cochlea, probably unite at some focal spot, like the meeting of two tidal waves, and increase the effect produced. These undulations must of course be variously modified, according to their frequency, and the order of their succession, and the impressions made on the nerve must undergo corresponding modifications. But we are so completely in the dark as to the real office of the several parts of this elaborately constructed organ, that it is exceedingly difficult to prosecute the physiology of this sense with such imperfect data. We are unable even to form a rational conjecture as to the offices of the delicate muscles provided for directing the movements of those ossicula, which are articulated with such great nicety, and which seem calculated to alter the tension of the membrana tympani, and bring it into a state capable of vibrating in unison with the sonorous undulations that impinge upon it. What adds in no small degree to our embarrassment, is the knowledge we have acquired of the power of hearing being retained, without apparent diminution, when the greater part of this apparatus of bones, with their joints and muscles, and even the ear-drum itself, has been destroyed by accident or disease.[1] It should be observed, however, as Mr. Mayo[2] remarks, that the stapes is so strictly applied to the membrane of the fenestra ovalis, that the loss of this bone necessarily produces incurable deafness, by the attendant injury of the labyrinth.

(639.) Sir Everard Home imagined that the muscular structure of the membrana tympani, enabling it to contract or relax according to circumstances, so as to vibrate in unison with the musical notes which reached the ear, conferred the power of distinguishing musical tones. But this ingenious hypothesis is completely overturned by the fact above stated, of the integrity of the membrane of the tympanum not being necessary for the perfect accuracy of the sense of hearing, even with relation to the distinction of musical sounds. Dr. Young thinks it probable that the semicircular canals which are disposed in a remarkable manner in three orthogonal planes, corresponding to the three dimensions of space, enable us to estimate the acuteness or pitch of a sound; and that the cochlea serves the office of a micrometer of sound.[3] But the grounds of these opinions are too vague and conjectural to inspire us with any confidence in their solidity. When the external passages are totally obstructed, sonorous vibrations may still be transmitted to the auditory nerves by means of the bones of the head. Thus, the sound of a tuning fork applied to the teeth, or even to other parts of the head, is perfectly audible under these circumstances. We thus possess a criterion for de-

[1] See two papers by Sir Astley Cooper, in the *Philosophical Transactions* for 1800, p. 151; and for 1801, p. 437.

[2] *Outlines of Human Physiology*, 3d edition, p. 221, note.

[3] *Medical Literature*, p. 98; and *Lectures*, vol. i. p. 387.

termining, in cases of deafness, whether the disease consists in the insensibility of the nerves to these impressions, or is seated in the passages leading to the labyrinth.

SECT. V.—VISION.

(640.) The physiology of the eye is more interesting than that of any of the other organs of the senses; because, from the knowledge we possess of the laws of optics, to which it is so admirably adapted, we can understand the offices of its several parts, and the mode in which they concur in the production of the resulting effect. The study of the eye has been said to be the best cure for atheism; and it furnishes, indeed, the most striking and unequivocal proofs of the existence of design and intelligence in the construction of the animal fabric. These proofs have accordingly been always amongst those most prominently adduced by philosophers in support of the arguments of natural theology.

(641.) The organs subservient to vision are lodged securely in the bony cavities of the orbits, where the surrounding bones protect them on every side, excepting in front. They may be divided into the internal and the external parts; the former consisting of the spherical bodies denominated the *globes of the eye*, or *eye-balls*; and the latter comprising parts which give motion to the globe, and otherwise assist it in its functions.

1. *Internal parts of the Eye.*

(642.) The eye-ball is composed of segments of two unequal spheres; one of which, constituting about four-fifths of the whole, forms the portion which is within the orbit; while the other fifth is that part which is seen in front, and which, being a portion of a smaller sphere, is more protuberant. The diameter of the eye-ball, from behind forwards, is accordingly longer than its transverse diameter; the proportion being that of twenty-five to twenty-three.

(643.) The eye-ball is made up of coats and humors. The former consist of the *sclerotica*, *cornea*, *choroides*, and *retina*, together with the *conjunctiva*. Of the latter there are three, viz. the *vitreous*, *crystalline*, and *aqueous humors*.

(644.) The *sclerotica*, which is the exterior coat, is, from its compact fibrous texture, the densest and strongest, as well as the thickest of the tunics of the eye, and the one from which the other parts of the eye-ball derive their principal support. It covers all that portion of the globe of the eye, which has already been pointed out as constituting its largest segment. At its anterior edge it is joined to the more convex tunic, which completes the figure, and is named the *cornea*, from its being composed of a great number of concentric laminæ, of a horny elastic texture. Some authors have given it the name of the *cornea lucida*, from its perfect transparency, and by way of contrast to the sclerotica, which they had named the *cornea opaca*.

(645.) The *choroid coat*, or *tunica choroides*, lies immediately within the sclerotica, and is composed of a congeries of blood-vessels connected together by membrane. It has been distinguished into two layers, the innermost of which has been termed the *tunica Ruyschiana*. At the middle of the choroid coat are observed numerous vessels convoluted into a spiral form. These have been termed the *venæ vorticosæ*. The internal surface of the tunica Ruyschiana, or *tapetum*, as it has been called, seems, from its villous or fleecy appearance, to be a secreting surface. It is everywhere lined with a black or deep-brown mucous substance, included in a fine cellular tissue. This is the *pigmentum nigrum,* which forms a layer, separating the choroides from the next coat, or *retina.* This latter tunic is an expansion of the pulpy substance of the optic nerve, spread over a fine membrane. The optic nerve, from which this medullary matter is derived, enters the eye at its back part, at a point nearer to the nose than the centre, or axis of the eye, and perforates the sclerotic and choroid coats.

(646.) From the inner margin of the junction of the cornea and sclerotica, there extends across the fore part of the globe of the eye a membranous partition, called, from the variety of its colour, the *iris;* it is perforated in the centre by an aperture, called the *pupil,* because, as it is said, it represents objects no larger than a pupilla, or puppet. The structure of the iris is exceedingly peculiar; it appears to be made up of a number of fibres, which pass from the inner to the outer margin in a radiated direction, together with others which run circularly. These fibres have been presumed to be of a muscular structure; but doubts are still entertained with regard to this point. The posterior surface of the iris is lined with a pigment similar to that which is found within the choroid coat. It has been called the *uvea,* from its fancied resemblance in colour to the grape.

(647.) The iris is connected with the choroid coat by an intermediate structure, called the *ciliary ligament, ciliary circle,* or *orbiculus ciliaris,* which is a circular belt, more than a line in breadth, made up of a soft and pulpy tissue, and of a whitish colour. It is also at this part that the choroides adheres firmly to the sclerotica. From this part, also, there extends inwards a dark coloured ring, which is a continuation of the choroides, and is termed the *corpus ciliare.* It is about the sixth part of an inch in breadth towards the temple, but somewhat narrower towards the nose. It is covered in every part by the pigmentum nigrum. It is marked by radiated striæ at its inner part, but they are somewhat obscured by the pigmentum nigrum. At the outer part these striæ become gradually broader and more elevated, and appear like folds, only the intervals between them being covered with the pigment. These folds are termed the *ciliary processes*. Each of these processes is of an irregular triangular figure, with the base outwards, or at the ciliary circle, and its apex inwards, or towards the axis of the eye. Their number is generally about sixty, and they are alternately longer and shorter.

(648.) About three-fourths of the globe of the eye, within these several tunics, is filled by a very transparent and gelatinous humor, which, from its supposed resemblance to melted glass, has been termed the *vitreous humor*. It is nearly of the consistence of the white of an egg, and consists of a fluid substance contained in the cells of a very fine and delicate cellular tissue, called the hyaloid membrane. It is invested by a transparent membrane, termed the *tunica vitrea*, or *capsule* of the vitreous humor. The anterior surface of the vitreous humour is depressed, for the lodgment of the *crystalline lens*, or *humor*, which is a dense body, perfectly transparent, and has the shape of a double convex lens, of which the posterior surface has a greater convexity than the anterior surface. The lens is composed of a great number of concentric laminæ, which become more and more dense towards the centre, and each lamina is made up of very distinct parallel fibres. It is enclosed in its own peculiar *capsule*, in which it appears to float loosely, a watery fluid, called the *liquor Morgagni*, being interposed.

(649.) The fore part of the eye-ball, between the crystalline lens and the cornea, is filled by a watery fluid, called the *aqueous humor*, in the middle of which the iris is suspended, thus dividing the space into what are called the *anterior* and *posterior chambers* of the aqueous humor. The aqueous humor, like the other humors, is contained within a delicate membrane, which lines the inside of the cornea, and passes over the crystalline lens and the convex margin of the vitreous humor.

(650.) The capsule of the lens adheres closely to the tunica vitrea. Behind the edge of the former, and between the margin of the ciliary zone and capsule of the vitreous humor, a triangular passage is formed, called from its discoverer, the *circle of Petit*, or *canalis Petitianus*. When air is blown into this passage, it passes freely round the edge of the lens.

(651.) At that part of the retina which is situated in the axis of the eye, there is a small circle, where the retina is transparent, giving rise to the appearance of a hole, as if the retina were deficient in that part. It was discovered by Soemmerring, and bears the name of the *foramen centrale of Soemmerring*. It is surrounded by a yellow circle, about a line in diameter. The fibres of the optic nerve, in passing to form the retina, perforate a thin plate of membrane which is extended from the sclerotica, and which is termed the *lamina cribrosa*. The centre of the optic nerve is perforated by the *arteria centralis retinæ*, forming an aperture which has been called the *porus opticus*.

2. *External parts of the Eye.*

(652.) The orbit is a conical cavity, in the fore part of which the globe of the eye is situated, the remaining space behind the globe being chiefly filled with fat, which surrounds the optic nerve, and intervenes between it and the straight muscles that extend between the margin of the foramen opticum, through which the optic nerve passes out of the skull and the fore part of the sclerotic coat, where they are inserted by broad and flat tendons. These tendinous expansions have been improperly considered as composing one of the tunics of the eye, which being of a white colour, has received the name of *tunica albuginea*.

(653.) The globe of the eye is covered at the fore part by two eye-lids, or *palpebræ*, which are composed of muscular fibres, covered by the common integuments, supported at their edge by a cartilage called the *tarsus*, and furnished with a row of hairs, termed *cilia*, or eye-lashes. At the roots of the eye-lashes are sebaceous follicles, named from the anatomist who first observed them, the *glandulæ Meibomii*, and which secrete a glutinous liniment. The eye-lids are lined on their interior surface by a very fine and smooth serous membrane, which is reflected over the anterior part of the globe of the eye, and even over the surface of the cornea. This membrane is called the *tunica conjunctiva*.

(654.) Between the ball of the eye and the upper vault of the orbit, on the temporal side, lies the *lacrymal gland*, which secretes the tears. It is composed of a number of small, whitish, granular bodies, which are collected together into two lobes. There is also a chain of smaller glands lying between the principal gland and upper eye-lid, and connecting them together. The excretory ducts from all these glands are exceedingly minute, and terminate in the inner surface of the upper eye-lid, near the outer angle of the eye. After moistening the surface of the eye, the tears are again collected by two small orifices, called the *puncta lacrymalia*, placed on a small eminence in each eye-lid, near the inner angle of the eye, at the extremity of the tarsus. They are the beginnings of two small canals that run in the direction of the edges of the eye-lids, towards the side of the nose, where they approach each other, and terminate together in the *lacrymal sac*, which is a membranous bag situated on the os unguis, and leading to a passage into the cavity of the nostrils. The puncta are kept separate by the interposition of a small reddish body, called the *caruncula lacrymalis*, situated between the inner angle of the eye-lids and the ball of the eye. Minute hairs are found upon the surface of this body, which serve to entangle small objects which might otherwise get into the eye. There is also a reduplication of the tunica conjunctiva, shaped like a crescent, and hence termed the *valvula semilunaris*, the points of which are directed towards the puncta, and which assists the caruncle in directing the tears to the puncta.

Having thus described the apparatus for vision, we shall now proceed to consider the mode in which that function is performed.

3 *Optical Principles.*

(655.) The object of this sense is to convey to us a knowledge of the existence and visible qualities of distant objects, by means of the light which they send to the eye. This is accomplished by altering the natural direct course of these rays, so that they may form a distinct image of these objects on the retina. That such images are actually formed on the retina may be easily shewn in the eye of an animal recently killed, by carefully removing the opaque sclerotic and choroid coats, together with the black pigment from the back of the eye, so as to expose the retina. The objects on the other side, in front of the cornea, will then be seen beautifully depicted on the retina, their images being inverted; precisely in the same way, and on the same principles as they are seen in a simple camera obscura.

(656.) In order to understand and trace the operation of the principles concerned in these phenomena, it will be necessary to refer to the laws of optics.

The rays of light in traversing any medium of uniform density, move always in straight lines; but when the density changes they deviate somewhat from this rectilinear course, according to the direction of the ray with respect to the planes in which the change of density occurs. Thus a ray from the sun, or other celestial body, traversing obliquely through our atmosphere, the different strata of which are of increasing density as they come nearer to the earth, is gradually bent in its course, and arrives at the surface of the earth in a direction somewhat nearer to a perpendicular line than if there had been no atmosphere. This deflexion from a straight line is termed *refraction*. Refraction takes place suddenly, if the ray passes abruptly from one medium to another, which sensibly differs from it in its density; the direction of the deflexion being always towards the denser medium; or, to speak more accurately, towards a line drawn perpendicular to the surface common to the two media, and situated in the denser medium.

(657.) In the case of the passage of a ray through the surface of a new medium of very different density from the first, another phenomenon takes place; the ray is decomposed, part being transmitted and refracted, while another portion is turned completely back into the medium it was already traversing. This is termed *reflexion*. Objects which are not luminous in their own nature are rendered visible only by the reflexion from their surfaces of the light which they receive from other bodies. The law in this case is, that the angle of reflexion, by which is meant the angle which the course of the reflected ray makes with a line perpendicular to the surface, is equal to the angle of incidence, or the angle which the incident ray makes with that same perpendicular; and also, that it is in the same plane with the incident ray, and the perpendicular line.

(658.) The law of refraction is, that the course of the refracted ray is deflected towards that part of the perpendicular which is situated in the denser medium, and that the sine of the angle of refraction, (or the angle it makes with the perpendicular) has to the sine of the angle of incidence the same constant ratio. This ratio increases in proportion to the difference there is between the two media in respect of density.

4. *Formation of Images in the Eye.*

(659.) It follows as a consequence of the above laws, that a pencil of rays proceeding through the air, and falling on the convex spherical surface of a medium of greater density than the air, (as is the case with the cornea of the eye,) is so refracted as to be collected, after proceeding a certain distance, into one and the same point. This will readily appear when we consider that those rays fall with more obliquity on the cornea, according as they are more distant from the central ray of the pencil, or that which may be conceived to fall perpendicularly on its surface. These more oblique rays are consequently more refracted; that is, more bent from their original course; and this law being observed throughout the whole pencil, all the rays will tend after refraction to the same point, which point is called the *focus* of that pencil of rays.

(660.) The same process taking place with regard to all the other pencils of rays proceeding respectively from the several points of the objects viewed, and each being collected into separate points in different parts of the retina which receives them, images of those objects will be delineated on that membrane; for it is evident that all the focal points will have, with respect to one another, the same relative positions as the points of the external objects from which each pencil of rays proceeds, when referred to the sphere of vision. The impression thus made on each respective point of the retina, is transmitted to the sensorium, where it makes a distinct impression, and gives rise to the sensation of light and colour; and in conjunction with the experience gradually gathered from the sense of touch, imparts to us a knowledge of the existence, relative situation, form, magnitude, distance, and colour of the objects before us. This, then, is vision.

(661.) Such is the general outline of the mode in which vision is accomplished; but there are a thousand beautiful contrivances and adjustments provided for ensuring the accuracy with which this picture of the surrounding scene is portrayed on the retina. The perfection of vision is entirely dependent on the distinctness, the vividness, and the fidelity of this picture; and the whole apparatus of the eye is calculated to obtain these qualities.

(662.) The purposes served by the apparatus external to the globe of the eye, are sufficiently obvious. The effectual protection given to the eye by the arched form of the bones which compose the orbit,—the provision of a soft cushion in the fat which occupies the bottom of the cavity,—the beautiful contrivance of the eye-lids, which, on the least appearance of danger, are ever ready to close upon the organs they are appointed to guard,—and even the direction of the eye-brows, intended to divert the course of the perspiration from the forehead, are all calculated to call forth our admiration, because the end to be answered being obvious, we can judge of the fitness of the means for the accomplishment of those ends. A still further proof of exquisite design offers itself in the lacrymal apparatus, which provides the means of preserving the surface of the cornea always clean and transparent, and fitted for its office of regularly refracting the rays of light.

(663.) The humors of the eye, through which the light passes before arriving at the retina, have different degrees of density, and consequently have different degrees of refractive power. The first and greatest refraction of the rays takes place at the outer surface of the cornea; the next is at the inner surface, where the rays meet with the aqueous humor. Now this humor is rather less dense than the cornea, and consequently the rays already refracted, and rendered convergent by the cornea, have their convergence slightly diminished, when they traverse the aqueous humor. These, in fact, are converging towards points at some distance beyond the retina. The iris is interposed in the course of the rays while they are passing through the aqueous humor; the circular aperture of this membrane, the pupil, admitting only the more central portion of each pencil of rays. By intercepting the extreme rays, which, in consequence of a peculiarity in the law of spherical refraction, hereafter to be explained, would, if allowed to reach the retina, somewhat confuse the image, greater clearness of that image is obtained, at the sacrifice, indeed, of a portion of brightness. It serves, accordingly, the same purpose with regard to the eye, which the circular ring, placed in the interior of a telescope, effects in contracting the aperture of the instrument; rendering the image more distinct, though less illuminated than it would otherwise be. But the iris has this great superiority over the circle in the telescope, inasmuch as it is capable by its contractile power of enlarging or diminishing the aperture of the pupil, as occasion requires. Thus, when the object viewed is but faintly illuminated, the pupil is enlarged, and admits more light, thus giving greater brightness to the picture; an advantage which more than compensates for the slight indistinctness of the fainter images composing that picture. When, on the contrary, an object is too bright, so that its image would produce too vivid an impression on the retina, the pupil immediately contracts, so as to reduce the quantity of light admitted into the interior of the eye, and to prevent any injurious effect upon the retina.

5. *Adjustments for the Correction of Aberration.*

(664.) That part of the converging pencil of rays, which is admitted through the pupil, falls upon the anterior convex surface of the crystalline lens, which being denser than the aqueous humor, occasions a new refraction of the rays, and gives them an increased degree of convergence, so that they now tend to foci nearer to the retina than before, though still somewhat beyond it.

(665.) An exquisite provision is found in the peculiar structure of the lens for correcting what is termed the *spherical aberration*. It is a necessary consequence of the mathematical law of refraction, that in a pencil of rays falling on the convex spherical surface of a denser medium, those rays which are farthest from the central ray, will be bent somewhat more than is requisite to bring them to the same focal point as the rays which are nearer to the centre of the pencil; hence all the rays can never be collected accurately into the same point; although in ordinary optical instruments, such as common telescopes, and camera obscura, the aberration thus resulting is confined within such narrow limits as not to produce any very great inconvenience. But in the eye even this minute defect of ordinary optical instruments is remedied. The lens is composed of successive laminæ, increasing in their density and refractive power, in proportion as they approach the centre; that central part being the hardest and densest of the whole. The central rays of each pencil, therefore, are subjected to a greater refractive action than the more exterior rays, and the whole are brought accurately to convergence at the same focal point.

(666.) After passing through the crystalline lens, the rays enter the vitreous humor, where, again, there is a change of density in the medium. The density of the vitreous humor is less than that of the lens; and were its surface convex, the convergence of the rays would be diminished by the refraction they would then experience; but the surface being concave, the refraction contributes still farther to increase the convergence of the rays, which now traverse the aqueous humor, and are collected accurately into their respective foci on the retina itself.

(667.) Rays proceeding from objects at different distances from the eye, will arrive at the cornea with different degrees of divergence, and the same refractive powers of the humors would cause them to converge at different distances; in order, therefore, to obtain distinct images of these objects on the retina, either the distance of that membrane from the cornea must be altered, or the refractive power of the humors must be changed. Thus, if the power of the eye at any one time be suited to distinct vision of distant objects, near objects will appear confused, from the indistinctness of their images on the retina; because the focus of convergence of the rays proceeding from those objects is farther back than the situation of the retina. If, either by elongating the axis of the eye, the retina could be removed to this new focal distance, or else by increasing the refractive power of the humors, the rays could be made more convergent than before, we should again obtain distinct images of those near objects on the retina; but then the images of distant objects would, at the same time, and from the contrary cause, be indistinct; and in order to give distinctness to these, the contrary changes are required to be made in the eye to those already mentioned. Now, it is found that the eye really possesses the power of accommodation here described, adapting itself, by some internal changes, to the vision of both near and remote objects, according as the attention is directed respectively either to the one or to the other.

(668.) The effort by which the eye changes its internal state, so as to accommodate its powers to the vision of near objects, after having viewed those more distant, is always attended with a contraction of the pupil; and the exclusion of the remoter rays, consequent upon this diminution of aperture, must partly contribute to the greater distinctness of the images, by excluding the rays near the circumference of each pencil. But it is certain that the refractive powers of the eye are also increased; and it is a question of considerable difficulty to determine the manner in which this increase is effected. Sir Everard Home[1] supposed that it was accomplished by the joint actions of the straight muscles which surround the ball of the eye, and which, by compressing it all round its sides, might elongate its axis and increase the distance of the retina from the cornea, while they at the same time would make the cornea more convex, by drawing back its circumference, and thus rendering its central part more protuberant. This plausible theory is overturned by the fact discovered by Dr. Young,[2] that when the effect of any change in the curvature of the cornea is removed by placing the eye under water, the eye still retains its power of accommodation to the vision of objects at different distances, by changes which take place in its refractive powers.

(669.) The most probable supposition relative to this operation is, that the ciliary ligament has the power of contracting at the same time with the sphincter of the iris; a change which will be attended with the effect of bringing the lens somewhat forwards, and of increasing the convexity of its surfaces, while the convexity of the cornea will also be increased. Any cause which produces the contraction of the pupil, such as a bright light, enables the eye to adjust itself more rapidly to vision at a shorter distance; and on the contrary, the suspension of this power of contraction of the circular fibres of the iris, occasioned by belladonna, is accompanied by the total but temporary loss of this power of adjustment. Those who, by frequent practice in experimenting on their own eyes, have acquired a considerable voluntary power of changing the refracting condition of the

[1] See *Philosophical Transactions* for 1794, p. 21; 1795, p. 1; 1796, p. 1; 1797, p. 1.

[2] *Ibid.* for 1793, p. 169; and for 1801, p. 53.

eye, even although there be no object before the field of vision requiring such change, when they exert this power, also contract the pupil, which by this means indirectly acquires the character of a voluntary muscle; although in other respects, and with other persons, it is strictly to be ranked in the class of the involuntary muscles. The writer of this treatise possesses this power, and has given an account of the circumstances attending its exertion in a letter to Mr. Travers.[1]

(670.) The same gradation of density in the successive laminæ of the crystalline lens, and the consequent successive refractions of the rays effected by the several humors of the eye, have also the effect of correcting the dispersion of light, arising from the difference in refrangibility of the differently coloured rays. The eye, in addition to its other perfections, has the properties of an achromatic optical instrument, correcting the confusion of colour in the images it forms on the retina.

(671.) All extraneous light, which might be reflected from one part of the eye to another, and might be mixed with the rays which should exclusively form the image on the retina, is absorbed by means of the *pigmentum nigrum*, which is placed immediately behind the retina, which lines every part of the interior of the eye, and which extends over the ciliary circle, and over the posterior surface of the iris.

(672.) Different parts of the retina possess different degrees of sensibility; the centre, or that situated in the axis of the eye as it is called, immediately opposite to the pupil,

[1] Contained in the sketch of the Physiology of the Eye, prefixed to Mr. Travers' *Synopsis of the Diseases of the Eye and their Treatment*, p. 72.

being by far the most sensible part. We accordingly see most distinctly those objects, the images of which are formed on that spot. Hence, whenever we pay attention to an object, we immediately direct both eyes towards it in such a manner as that the centre of both retinæ may receive its image. It is very remarkable that there is a minute circular space situated exactly in the axis of the eye, where the retina seems to be deficient, so as to produce the appearance of a perforation at the very point where vision is most distinct. No satisfactory explanation of this curious circumstance has yet been given.

(673.) When the eye is at rest, the field of distinct vision is very limited; it extends, however, according to Dr. Young, to a space formed by a radius of about 60 or 70 degrees; it extends to a greater distance outwards than inwards, being 90 degrees in the former direction, and only 60 degrees in the latter. It extends downwards 70 degrees, and only 50 degrees upwards.

(674.) Mariotte[1] of the French Academy of Sciences, made the curious discovery that there is a part of the retina situated at the termination of the optic nerve which is insensible to light; so that when the image of any object falls upon that precise spot, it is no longer seen. The conclusion which he drew from this fact was, that the seat of vision is not the retina, but the choroid coat; for at this spot the choroid coat is wanting, being perforated to admit of the passage of the optic nerve. But the phenomena is better accounted for by the consideration that there is present at that spot the central artery of the retina, which here divides itself into a number of radiating branches, and excludes the

[1] *Phil Trans.* for 1668, vol. iii. No. 35, p. 668; and also *Mémoires de l'Acad.* i. 68, and 102.

presence of nervous matter, in which, judging from the analogy of all the other senses, the power of communicating sensation exclusively resides. This defect in vision, if we may so term it, is seldom perceived when both eyes are used, because the optic nerve enters each eye obliquely, and on different sides of the centre of the retina; so that they can never both receive the image of the same object at the same time.

(675.) The defects of the eyes of some persons with respect to their refractive powers produce what is called *long-sightedness*, when these powers are deficient; and *short-sightedness*, when too great. The source of former imperfection, which constitutes the *presbyopic eye*, may often be traced to the effects of age, which produces a flattening of the cornea; and probably also impairs that voluntary power by which the refractions may be increased when near objects are viewed. The short-sighted, or *myopic* eye, has generally an excessive convexity of the cornea, which may be diminished, but is very seldom materially so, by the progress of age. The remedies for these defects are obvious; namely, the use of convex spectacles for the presbyopic, and of concave spectacles for the myopic eye; the former supplying the deficiency in the power of refraction; the latter correcting its excess.

(676.) Such then are the means employed for producing certain impressions on each retina, which it is the office of the optic nerves to transmit to the sensorium, where these give rise to corresponding sensations. The inquiry into the perceptions arising in the mind in consequence of these sensations belongs to another branch of the subject hereafter to be considered. It will be sufficient in this place to point out the general fact relating to the physiology of the eye, that the impression made upon each point of the retina, produces in the sensorium a distinct impression, suggesting to the mind a distinct sensation.

CHAPTER XV.

PHYSIOLOGICAL LAWS OF SENSATION.

SECT. I.—PHENOMENA OF SENSATION.

(677.) Having examined the different modes in which impressions are made upon the extremities of the nerves situated in the respective organs of sense, we have next to direct our attention to the physiological phenomena which ensue on those impressions being received.

1. *Specific Endowments of the Nerves of Sensation.*

(678.) The extremities of the nerves intended to receive these impressions appear in general to be expanded over a certain extent of surface, and to be of a softer texture than the nerves themselves. This difference appears to arise from their being divested of the membranous covering which closely binds together the filaments composing the nerves, while they are pursuing their course from one part to another. Such expansions are noticed in the optic, auditory, and olfactory nerves, and probably also in those distributed to the papillæ of the tongue, and the cutis. The nerve of each particular sense appears to have different specific endowments. Thus the optic nerve and retina are peculiarly adapted to be affected by the impressions of light; and are not fitted to convey any other impressions. There are experiments recorded which tend to shew that irritation of these nerves do not communicate pain, as is the case with that of nerves sent to other parts of the body. On the other hand no other nerve in the body is capable of exciting, by any change that can be induced upon it, the sensation of light, as was pretended in the case in the celebrated imposture of Miss M'Avoy of Liverpool, who endeavoured to persuade people that she could see with the tips of her fingers: or in the more elaborate delusions of animal magnetism, in which persons are stated to be able to read a piece of writing applied to the pit of the stomach, or nape of the neck, by optical impressions made on different parts of the skin.[1]

(679.) That the optic nerves are incapable of exciting by their action any other sensations than those of light, is farther rendered probable by the circumstance that these sensations may be produced by other causes than those which usually give rise to them; such as impressions of a mechanical nature. A blow in the eye, producing sudden pressure on the retina, excites the sensation of a flash of light. The appearance of brilliant spangles in the field of vision is often the result of too active a state of circulation in the vessels of the retina, which excites in the fibres of the nerves actions similar to those produced by the presence of light. The galvanic influence affecting the same, or even neighbouring nerves, produces, in like manner, the sensation of a flash of light. Analogous facts have been noticed with regard to other senses. The well-known sensations of singing in the ears is the consequence of an action of the auditory nerves, excited by the state of the circulation in the

[1] See Magnetism, Animal.

organ of hearing, and is probably totally unconnected with any real sonorous vibrations communicated to that organ.

2. *Modifications of Impressions.*

(680.) In order that an impression made upon the sentient extremity of a nerve may excite sensation, it must be applied for a certain time; for if it be of too transient a duration, no effect, as far as regards sensation, is produced. This is well exemplified in the case of vision; we lose sight of an object in very rapid motion, because the impression made by its image on the different points of the retina on which it is successively formed, is of too transient a nature to excite those actions which produce sensation.

(681.) On the other hand, when a distinct impression has been made on the nerve, that impression has a certain duration, independently of the continuance of the cause which excited it; for the sensation produced is, to a certain extent, permanent. This is also shewn, in the case of vision, by several experiments familiar to all, such as whirling rapidly with a circular motion, an object brightly illuminated, which gives rise, as is well known, to the appearance of a continuous circle of light. Many optical deceptions are founded on the same principle, such as that of the *Thaumatrope*, of the *Phantascope*, or *Phenikisticope*, and the curved appearance of the spokes of a revolving wheel when viewed through parallel bars, of which last phenomena the theory has been elsewhere given by the writer of this treatise;[1] and also the appearance of a similar kind noticed by Mr. Faraday.[2]

(682.) One of the consequences of the law of the perma-

[1] *Philosophical Transactions for* 1815.

[2] *Journal of the Royal Institution*, vol. i. p. 205. See also Dr. Roget's *Bridgewater Treatise*, vol. ii. p. 524.

(686.) We may here observe, that the appearances of spectra above described, are merely temporary; for the several parts of the retina soon regain their natural state of equable sensibility.

(687.) Illustrations of this law readily present themselves when we search for its application with regard to all the other senses. Sounds which are too loud produce temporary deafness, or at least impair for a time the sensibility of the ear to weaker sounds. Similar phenomena are observed as to odours and tastes, with reference to their appropriate senses. The sensibility of the skin to different temperatures varies considerably according to the previous impressions which have been made upon it. Thus the same body may appear either hot or cold, according to the previous temperature of the hand which is applied to it.

SECT. II.—CONDITIONS NECESSARY FOR SENSATION.

(688.) The sensibility of the sentient extremities of nerves, or their capability of receiving such impressions as lead to their appropriate sensations, is dependent on certain conditions of the organ. These conditions are principally the following. First, it is necessary that the organ receive a proper supply of arterial blood by the vessels circulating through it, and particularly through that part on which the nerves are distributed. Secondly, it is required that the expansion of the nerve belonging to the organ should be exempt from excessive pressure. Compression of a nerve in any part of its course immediately puts a stop to all its functions; and consequently its power of receiving and convey-

published in the 76th volume of the *Philosophical Transactions*, and reprinted in Dr. Darwin's *Zoonomia*.

ing impressions is suspended as long as the pressure is continued. On the removal of the pressure, provided it has not been too violent, or too long continued, the nerve after a certain time, generally recovers its powers. Thirdly, a certain temperature is requisite for the maintenance of sensibility in the nerves. The benumbing effect of cold is well known, and extends generally to all the functions of the nervous system. It is very probable that this operation of cold is referable to its retarding or arresting the circulation in the capillary vessels ; and it might, therefore, perhaps, be included in the causes which influence the first of the conditions here enumerated. Lastly, the office of every nerve being to transmit impressions from one of their extremities to the other, it is necessary for the due performance of this function, that an uninterrupted continuity of their filaments should be preserved throughout their whole course. The complete division of a nerve in any part, necessarily prevents this transmission, and destroys the function of the nerve.

(689.) Irritations applied to the nerve in any part of its course, produce sensation, provided the communication of that part with the brain be uninterrupted by any of the causes above specified. Thus, if a nerve be tied or divided at any point, irritations applied below the ligature or division will produce no effect as to sensation ; but when applied above that point, sensation immediately follows. What is here said applies more particularly to the nerves distributed to various parts of the body, and especially to the integuments ; the irritation of which nerves gives rise to a sense of pain. The nerves of the senses of sight, of hearing, of smell, and of taste, are so situated as hardly to admit of being the subjects of experiments which might decide the question as to what kinds of sensation would be excited by irritations directly applied to them; and whether these sensations would be similar to those they usually convey from impressions made upon their extremities. Analogy would undoubtedly be in favour of such similarity. Persons who have lost a limb by amputation, experience sensations not only of pain, but also of touch, and of muscular motion, exactly similar to those which they formerly derived from the parts of the limb which they have lost. These sensations arise from imitations taking place, either in the lower extremities of the nerves which have been divided, and which remain in the stump, or in the brain itself.

(690.) The most remarkable circumstance attending the communication of irritations along the nerves of sensation, is the celerity of the transmission. It appears, indeed, to be instantaneous, and can be compared only to the rapidity of the electric fluid passing along a conducting body.

SECT. III.—THEORIES OF SENSATION.

(691.) We are completcly ignorant of the nature of that power by which the nerves effect this rapid communication along the lines of their fibres, and even of the changes which take place in the nerve while it is performing this function. Several hypotheses have been proposed with a view to supply this chasm in our knowledge. The oldest of these, and that which maintained its ground for many centuries, is, that the brain and nerves are furnished with a certain fluid, which was called the *animal spirits*, and was the medium of communication between the different parts of the nervous system. Traces of this theory may be found in the writings of Hippocrates; but it derived its principal support from Descartes, who reduced it to a regular form, and powerfully recommended it by the force of his authority. According to the views of those who espouse this theory, the brain is considered as an organ whose principal office it is to secrete the animal spirits, which are of a very subtile and ethereal nature, and to supply them to the nerves, which were considered to be the natural excretory ducts of the brain. The existence of this fluid was, for a very long period, universally admitted by physiologists, and the doctrines founded upon it were more or less mixed up with all the reasonings of physicians respecting the causes and phenomena of diseases, and the effects of remedies. Traces of the influence of this doctrine may be found in the popular language of medicine even in the present day, when the hypothesis from which it is derived is deservedly exploded as perfectly gratuitous, and devoid of any just foundation.

(692.) Another hypothesis invented to account for the propagation of impressions along the fibres of nerves, was that of their depending on vibrations or periodical oscillations of their particles, analogous to those of the strings of a harpsichord when producing musical notes. The great champion of this doctrine was Hartley,[1] who embellished it by his beautiful applications to a great variety of phenomena relating to sensations, and even to the intellectual operations. It afforded a happy explanation of many of the phenomena of ocular spectra, and of those depending on the permanence of sensations. It is needless to remark, that this hypothesis is equally visionary and destitute of any solid basis as the former.

(693.) All these mechanical theories are overturned by

[1] *On Man.* A full account of Hartley's theory is given by Dr. Priestley, in a separate work bearing that title.

the fact that no tabular structure can be discovered, on the minutest anatomical scrutiny, to exist in the filaments which compose the nerves; nor can the slightest motion be detected in any of their parts, while they are actively transmitting the impressions of sensation.

(694.) The latest hypothesis as to the nature of nervous power is, that it is identical with electricity. It is supported principally by the experiments we have already mentioned, in which, after the par vagum was divided, so as entirely to intercept its action in promoting the secretion of the gastric fluid, secretion was restored by transmitting the galvanic fluid along the lower portion of the nerve. The experiment, indeed, applies only to a particular office of the nervous power, namely, that of promoting secretion; but the hypothesis it suggested has been extended to all the other functions of the nerves, and of course to their power of transmitting those impressions which give rise to sensation.

CHAPTER XVI.

FUNCTIONS OF THE SENSORIUM.

SECT. I.—LOCALITY OF THE SENSORIUM.

(695.) If we except the nerves appropriated to the organs of the special senses of sight, hearing, smell, and taste, and those distributed on the face, and other neighbouring parts, all the nerves subservient to sensation appear to terminate in the spinal cord. We are then, in the first place, to determine whether the impressions which these nerves convey to that organ, are transmitted to any other part of the nervous system, previously to sensation being produced.

(696.) Experiments in all the animals whose structure, as far as regards this part of the nervous system, is analogous to the human, have established the general fact, that sensation does not take place, unless the part of the spinal cord to which the nerve is connected, communicates by an uninterrupted continuity of substance with the brain. The division of the spinal cord near the foramen magnum, instantly renders the whole body insensible; but it does not appear so immediately to deprive the parts about the face of sensibility, for some degree of it appears to be retained as long as the circulation continues. The injury, indeed, soon becomes fatal, by the circulation ceasing in consequence of the interruption to the function of respiration. The effects of injuries to the spinal cord occurring to men from accidents of various kinds, afford ample confirmation of the fact that the brain is the general centre to which all impressions made upon the nerves must ultimately be brought before they can excite sensation.

(697.) Admitting the brain to be the immediate organ of sensation, it next becomes a question, whether any particular part of the brain is more especially appropriated to the exercise of this function. It is to such a part, supposing it to exist, that the name of *sensorium* has been applied. There are two modes of conducting this inquiry; the first is by tracing very carefully, the filaments of all the nerves which are immediately connected with the brain, and endeavouring to discover if they unite in any central part of that organ, which may accordingly be supposed to be the seat of sensation; or, in other words, the sensorium. The second mode of investigating the subject, is to ascertain if any one part of the brain can be discovered, on which impressions directly made, are invariably productive of sensation.

(698.) The fibrous substance of the spinal cord, being directly continuous with the medulla oblongata, may be supposed to terminate in that part of the brain; so that, viewing the spinal cord as a collection of all the fibres of the nerves of sensation continued along its whole length, these nerves themselves may be considered as following this course, and having this termination. These fibres are found more particularly to converge towards the corpora quadrigemina, and crura cerebri. Now, it happens that this is also the very spot with which the nerves of the senses, whose organs are in the head, namely, the fifth, seventh, and eighth pairs, are more particularly connected. It appears also, from the late investigations of the French physiologists, that no part of the brain higher than the corpora quadrigemina, and no part whatever of the cerebellum, is essentially concerned in sensation; for it is found that in animals the power of sensation remains, even after the removal of all the parts of the brain, or of the cerebellum, higher than this spot. The conclusion which has been deduced from these experiments is, that the medulla oblongata, and more particularly that segment of it to which the nerves of the head are united, is the organ most essentially connected with the mental change constituting sensation. But it is not probable that these corporeal changes immediately connected with sensation, are confined to a *single point* in the brain, which might emphatically be termed *the seat of the soul*, as Descartes expressed it, when he boldly pronounced the pineal gland to be that spot.

SECT. II.—REQUISITE CONDITIONS OF THE SENSORIUM.

(699.) A multitude of facts tend to confirm the view of the subject which has here been taken. The same conditions as those which are required for the exercise of the functions of the nerves in every part of their course, are equally necessary for the performance of those of the brain. It is indispensable that the circulation in the brain should be in a healthy state, and that arterial blood be supplied by its vessels. It is indispensable that a proper temperature be preserved; and it is likewise indispensable that the brain be not compressed by any considerable force. A failure in any one of these conditions, produces total deprivation of the power of sensation, as well as of all the other functions of the brain. This effect is found to result more particularly when pressure is made in the direction of the medulla oblongata; for in that case complete insensibility takes place; and on the removal of the pressure, the faculty of sensation slowly returns; but if any considerable injury has been inflicted on that part, the power of sensation is irrecoverably lost.

(700.) It is probable that most of the laws which regulate the functions of the nerves with respect to sensation, apply with equal truth to the sensorium itself; but with regard to several of the phenomena, it is difficult to determine whether they depend on affections of the sensorium, or of the extremities of the nerves, situated in the organ of sense. We must despair of being able to resolve this question, because the changes which take place in both these parts, appear to be simultaneous. The impaired power, for example, which is the result of a strong impression from an object of sense, may arise equally from the exhaustion of that part of the sensorium to which the impression is communicated, as of that of the sentient extremity of the nerve; and we have no means of discriminating between them.

(701.) Another point of resemblance is, that irritations applied to the sensorium, from other sources than the nerves themselves, give rise to the same train of sensations as impressions communicated through the nerves. These irritations may be given by the pressure of blood circulating in the arteries of the sensorium; and this is probably the source of many of those sensations generally ascribed to affections of the nerves, or of the organs of sense. Pains, and other sensations in various parts of the body, arise from affections of the brain. The same origin may often be assigned to sensations which arise in dreams, and likewise to various spectral illusions which affect persons who are awake, and aware of their being deceptions of the sense. In delirium and insanity, the sensations from this cause assume a fearful degree of intensity, and are accompanied by a fixed belief in their reality.

SECT. III.—LAWS OF RECURRENCE, AND OF THE ASSOCIATION OF IMPRESSIONS.

(702.) With regard to all the subsequent changes and operations which take place when sensation has been excited, it is extremely difficult to pronounce how much of the phenomena are purely mental, and how much are strictly the result of corporeal changes connected and associated together by physical laws. In other words, it is difficult to determine what are the operations in which the mind is purely passive, and dependent on the actions of its bodily organs, and what are those in which it exerts a spontaneous power of action, and thereby reacts upon those organs, and produces in them a series of changes which lead to the most important results. The distinction we are attempting to draw, is founded upon this essential difference in the order of sequence of the phenomena, that in the one the organic change precedes the mental change, and in the other succeeds to it.

(703.) The two principal physiological laws relating to the former of these physical changes, namely, those which precede the mental affections, are, first, the *law of spontaneous recurrence.* Whenever an impression of a certain intensity has been made upon the organs of sense, the sensation which is produced by it, after disappearing for a certain time, recurs without the presence of the cause which originally excited it; and this happens repeatedly, and without any corresponding effort of the mind, and often in opposition to any effort which can be made to counteract the tendency. This spontaneous recurrence of sensations is probably the result of the repetition of those changes in the sensorium which originally gave rise to them. In the language of metaphysics, the corresponding mental affections are termed *ideas*, in order to distinguish them from the similar and more vivid affection excited by the primitive impression, and to which the term *sensation* is more particularly appropriated.

(704.) The second law which regulates the unknown affections of the brain connected with the passive phenomena of mind, is that of *association*, or the law by which impressions, and consequently the corresponding ideas, recur in the same order of sequence as that in which they were originally excited. The phenomena of disease, and the operation of different agents which modify the state of circulation in the brain, and the conditions of the nervous powers, afford ample evidence that the modes of association, and of the sequence of impressions and ideas, are dependent on the physical condition of the brain, and result from certain changes taking place in that organ.

(705.) The views here presented, far from being favourable to the doctrine of materialism, are directly opposed to it ; since they necessarily imply the existence of an essential distinction between mind and matter, and aim only at tracing the connexions which have been established between them by the divine Author of our existence.

(706.) Such, then, being the physiological connexions which exist between the physical changes taking place in the brain, and the passive phenomena of the mind, it is not an unreasonable supposition, that the voluminous mass of cerebral substance which, in the human brain especially, has been superadded to the medulla oblongata, or to the immediate physical seat of sensation, is in some way subservient to that astonishing range of intellect and combination of mental faculties which are found in man. We may conjecture also, with much appearance of probability, that in the lower animals, the intellectual endowments which mark several of the more intelligent races are connected with similar, though inferior, expansions of cerebral substance.

(707.) All the mental phenomena in which the mind is passive have been referred by metaphysicians to the principle of association, and consequently may, in as far as this principle is concerned, be connected with the physical changes above noticed. Hence we find the memory, which is the direct result of that law, is more especially liable to be impaired by certain physical states of the brain, such as those induced by severe concussion, by fevers, and by the progress of age.

(708.) As scarcely any thing is known with regard to the physical changes which take place in the brain in the relations which they bear to mental phenomena, the further consideration of these phenomena belongs properly to psychology rather than to the subject of this treatise. The inquiry must here be taken up by the metaphysician, whose province it becomes not the physiologist to invade.

SECT. IV.—VOLITION AND VOLUNTARY MOTION.

(709.) Leaving, therefore, to the metaphysician the analysis of those mental phenomena, which, however dependent they may be for their existence on the healthy actions of the brain, require modes of investigation different from those of physiology, and lead to results very remote from any conceivable laws of material agency; we may resume the subject at the point when, in consequence of the mental acts of *volition*, by which term we here mean to express the endeavour to produce certain specific movements of the body, new changes are again produced in the cerebral organs, and new trains of physical phenomena succeed. That this mental effort of volition constitutes a distinct step in the series of phenomena, is proved by the instances of paralysis, in which the patient is conscious of making the effort to move the palsied limb, yet no motion, or even sensation of motion, ensues. Another illustration of the same distinction is derivable from a different disease affecting the limbs, namely, *anæsthesia*, which consists of the loss of sensation only, while the power of voluntary motion remains; and in which the voluntary act so exerted produces the intended muscular contractions, unattended, however, with the feelings which usually accompany them. The same complete ignorance in which we are with regard to the changes which take place in sensation, pervades our notions of those which attend volition, in as far as they occur in the brain. A few facts, indeed, have been collected with regard to those parts of the brain which are impressed, if such a term may be used, antecedently to the voluntary motions of the limbs. They appear to be chiefly the crura of the cerebellum, and the adjacent parts of the medulla oblongata.

(710.) All the physical conditions which are necessary in order that sensations may be felt, are equally necessary for rendering the cerebral organs capable of receiving from the mind those impressions which lead to voluntary motion. The mental stimulus of volition produces a certain effect on the origin of the nerves, leading to the muscles employed in these motions, which impression, being propagated along the course of those nerves, excites these muscles to contraction. The transmission of thoe impresssions is made with the same celerity, and probably by the same agency, as those which produce sensation ; but they are made in the contrary direction, namely, *from* the brain, instead of *towards* it. The same conditions of perfect continuity of fibres, of freedom from pressure, and of healthy circulation, are essential requisites in both cases ; and every thing that has been said with regard to the former, is also applicable to the latter. Mechanical irritations, applied either at those parts of the brain which adjoin the origin of the nerves, or to the nerves themselves, either at their origin, or in any part of their course, whether that portion of the nerve situated between the point to which the irritation is applied be entire or divided, or compressed by a ligature, are found to produce the same muscular contractions as those which are the result of volition.

(711.) Mr. Mayo[1] ascertained, that after any nerve which supplies a voluntary muscle is cut through, either in a living animal, or immediately after death, mechanical irritation of the part of the nerve disconnected with the brain, as for instance the pinching it with a forceps, causes a single sudden action of the muscle or muscles it supplies. On the other hand, a like effect cannot be produced by irritating mechanically the nerves distributed to those muscles over which the will has indisputably no influence. "It must be admitted, however," he remarks, "that this phenomenon is not exclusively confined to those muscles which are allowed on all hands to be voluntary ; nor, indeed, is it shewn in all the muscles which seem at first sight to be directly under the

[1] *Outlines of Human Physiology*, third edition, p. 39 to 42.

controul of the will." But it is not easy, in various instances, to determine whether muscular actions are voluntary or not; while the point of distinction proposed by Mr. Mayo has the recommendation of being easily verifiable. Setting aside, therefore, in the first instance, the question of the influence of the will, let us be satisfied with observing what muscles act when a divided nerve that enters their substance is mechanically irritated, and what do not. We may afterwards trace the collateral differences of the two classes of muscles which are thus distinguished.

(712.) The parts which are susceptible of this mode of excitement, are the muscles of the trunk, head, and limbs, of the tongue, of the soft palate, of the larynx, of the pharynx, and œsophagus, and of the lower outlet of the pelvis. The opposite class comprehends the heart, the stomach, the small and great intestines, and the bladder.

(713.) The collateral differences which characterize either class are, with exceptions afterwards to be adverted to, the following:—

Of the muscles which act when a nerve distributed through them is mechanically irritated, it may be remarked:

1. That they admit of being thrown into action by an effort of the will.

2. That with sufficient attention and resolution, their action may be refrained from.

3. That their action is attended with a conscious effort, and is guided by sensation.

4. That if divided, the separate parts retract instantaneously to a certain distance, and subsequently undergo no farther permanent shortening.

5. That when mechanically irritated, a single and momentary action of their fibres alone ensues.

6. That they remain relaxed, unless excited by special impressions, both in the living body, and before the loss of irritability after death.

7. That their action in the living body habitually results from an influence transmitted from the brain or spinal cord through the nerves.

(714.) The exceptions to be made against this statement, if applied generally, are, that the three first affections are not easily brought home to the muscular fibres of the œsophagus, or of the lower part of the pharynx; but it deserves at the same time to be considered, that the lower part of the pharynx and the œsophagus are in the peculiar situation of parts employed on one object alone, instinctively and habitually, on the recurrence of one impression; a condition which would soon reduce a strictly voluntary muscle to a state apparently removed from the control of the will.

(715.) Muscles of the preceding class, if we except the fasciculi belonging to the pharynx, and œsophagus, and urethra, are so disposed as to extend from one piece to another of the solid frame-work of the body; they enlarge or straighten the cavities of the trunk; they produce the phenomena of the voice; they close the excretory passages; the greater number are employed to move the limbs on the trunk and the frame on the ground. Muscles of the second class are used, like the exceptions in the preceding, as tunics to the hollow viscera, the cavities of which they diminish in their action, and thus serve to give motion to their contents. The œsophagus, indeed, appears to partake of the nature of both classes of muscles; when the nervi vagi are pinched, one sudden action ensues in its fibres, and presently after a second of a slower character may be observed to take place.

(716.) Of the muscles which do not act on the mechanical irritation of any nerve distributed through them, it may be remarked,

1. That the will cannot instantaneously or directly produce action in them.

2. That the resolution to abstain from their action is insufficient to repress it.

3. That their action is not attended with a conscious effort, and seldom has reference to sensation.

4. That if divided, the retraction which follows is in most instances slow and gradual.

5. That if they are mechanically irritated, not one, but a series of actions ensues.

6. That their natural state, in the absence of external impressions, is not continued relaxation. When the heart and bowels are removed from the body of an animal immediately after death, they continue for a time alternately to contract and to dilate.

7. That an impression transmitted through the nerves does not appear the usual stimulus to their action.

(717.) From the experiments of the French physiologists it would appear, that in an animal deprived of all the upper portions of the brain, but in which the medulla oblongata is preserved, all indications of the more complex operations of thought disappear, but the animal still remains capable of executing such voluntary motions as are of an instinctive character, as, for example, swallowing. Animals deprived of the cerebellum, provided the medulla oblongata remains, and is free from compression, not only appear to be capable of sensation, but give all the usual indications of intelligence, and evidently exert volitions, which occasion the action of many voluntary muscles. But they have lost the power of regulating the contractions of those muscles so as to execute any definite voluntary action, excepting those which are instinctive. All the other voluntary movements of the body and limbs are performed in so irregular a manner, that they are generally ineffective for the purposes for which they are intended; and most of the usual complex movements required for progressive motion cannot be performed at all. This has been explained by the supposition that the animal has lost all recollection or association of those trains of muscular sensations which used to accompany and to guide these movements, in consequence of the loss of the cerebral organs which are instrumental in furnishing those associations. One of the inferences drawn from these facts (which themselves require more ample confirmation before they can be regarded as established) is, that the recollection of those associations connected with voluntary motion depends on the cerebellum, in the same way in which the associations of sensations and ideas depend on the hemispheres of the brain.

(718.) It is a remarkable circumstance that injuries or diseases occurring in the hemispheres either of the cerebrum or cerebellum produce paralysis, that is, destroy the power of voluntary motion, of the muscles situated on the opposite side of the body. This has been endeavoured to be explained by the alleged decussation or crossing of the nervous fibres of the lower part of the corpora pyramidalia on each side. But in order to account for all the phenomena of this kind, we must suppose the decussation to take place between the fibres which compose the posterior and the anterior columns of the spinal cord.

(719.) Although the function of the nerves in transmitting impressions from the organs of sense to the brain, which give rise to sensation, and in transmitting impressions of volition from the brain to the muscles of voluntary motion, which give rise to the contraction of those muscles, appear to be of the same kind, and to differ only in the direction in which the impression is transmitted, the question has often been asked, whether the same nervous filaments which transmit the one class of impressions are employed to transmit the other likewise; or whether different portions of the nerve are appropriated to these different offices. The truth of the last of these propositions may now be considered as being firmly established.

(720.) The observations which first suggested the idea of there being two sets of nervous filaments, the one subservient to sensation, and the other to volition, were those in which a limb was only partially paralysed, the power of motion being retained, while that of feeling was lost. Experiments had also been made in which nerves that had been divided, and had afterwards spontaneously united, were found to have recovered the power of placing the muscles to which they were distributed under the command of the will, but yet had no power of conveying sensitive impressions. Erasistratus and Herophilus had long ago taught the doctrine of there being two species of nerves respectively appropriated to these opposite functions; and Galen was inclined to the same opinion, from observing that both the tongue and the eye are supplied with two separate sets of nerves, the one apparently subservient to sensation, the other to motion. But it is to Sir Charles Bell and to Magendie that the merit belongs of bringing forward decisive proofs of the reality of this distinction between nerves for sensation and nerves for motion, the idea having before been only loosely thrown out by speculative physiologists as a plausible conjecture.

(721.) It results from this discovery that the transmission of impressions in opposite directions, that is, in the one case from the extremities to the brain, and in the other from the brain to the muscles, is effected by different nerves, or at least by different sets of nervous filaments, and that no filament is capable of transmitting impressions both ways indiscriminately, but always in one particular direction. These two kinds of filaments are, it is true, conjoined together into one nerve; but the object of this union is not community of function, but convenience of distribution, the two kinds of filaments still remaining distinct in their functions as they are likewise distinct in their origins. We know that all the nerves connected with the spinal cord have a double origin; that is, are composed of two nerves, the one proceeding from the anterior, and the other from the posterior columns of the spinal cord. It is found that an injury done to the anterior roots of those nerves excites convulsions in the muscles which they supply, but does not appear to excite any sensation of pain in the animal on which the experiment is made; and the division of those nerves is followed by the immediate paralysis of those muscles, that is, by their incapability of being excited to contract by any voluntary efforts. On the contrary, the irritation of the posterior roots of the same nerve is attended with no contractions of muscles, but calls forth expressions of violent pain. The section of these nerves is followed by insensibility of the parts which those nerves supply, while the power of voluntary muscular contraction remains.

(722.) From the symmetrical situation of these nerves with reference to the spinal cord, Sir Charles Bell has given them the name of the *original*, or *symmetrical nerves*. They comprehend, of course, all the spinal nerves which arise by double roots, the posterior of which has invariably a ganglion near its origin, while the anterior branch has no such appendage. These spinal nerves are distributed laterally to the two halves of the body; those of the one side having no connexion with those of the other. Sir Charles Bell ranks the fifth pair of the cranial nerves in the same class as the spinal nerves; considering its two roots as composed of filaments, appropriated the one to sensation, the other to motion; the former being provided with a ganglion near its origin, and the latter having no ganglion. He regards the third, probably the fourth, the anterior branch of the fifth, the sixth, the portio dura of the seventh, and the ninth, as being exclusively motor nerves, distributed to the muscles of the eye-ball, lower jaw, face, and tongue, and placing these muscles under the control of the will. The ganglionic portion of the fifth pair, on the other hand, he regards as the great sentient nerve of the head; which gives exclusively sensibility to the face, eye-ball, mucous membrane of the nose, mouth, and tongue. This nerve is in communication with the posterior column of the spinal cord; whilst the motor nerves, above enumerated, appear to communicate with the anterior column. An exception to this rule, however, occurs in the case of the fourth pair, which has never been proved to communicate with the anterior column of the spinal cord. It would appear also that the larger portions of the eighth pair, which seem to be more connected with the posterior than with the anterior columns, are nerves both of sensation and of motion; so that the exclusive appropriation of the nervous filaments, originating from the different surfaces of the spinal cord, to motion or to sensation, is perhaps not yet rigidly demonstrated.

(723.) It is remarkable that the peculiar sensations conveyed by the optic, the olfactory, and the auditory nerves, have been found by Magendie to be much impaired, or even entirely lost, by injuring the branches of the fifth pair of nerves, which also supply the respective organs to which the above nerves appear to be particularly appropriated. The cause of this anomaly has not yet been satisfactorily explained.

(724.) Sir Charles Bell has distinguished another class of nerves, which he conceives to be altogether subservient to the function of respiration, and to be distributed to the muscles concerned in that function. These he terms the *irregular*, or the *superadded*, or the *respiratory nerves*. They arise by single roots; they pass from one organ to another in various directions, and pursue a very irregular and intricate course, passing across the nerves belonging to the symmetric system, occasionally uniting with them, and connecting together the two halves of the body. These nerves, according to Sir Charles Bell, are not under the control of the will, and are not capable of exciting sensations; their only office being that of transmitting impressions from one part to the other. The nerves which strictly belong to this class are the eighth pair, the spinal accessory nerves, the phrenic, the external respiratory nerve of Sir Charles Bell, and the great sympathetics.

(725.) The first pair, or the olfactory nerves, the second, or the optic, and the portio mollis of the seventh pair, are wholly nerves of sensation; and from the special nature of the impression they convey, may be considered as forming a separate class of nerves.

(726.) Most nerves pass through *ganglia*, or are interwoven with others in *plexuses* before they reach their destination. The purposes answered by this intermixture of filaments, which, in either case, appears to take place, is to provide extensive connexions between the parts supplied with nerves and different portions of the spinal cord, or medulla oblongata, from which the several fibres originate. Thus the sensative and the motory filaments are intimately united in the same nervous cord, which is thus rendered capable of performing all the functions of nerves. Many hypothetical uses have been assigned to the ganglia, which appear to be unsupported by facts. Drs. Gall and Spurzheim suppose that they contribute to increase the nervous power in those nerves on which they are placed; but there does not seem to be any solid foundation for this opinion.

(727.) Muscular contractions, then, may be distinguished, with reference to the nervous power which excites them, into four classes; namely, 1. The purely voluntary motions; 2. The automatic motions; 3. The instinctive motions; 4. The involuntary motions. We have now fully considered the first of these classes, the purely voluntary motions, which may be defined to be those consequent on an effort of volition of which the mind is conscious, and which is accompanied by a distinct idea of the end intended to be accomplished. No examples or illustrations are necessary of motions belonging to this class, as they are those with which we are most familiar. We pass on then to the other classes in the order in which we have enumerated them.

SECT. V.—AUTOMATIC MOTIONS.

(728.) Automatic motions are those which consist of a series of actions, each of which was originally the object of a distinct volition; but which by habit, that is, by repeated association, have become linked together in such a manner, that a simple act of volition is sufficient, apparently, to renew the whole series, without requiring any separate effort of attention to each. Most of the actions which we daily perform, such as walking, speaking, writing, or playing upon a musical instrument, afford examples of automatic motions, being linked together by associations which, far from requiring any conscious acts of volition, follow one another in a regular order of sequence that cannot be broken unless by the exertion of a separate effort of atttention. All these movements, however, are still voluntary, inasmuch as they remain under the control of the will, which commands their commencement, can regulate their course, and can stop them at pleasure.

(729.) The muscular actions required for respiration may probably be classed under this head. The immediate exciting cause of the act of inspiration is a sensation felt in the chest from the presence of venous blood in the capillary vessels of the lungs ; and this sensation, if not speedily relieved, increases rapidly to one of extreme distress, and even agony. The influence of this sensation in exciting the very complicated actions which are necessary to relieve it by drawing air into the lungs, and which, indeed, are continued during sleep, and even when sensibility to all other impressions appear suspended, as in the state of apoplexy, is rendered manifest by the increased frequency and energy with which these actions are performed whenever any cause exists obstructing the free access of air into the lungs, and thus augmenting the intensity of the sensation.

(730.) Since the actions of respiration are caused, in the first instance, by sensations, they must be dependent on the sentient nerves of the lungs, and especially on those that establish the most direct communication between them and the medulla oblongata, namely, the eighth pair of nerves. We find, accordingly, that after the section of those nerves the actions of respiration are performed more slowly and less perfectly than when entire. They, nevertheless, continue, probably by means of the other communications which the lungs have with the brain, through the branches of the great sympathetic proceeding from the spinal cord. When the part of the medulla oblongata from which these nerves originate is injured, all attempts at inspiration are finally arrested, because a final stop is put to the sensation which prompts them. The section of the phrenic nerves, or an injury to the spinal cord at any part above the origin of those nerves, paralyses all the respiratory movements of the chest, and thus occasions asphyxia and sudden death.

(731.) When the sensation which prompts inspiration, is intense and long continued, all the muscles performing movements auxiliary to this act, such as those which assist the intercostals in elevating the ribs, which hold the glottis open, which raise the velum pendulum, which open the mouth, and which expand the nostrils, are called into simultaneous action, and the movements themselves are performed in concert, and with perfect precision. These actions are under the control of the will, as respects their force, their rapidity, and their frequency, and they may even be performed at pleasure, either separately or in conjunction; unless, indeed, the sensation which prompts them be unusually intense; in which case they cease to be voluntary and automatic, and pass into the class of instinctive motions we are next to describe. Sir Charles Bell supposes that the nerves of all the muscles employed in these auxiliary actions have peculiar connexions among themselves at their origin from the lateral columns of the spinal cord, from which the eighth pair, which is the great sentient nerve of the lungs, also arises; and that these connexions are the principal cause of their conjunction of action, whenever the sensation imperiously demands that they should act in concert. Yet, on other occasions, we find that all the muscles concerned in these actions, are strictly voluntary muscles, and are perfectly obedient to the will.

SECT. VI.—INSTINCTIVE MOTIONS.

(732.) It is the essential character of motions which are strictly voluntary, that they are accompanied not only by a consciousness of their being performed, but also by a conviction that we may, or may not perform them, as we please; or, to speak more philosophically, according as there exists or not, a sufficient *motive* for their performance. But there are also, in the healthy state, many muscles, of the actions of which we are always conscious, and which, under ordinary circumstances, are perfectly obedient to the will, but whose actions we have, on other occasions, no direct power of controlling by any effort of the will. They occasionally seem even to be rebellious to its authority, and as if they were transferred to the agency of some other power. They are always preceded by some sensation, as in the case of coughing, sneezing, and vomiting; or some internal affection of the mind, which has been termed *emotion*, as in the case of laughing and weeping; and they take place without any previous conception of the object they are calculated to attain, and therefore without the previous existence or operation of a motive. A very large proportion of the actions of brute animals appear to belong to this class; being characterized by the absence of that train of mental operations, which imply the agency of motives, and the previous knowledge of the consequences resulting from such actions ; operations which are comprehended under the term *reason*, as contradistinguished from *instinct*, or blind and inexplicable impulse derived from other sources.

(733.) Instinctive motions are distinguished by Dr. Alison into two kinds, the one comprising such as are not only prompted by an act of which we are conscious, but are also directed without our being aware of it at the time, to an end which we desire ; the other, those in which our actions are consequent indeed on a sensation, but are prompted by a blind impulse, the consequences which are to flow from the action being either unknown or disregarded ; as, for instance, in gratifying the appetites, guarding the eyes from danger by closing the eyelids, or the body from falling by throwing out the hands. Dr. Alison, in his *Outlines of Physiology*, to which we are indebted for several of the preceding remarks and illustrations, has very clearly treated of the whole subject of the functions relating to muscular motion. He farther remarks that the instinctive actions are closely connected with the motions which proceed directly from sensations on the one hand, and with the strictly voluntary motions on the other. In the adult human being, it is hardly possible to distinguish them from movements which have been prompted by reason, and become habitual ; but in the infant, and in the lower animals, they are easily recognised, being distinguishable by two marks ; first, that they are always performed in the very same way ; whereas actions which are strictly voluntary, and prompted by reason, although directed to the same ends, vary considerably in different individuals ; and, secondly, that, however complicated the movements may be, the truly instinctive actions are performed equally well the first time as the last; whereas even the simplest of the strictly voluntary movements require education. The com plex acts of sucking and deglutition performed by a new-born infant, may be given as examples of strictly instinctive motions.

(734.) It is important, however, in the consideration of this subject, that we bear in mind, that these actions, although in themselves instinctive, are yet performed by muscles which are at other times voluntary, and whose nervous connexions with the sensorium, render it necessary for the performance of these actions, that the muscles themselves should communicate by their respective nerves with the sensorium. We may fairly presume, therefore, that such actions are immediately dependent on a change taking place in the sensorium, through the medium of which alone the impression which is the occasion of the actions, becomes effective in their production.

(735.) The same remark applies also to those sensations which arise from *sympathy*, as it is termed; that is, which are referred to a part of the body very different to that to which the actual irritation is applied. Of this kind is the pain of the shoulder accompanying inflammation of the liver; pain of the knee from disease of the hip-joint; and itching of the nose from irritations in the bowels. These sympathetic sensations may perhaps be explained by the nerves of those corresponding parts having their origins from the same parts of the brain; but much yet remains to be done towards establishing the truth of this hypothesis.

SECT. VII.—INVOLUNTARY MOTIONS.

(736.) Under the head of the involuntary motions, we mean to comprehend all those muscular contractions which are performed without the intervention of any change in the sensorium, and consequently without being attended with either sensation, consciousness, or any other mental change. The most unequivocal examples of this class of motions are those in which muscular actions are excited by irritations applied directly to the motor nerves which are sent to the muscles themselves; for although, in the living body, such irritations are usually accompanied with the sensation of pain, that sensation must be regarded as an accidental concomitant, and not a necessary part of the phenomenon; as is proved by the absence of all sensation, when the nerve has been divided between the brain and the part to which the irritation is applied, and yet the muscles in which the nerve terminates, exhibit the same involuntary contractions as before. The same phenomenon, indeed, may be reproduced after the death of the animal, or when the brain or head has been removed.

(737.) Other cases are met with of a more complex and dubious character; namely, those in which muscles usually under the influence of the will, exhibit contractions in consequence of irritations applied, not to their own nerves, but to some more distant part, which receives other nerves. It is manifest that in these instances, the irritation of these latter nerves produces an impression which is propagated along their course towards the central parts of the nervous system, and is from thence again transmitted along the course of the nerves supplying the muscles, in which they excite contractions of the same kind as those originating in volition. Yet these motions may take place wholly independently of the sensorium, and are found to occur, indeed, when all communication with the brain is intercepted. For if, a few seconds after an animal has been deprived of life, the spinal cord be divided in the middle of the neck, and also in the middle of the back, upon irritating either by a mechanical or chemical stimulus, or by the application of heat, any sensitive portion of the body connected by nerves with either of these isolated segments, the muscles of that portion of the limb, so connected with the spine, are thrown into action. If, for instance, the sole of the foot be pricked, the foot is suddenly retracted, with the same gesture as it would have been during life, and of course with the same apparent indication of suffering.[1] It is evident that here an irritation applied to a nerve, the usual office of which during life was to transmit impressions to the sensorium productive of sensations of pain, has now produced an impression which is conveyed to the spinal cord only; but which yet is followed by the contractions of those very same muscles, which, during life, obeyed the determinations of the will, and produced a motion of the limb directed to its removal from the cause of injury.

(738.) Phenomena of this description may be observed more readily, and are exhibited in a manner still more marked, according as the animal on which the experiment is made, occupies a lower place in the scale. Among vertebrated animals, the motions just described, and others of a similar character, indicative of sensation and volition, are most easily produced in reptiles, as in the turtle, the serpent, and the frog; in which we find that isolated portions of the spinal cord perform functions analogous to those of the brain, as far as relates to the receiving of impressions from a certain set of nervous filaments, and the transmit-

[1] See Mayo's *Outlines of Human Physiology*, p. 231.

ting of impressions to other nervous filaments, which proceed from the same part of the spinal cord, and are distributed to the muscles. These two sets of nerves correspond in their functions to the sensory and motor nerves by which sensorial phenomena are produced, (see § 721.) In articulated animals, whose spinal cord consists of a series of nodules of nervous matter, resembling ganglia, connected by two longitudinal cords, and severally giving origin to their respective bundles of nerves, which radiate on each side from these ganglia, as from so many centres, the capability of each ganglion to perform this double function is still more susceptible of demonstration; and each segment of a worm or an insect, for example, appears, in consequence, to enjoy a separate life, and exhibits the semblance of possessing powers of sensation and voluntary motion independently of the rest.

(739.) The question now arises whether these indications of sensorial powers actually proceed from the exercise of those faculties; that is, whether they are accompanied by actual feeling and actual volition, of both of which consciousness is the essence; or whether they exist in appearance only, and without any real consciousness on the part of the individual percipient being. This question, taken in all its generality, it is extremely difficult, perhaps impossible, to decide; and its solution involves that of another problem, equally obscure, which is presently to come under our notice: namely, as to the locality and extent of the sensorium in all the classes of the animal kingdom. The plan of structure, and the vital constitution of articulated animals, are so different from what occurs in the system of animals of the vertebrate type, that whatever may be the conclusions we may form with regard to the sensorial powers and the organs which exercise them in the former class, we are not warranted in extending the same conclusions to the latter class of beings, in all of which we cannot fail to recognise the most decided character of individuality. It is hardly possible to conceive the co-existence of two separate centres of sensation and volition in any vertebrate animal, because we find it impossible to understand how consciousness can be subdivided into portions corresponding to the different segments into which the spinal cord may be divided. If, therefore, we regard the sensorium as occupying any portion of the brain, or rather of the encephalon, such as the medulla oblongata, we cannot admit the existence of a separate or accessary sensorium, situate in any part of the spinal cord, and capable of exercising the sensorial functions independently, when all nervous communication with the principal sensorium is cut off. If the power of sensation could ever be retained, even for a second, after the head has been severed from the body, we must suppose that the seat of that faculty is still in the head, and not in the trunk, the movements of which, when excited by galvanism, however they may resemble those which were performed during life in obedience to volition, in conformity to the design, and prompted by motives arising from bodily sensations, must be regarded as purely mechanical, or rather as the result of mere nervous irritation, and without the existence of either sensation or volition of any kind. We have decisive proofs that in the human system phenomena of this kind occur without any participation of the mind, that is, without either sensation, perception, or volition, in cases where, from accident, the spinal cord has been divided or compressed in the neck, or back, and where the muscles of the trunk that receive their nerves from that part of the spinal cord, which is situated below the injury, are affected with involuntary movements. We are therefore fairly entitled to extend the analogy to other animals whose construction does not materially differ from that of man, however appearances may seem to countenance the hypothesis of the sensibility of the trunk, after its communication with the brain has been intercepted.

(740.) Great confusion has been introduced into this subject by the inaccurate language employed by physiologists in theorizing on these phenomena; and in using which language they have lost sight of the essential distinction which should ever be kept in view between psychological and physical phenomena. The term *sensibility* should be strictly confined to such properties as are immediately connected with the mental changes which are denominated sensations, and which are characterized by attendant consciousness: All other corporeal properties or phenomena which do not produce these mental changes, are simply of a physical nature, and belong to another class to which the same appellation ought never to be applied. Bichat has committed this great error in employing the term *organic sensibility* to denote phenomena of this latter kind; and the introduction of this term has led to an interminable confusion of ideas among those who have adopted his system, and who have been thereby led, from this misapplication of terms, to some vague notion of a peculiar but obscure kind of actual sensation, which they attributed to portions of the nervous system unconnected with the sensorium, independent of all percipience, and partaking of the mystical doctrines of Stahl and Von Helmont as to the operations of their supposed *anima* and *archæus*. (See § 101.)

For the dissipation of these clouds which have too long obscured the ideas and perplexed the reasonings of physiologists, we need only direct on the subject the searching light of philosophical analysis, which will render its outlines clear and distinct, and enable us to follow their various flexures and crossings, and obtain more correct views of the landscape in all its details.

(741.) The power exercised in the instances we have described by the central parts of the nervous system, independently of all sensorial phenomena, is that power which we have already distinguished by the term *nervous power*, in contradistinction to the *sensorial power* exercised by the same system. (See § 96, 536, 537.) To Dr. Wilson Philip belongs the merit of having first clearly pointed out the distinction between these two orders of functions, and of having given them specific appellations. Dr. Marshal Hall has lately introduced a new term, that of *reflex function*, to designate the series of phenomena consisting of the transmission of impressions by certain nerves to the central parts of the nervous system, (which he limits to the spinal cord,) and the consequent transmission of an action by the muscular nerves, which is followed by the contractions of muscles. To the whole system concerned in this function he gives the name of the *excito-motory system;* the nerves receiving the impression he calls the *incident* nerves; and those conveying it to the muscles, the *reflex nerves*.

(742.) It would appear from what has been already noticed, (§ 711,) that every muscle the action of which is capable of being brought under the dominion of the will, and which is therefore entitled to be classed among the voluntary muscles, may occasionally be made to act by other causes, applied either directly to their own fibres, to the nerves distributed to them, or to other parts connected with them only by the medium of portions of the brain, spinal cord, or the ganglia of the sympathetic: and it has been conjectured that the sets of nervous fibrils which are instrumental in the performance of these latter functions, are different from those which are employed to transmit the impressions of sensation and volition. This latter view is the one adopted by Dr. W. Philip, who observes that, "however blended the organs of the sensorial and nervous powers may appear to be, we are assured that they are distinct organs by the fact, that while the organs of the nervous power evidently reside equally in the brain and spinal marrow, those of the sensorial power appear to be almost wholly in man, and chiefly in all the more perfect animals, confined to the former."[1] It does not, however, appear that we as yet possess any direct means of either establishing or disproving the truth of this supposition.

(743.) There yet exists another class of muscles, comprehending those which never, under any circumstances, become voluntary. To this class belong the heart and blood-vessels; the muscular fibres of the excretory ducts, and other parts of the organs of secretion; and the coats of the stomach and of the intestines. As the influence of the nervous system on those muscles is of a very pecular kind, and as their motions are governed by different laws from those which regulate the voluntary muscles, it will be necessary to bestow on them a separate consideration.

(744.) M. Le Gallois, in a work entitled, *Expériences sur le Principe de la Vie, notamment sur celui des Mouvemens du Cœur, et sur le Siège de ce Principe*, thought he

[1] *Quarterly Journal of Science*, xiv. 93.

had proved that the muscular power of the heart is derived altogether from the spinal cord, and not from the brain. He found that on injuring the spinal cord, the heart is so enfeebled as no longer to be capable of propelling the blood; but that the contractility of the heart may continue unimpaired when the brain, and even the whole head, is removed, provided respiration be kept up by artificial inflation of the lungs. He conceived, therefore, that the use of the cardiac nerves is to establish the connexion between the spinal cord and the heart; and that whenever the heart is affected by passions and emotions of the mind, which produce their first changes on the brain, it is influenced through the medium of the spinal cord, which is itself affected by the brain. Dr. Wilson Philip has shewn the fallacy of this conclusion; and has completely established, by direct experiment, that under similar circumstances, the brain has just as much influence on the motions of the heart as the spinal cord. The motion of the heart is no more affected by the removal of the spinal cord than by that of the brain, if the same precautions be taken in either case, of effecting the removal slowly, and with as little disturbance to the remaining parts of the system as possible. If, on the other hand, either the brain or the spinal cord be suddenly crushed by a blow, which at once destroys its texture, the heart is instantly paralysed, and its motions cease. Although the muscular fibres of these organs are not excited to contraction by irritations of any kind applied to their nerves, nor their contractions arrested by the section of those nerves, yet these actions are immediately accelerated by the application of chemical stimulants, such as alcohol, either to the brain or to the spinal cord; and retarded by the application of opium, tobacco, or other narcotic agents, to the same parts.

(745.) It would appear, therefore, that although there is no essential difference between the real nature of the irritability of the involuntary, and that of the voluntary muscles, yet that each is influenced by different kinds of stimuli, and by stimuli applied through a different medium. Mechanical stimuli, such as punctures or partial divisions of the fibres of the muscles of voluntary motion, act on them only through the medium of their nerves; and if applied to the parts of the brain whence these nerves originate, will throw those muscles into the most violent spasmodic contractions. The heart, on the contrary, is but slightly disturbed in its movements by the same kind of injury done to the brain or spinal cord, provided the injury be confined to a small portion of those organs. That important organ appears to be affected only in proportion to the extent of the parts that have suffered injury, and to the suddenness with which that injury has been inflicted; as is exemplified by wounding the brain rapidly in many directions. Chemical stimuli, on the contrary, applied to any part of the brain or spinal cord, produce considerable and immediate increase of the action of the heart; while the voluntary muscles continue all the while unaffected; and the animal betrays no sense of pain. Accordingly the heart, having no direct dependence on any part of the nervous system, may continue its action when the brain and spinal cord are destroyed, and even when it is itself removed from the body. The nerves with which it is supplied, however, render it capable of being influenced through those causes, as, for example, by the passions, and by various poisons, which affect a considerable portion of the nervous system.

(746.) The contractile powers of the other parts of the vascular system, and most of the secreting organs, as well as the irritability of the stomach and intestines, are, like those of the heart, independent of the nervous system, yet capable of receiving an influence through the medium of the nerves; and the same law appears to extend generally to all the involuntary muscles. The extensive nervous communications which are naturally established between the whole system of involuntary muscles, and the organs in which they enter, seem to be necessary in order that any one set of these organs should be subjected to the influence of all the others. This purpose is effected by that complex arrangement of nerves, which has been termed the *ganglionic system*, from the great number of ganglia annexed to them. The great sympathetic nerve forms the principal connecting nerve in this system between all the muscles of involuntary motion; which, through the medium of filaments from the extensive chain of ganglia belonging to this nerve, are placed in connexion with every part of the brain and spinal cord. Each ganglion belonging to the sympathetic system has been considered as a secondary centre of nervous influence, receiving supplies from all the latter parts, and conveying to the former organs the united influence of the nervous system in general. The muscles of voluntary motion, on the other hand, are subjected to the influence of only small portions of these central parts of the nervous system, and receive their nerves directly from these parts; and usually without the intervention of ganglia, and with comparatively few intermixtures of nervous filaments; such intermixtures being designed for the purpose of effecting combinations with the nerves of sensation, and especially with those which convey impressions relative to muscular motion.

(747.) The ganglia of the sympathetic system have, accordingly, been considered by many physiologists as performing functions similar to those of the portions of the spinal cord exercising mere nervous power; that is, in the language of Dr. Marshall Hall, performing reflex functions, and belonging, together with the branches of the sympathetic nerve, to the excito-motory system.[1]

SECT. VIII.—PSYCHOLOGICAL RELATIONS OF THE SENSORIUM.

(748.) In treating of the functions of the nervous system which involve operations both of the body and of the mind, it is very difficult to draw the strict line of distinction between them, and avoid treating of subjects which properly belong to metaphysics. We have endeavoured, in the preceding account of the physiology of man, to confine ourselves strictly to the consideration of the corporeal changes which accompany the different mental affections, and to avoid, as much as possible, encroaching upon the province of the metaphysician. That certain physical changes take place in some portion or other of the cerebral mass in connexion with various mental changes, we have the clearest evidence: but of the nature of these physical changes we are wholly ignorant; nor does the present state of our information afford a shadow of hope that we shall ever gain any more precise knowledge of them. The mental changes, on the other hand, constitute a distinct and separate branch of science; to the knowledge of which we arrive by channels totally different from those which instruct us relatively to the former; namely, by consciousness, and by reflexion on the series of phenomena furnished to us by consciousness. These

[1] See Grainger's *Observations on the Structure and Functions of the Spinal Chord.*

two subjects of study, the material and the immaterial, however numerous may be the subtle and inscrutable links that connect them, constitute two worlds, which in our conception must for ever remain totally distinct; nor is it even possible for us to conceive how any knowledge which we can obtain with relation to any physical changes in our corporeal frame, or any physiological laws that may regulate the succession of those changes, can in the smallest degree assist us in understanding the phenomena of intellect, and the affections of the soul.

(749.) The brain has been very justly regarded as the organ of the mind; that is, the corporeal instrument invariably employed in the operations of the mind. This is a necessary corollary from the proposition that no mental operation can take place without the co-existence of some physical change in the brain. But a second proposition, the converse of the former, has been advanced; namely, that the mental operations are the "functions of the brain." But this latter proposition would be true only on the supposition that the physical change in the brain, and the corresponding mental change of which we are conscious, are one and the same thing. Until this fundamental doctrine of materialism, namely, the identity of matter and mind, be proved, we cannot include under the functions of the brain, both the mental changes and the corporeal changes. The physiological office, or function of the brain is the production of certain corporeal changes, connected in some inexplicable manner with certain mental changes; which two classes of changes are in their nature, as far as we are capable of forming any conceptions of them, radically and essentially different from each other.

(750.) The ambiguity of ordinary language is, indeed, a frequent source of confusion of ideas on this subject. We speak correctly when we say that the eye is the organ of vision, because it is an instrument without which vision could not be exercised; but were we to regard vision as the function of the eye alone, we should evidently be guilty of inaccuracy in extending too far the purpose of that instrument. The function of the eye is to produce certain impressions upon the retina, which impressions are but links in the series of changes, of which only the last constitutes vision. These impressions made on the retina are followed by changes in the course of the optic nerves, and these again by changes in the sensorium. The function of the optic nerves, and of that part of the sensorium in which they terminate, is the production of these physical changes. Vision, an affection of the mind, is undoubtedly the effect of these physical changes; but is not properly the function of any of these organs, except the term function be used in that loose and popular sense, in which it is made to embrace all the remote consequences of the phenomena, in the production of which the organ in question is concerned. In this sense, indeed, vision, and all the mental affections consequent upon vision, might certainly be said to be functions of the eye; but in the strict philosophical sense, the function of the eye is limited to the formation of images on the retina, and the impressions thereby received by the retina; and, in like manner, the proper function of the brain is the production of certain physical changes in the fabric of the brain, consequent upon certain impressions made on the nerves by external causes, and consequent also upon certain internal affections of the mind, which are capable of exerting on it this influence.

(751.) The affections of the mind are very various and complicated ; a great multitude of ideas and associations are treasured up in it, and constitute a variety of powers, of faculties, of propensities, of instincts, and of passions. The conformation of the brain, which is the organ of the mind, is also very complex, and appears to consist of an assemblage of different parts, constructed evidently with extreme refinement, and arranged with great care, and with very elaborate design. The idea naturally suggests itself, that these different portions recognised by the anatomist, may perhaps have some correspondence with the several faculties into which the phenomena of the mind have been analyzed by the metaphysician. This question has indeed been often started, and is quite distinct from that of the materiality or immateriality of the soul ; for it is perfectly conceivable that if the immaterial soul acts by means of material organs, and receives impressions from those organs, its different operations may require different organs. But this subject, together with the theories to which it has given rise, having been already amply discussed under the Treatise on PHRENOLOGY, we need pursue the subject no farther in this place.

SECT. IX.—SLEEP.

(752.) Whilst the functions which have for their object the reparation of the state of the body, and which include assimilation, absorption, circulation, respiration, secretion and nutrition, continue in constant activity, all those connected with sensation and volition require intervals of repose, and cannot be maintained beyond a certain time without great exhaustion of the nervous power. These periodical intermissions in the activity of the animal functions, so necessary for the renovation of the power on which they are dependent, constitute *sleep.* The eye-lids close to protect the eye from injury, and the eye-ball is turned upwards; the external senses and all the active intellectual operations are suspended; the voluntary muscles are relaxed; and we become insensible to all external impressions. The movement of the involuntary muscles continue, though with somewhat less energy than during our waking hours. The heart beats with diminished force and frequency, and the muscles of respiration act more slowly; but the inspirations are more full and deep, and the secretions are in general less abundant; but digestion and absorption are carried on with great activity. The power of sensation, though blunted, is not altogether lost during sleep, as is proved by the continuance of that part of the movements of the muscles of respiration, which depend on sensation. Instinctive movements of the limbs, producing a change of posture, frequently take place from an obscure sensation of constraint at their continuing long in the same position. Any unusual impressions made on the organs of the senses are felt during sleep, and even remembered; and, if the impression be sufficiently vivid, will interrupt sleep.

(753.) Neither is the mind wholly inactive during sleep; it is still occupied with a succession of ideas, which is often more rapid than when we are awake; the imagination is even more vividly exerted, and the images that pass before the mind are considered as realities. This constitutes *dreaming*, a state which is characterized also by the peculiar circumstance of the want of all voluntary power of directing the succession of ideas. Trains of ideas and images commence and follow one another, being indissolubly linked together by those laws of association which are independent of volition.

(754.) An extraordinary modification of dreaming occurs in what is called *somnambulism,* or sleep-walking; where the will recovers a certain degree of power over the mental operations, and over the voluntary muscles both of speech and of motion, whilst the body is still less capable of receiving external impressions than in ordinary sleep. In this peculiar kind of sleep, the insensibility to most external impressions is so profound, that it is scarcely possible to awaken the person without employing a considerable degree of violence. When at length he does awake, which often happens as suddenly as from natural sleep, he usually retains little or no recollection of what happened to him, or of what he did whilst in this singular state.

(755.) A state very similar to that of natural somnambulism, is induced in some nervous constitutions, especially those of young females, by certain manipulations which produce a long-continued reiteration of impressions made on the senses, and which probably act through the medium of the mind. These have been ascribed to a special agency, termed *Animal Magnetism,* or *Mesmerism.* For an account of these effects, we must refer our readers to the article MAGNETISM, ANIMAL.

CHAPTER XVII.

THE VOICE.

(756.) The function of the voice, and of its modulation into articulated sounds, by which it is rendered subservient to speech, has been already pointed out as an important part of the animal economy of a being designed, as man evidently is, to hold extensive communion with his fellow creatures, and effect the rapid interchange of ideas and feelings, through the medium of the sense of hearing, (§ 24.)

(757.) In order to understand the mode in which articulate sounds are produced, it will be necessary again to advert to the principles of acoustics, of which a brief account was given in introducing the subject of the physiology of hearing, (§ 623.) The object to be accomplished in the function of the voice is the production, not so much of single sounds, (such as those which result from single impulses given to the air,) but of continued sounds, composed of reiterated vibrations, repeated at short and equal intervals, and constituting a *musical note*. There are two principal modes in which such sounds are produced; the one, that which is practised in stringed musical instruments, in which the impulses are given to the air by the vibrations of solid bodies, which are generally chords having different degrees of tension; and the other, such as is adopted in wind instruments, where the air is thrown into undulations at regular intervals, by alternations of expansion and condensation, generally taking placing during the passage of a stream of air through a cavity in which it suffers certain reflexions and reverberations, alternately impeding and promoting its progress. In many cases the effect is obtained by a combination of both these means, as in a hautboy, where an elastic plate, or *reed*, is placed in the course of the air which is passing along a tube, capable by its form of producing a musical note, independently of such addition.

(758.) In the construction of the vocal organs of man, nature has resorted to combinations of this kind. Advantage is taken of the function of respiration to convert the passages through which the air is admitted to, and expelled from the lungs, into a sounding instrument; by adapting to the upper part of the trachea, a curious mechanism, consisting of a frame-work of elastic cartilages, with an apparatus of ligaments, muscles, membranes, and mucous glands, the assemblage of which is termed the *larynx*. The aperture through which the air passes is denominated the *glottis*. Here it is that the breath is *vocalised;* that is, rendered not only sonorous, but also modulated in its pitch, so as to give rise to a musical sound. Modifications are subsequently impressed on these sounds, by the changes which the undulations are made to undergo in the cavities of the pharynx, of the nostrils, and of the mouth, according to the various forms and dimensions given to those cavities by the motions of the muscles of the pharynx, the velum pendulum, the uvula, the tongue, the cheeks, and the lips; and according to the obstacles placed in the way of the passage of the air by the movements of these parts, and the application, in particular, of the tongue and of the lips to the palate and to the teeth.

(759.) The cartilages of the larynx are five in number, namely, the *thyroid*, the *cricoid*, the two *artenoid*, and the *epiglottis*. The *thyroid*, which is also called the *scutiform*, or shield-like cartilage, is placed at the upper and fore-part of the larynx, and is the largest of the whole. It consists of two lateral wings of a quadrangular form, uniting in front in a longitudinal angle, which is felt projecting in the fore-part of the throat, and has obtained the name of the *pomum adami*. From the posterior corners, four processes project, called its *cornua*, distinguished into two *superior*, and two *inferior*. The *cricoid*, *annular*, or *ring-like* cartilage, is placed below and behind the former; and it has four articular surfaces, two below, for its connexion with the inferior cornua of the thyroid cartilage, and two above, for the articulation of the *arytenoid* cartilages, which are bodies of a pyramidal shape, much smaller than the rest, and placed one on each side, upon the upper posterior and lateral parts of the cricoid cartilages. They give attachment to ligaments, and compose a part of the sides of the opening called the *glottis*. The whole passage is lined internally by a delicate mucous membrane.

(760.) The *epiglottis* is a cartilaginous lid, which has a pointed shape, resembling the leaf of an artichoke. It is fixed at its base to the os hyoides, to the thyroid cartilage, and to the root of the tongue; and hangs obliquely backwards over the opening of the glottis, which extends in a line from behind forwards, and is formed by the approximation of the vocal ligaments, or *chordæ vocales*. These ligaments, which consist of fibres endowed with a high degree of elasticity, are covered with the fine membrane which invests the whole of this delicate apparatus, and extends down the trachea into the lungs, and above to the posterior fauces.

These are attached together in front to the thyroid cartilage, and behind to the arytenoid cartilages, where, in the relaxed condition of the organ, they are at some distance from each other, so as to leave a triangular opening for the passage of the air. The effort to speak, or to utter a vocal sound, commences with the action of certain muscles, more particularly the *crico-thyroidæi*, which stretch the vocal ligaments, and the *crico-arytænoidei laterales*, and the *arytænoidei transversi and obliqui*, which conspire to make the arytenoid cartilages approximate. By these combined actions, the vocal ligaments are brought near to each other, in parallel directions, so that the interval between them or *rima glottidis*, as it is called, is reduced to a mere narrow linear fissure.

(761.) When, therefore, the air is forcibly propelled from the lungs through the glottis, whilst the vocal chords are in this approximated position, different vocal sounds will be produced, according to the degree of tension which is given to the chordæ vocales. The greater the tension of these ligaments, the more frequent will be their vibrations, and the higher the pitch of the note they produce. The loudness of the sound emitted is proportioned, not to the frequency of the vibrations, but to their extent, or the magnitude of the excursions made by the vocal chords in vibrating. The varied degrees of tension which can be imparted at will, and instantaneously, to the vibrating ligament of the larynx, by the finely regulated actions of their different muscles, constitute the chief source of superiority in the vocal organ to any instrument of human invention.

(762.) The muscles above enumerated as giving tension to the vocal ligaments, and clossing the glottis by the approximation of the arytenoid cartilages, are opposed by their antagonists the *thyreo-arytænoidei*, which relax the vocal ligaments, and place them in the vocalizing position, and by the *crico-arytænoidei postici*, which separate the arytænoid cartilages, and thereby open the glottis. Thus the instrument we are considering is capable of an infinite number of changes of form, and susceptible of the finest modulation.

(763.) It should be stated, however, that many physiologists have maintained that the musical tones of the voice depend, not merely on the tension of the vocal ligaments, but also on the size and form of the aperture through which the stream of air is propelled, and that the larynx partakes as much of the properties of a wind as of a stringed instrument. The principal advocate of this opinion was Dodart, whose first paper[1] contains a historical account of the views on this subject taken by the earlier physiologists. His chief antagonist in this controversy was Ferrein,[2] who compares the larynx to a violin, or harpsichord, and conceives that the voice is produced by the vibrations of the edges of the ligaments of the glottis; and compares the action of the air to that of a bow setting these parts into vibration. The hypothesis of Dodart has been adopted by Blumenbach, who conceives the action of the larynx to be analogous to that of the flute. But the generality of physiologists consider the action of the ligaments of the glottis to be vibration, and similar to that of strings resounding by their tension alone. Such is the view taken of the subject by Dr. Young,[3] Soemmerring,[4] Magendie,[5] Willis,[6] and Mayo,[7]

[1] *Mémoires de l'Académie*, pour 1700, p. 244; 1707, p. 66.
[2] Ibid. pour 1741, pp. 409, 416, 422.
[3] *Lectures*, p. 400, and *Philosophical Transactions* for 1800, 141.
[4] *De Corporis Humani Fabrica*, vi. 93. [5] *Physiologie*, i. 196.
[6] *Cambridge Philosophical Transactions*, iii. 231.
[7] *Human Physiology*, 3d edit. p. 350.

who all maintain that the voice depends on the vibrations of the chords; the frequency of which must, according to all acoustic principles, be regulated solely by the tension of the chords.

(764.) Dr. Willis observes that, for the production of laryngeal sounds, something more is requisite than a definite tension of the vocal ligaments. He has shown, by experiment, that in order that the edges of two membranes, such as those made of leather or of Indian rubber, opposed to each other with a narrow interval, may vibrate, the parts of the membrane near their edges must be brought parallel to each other. Comparing this disposition of membrane in his experiment with the parts of the larynx, he supposes that the latter will not vocalize, unless some change, independent of, and superadded to, the tension of the ligaments, be produced in their relative position.

(765.) The experimental proof on which Mr. Willis founds his conclusion that some change in the relative position of the vocal chords is necessary to produce an audible vocal sound, is the following. If the finger be placed upon the membrane which intervenes between the thyroid and cricoid cartilages, their approximation or increased remoteness may readily be felt. Now their approximation being produced by the action of the crico-thyroid muscles, involves an increased tension of the ligaments. But it is possible by an effort to keep these cartilages approximated, whilst something is still wanting in the internal arrangement of the larynx, to fit it for the production of sound. When the thyroid and cricoid cartilages are thus approximated, and the ligaments thus shewn to be in a state of tension, if air be impelled through the larynx, sound does not necessarily follow; the ligaments have still, Mr. Willis concludes, to be placed in the vocalizing position.[1]

(766.) There are still other parts of the vocal apparatus connected with the sounds produced at the larynx, which require to be adverted to. Amongst these the varying conditions of the trachea appear to have the greatest influence on those sounds, and of this influence Mr. Wheatstone proposes the following theory:[2]

"Such a vibrating apparatus as we have described the ligaments of the glottis to compose, is by itself capable, from the varying tension of those ligaments, of producing all those sounds of which we find the voice to be susceptible. But the intervention of a tube between the lungs and the larynx, must necessarily exercise an important influence on the voice, though it has never yet been taken into consideration. For, if we unite such an apparatus, or a free reed, which may serve as a substitute for it, with a tube (supposing it for the moment fixed to a determinate degree of pitch), it is found, that, unless the column of air in the tube is of such a length as to be separately capable of producing the same number of vibrations, the sound cannot be obtained in its greatest force and purity, and that when the tube is half this length, the discordance between the tube and the reed is so great, as to prevent the production of the sound: between these limits the sound is intermediate in intensity and quality. This influence of the tube is by experiment found to be the same, whether the tube be placed after the reed, as in several wind instruments, or be-

[1] See Mayo's *Outlines of Human Physiology*, 3d edition, p. 350, 351, from which the above account of Willis's theory is extracted.

[2] Ibid. p. 252.

fore it, as in the vocal organ. We will now suppose the tube to be unalterable in its length, and the reed necessarily to undergo all its varying modifications of pitch ; the sounds, instead of being of even quality, will be irregular in intensity, and require different degrees of effort to produce them, whilst in some parts of the scale, they will be totally extinguished. All this may be prevented, and the utmost regularity obtained, by shortening the tube, in proportion as the vibrations of the reed increase in frequency. The trachea is obviously incapable of changing its length within limits sufficiently considerable to serve this purpose ; but Savart's experiments have shown, that a tube of constant length may be made to produce a great range of sounds, by making it of elastic sides susceptible of variable tension. The analogy between such a tube and the trachea is perfect."

(767.) One mode of giving increased tension to the windpipe is the action of the transverse muscular fibres which bind the ends of its cartilages together. Another is the elevation of the larynx, which follows in so remarkable a degree the elevation of the pitch of the voice. Practice in singing improves the voice, partly by giving us a more ready command over the tension of the trachea, and partly by enabling us to regulate and vary the opening of the glottis whilst we preserve the tension of the vocal chords.

(768.) Such being the mode in which vocal sounds are produced in the larynx, the next step in the inquiry will relate to modifications they receive from the shape of the cavities of the pharynx and mouth, through which the expired air has yet to pass. When thus modified they become not merely vocal, but *articulate* sounds, and constitute the elements of speech.

(769.) This branch of the subject has been ably investigated by Sir Charles Bell,[1] who has traced the influence which the changes produced by the muscular actions of the tongue and fauces, on the shape of the cavities of the mouth and pharynx, have on the resulting articulate sounds. He has examined the succession of actions which must be performed before a word can be uttered, and which he finds to consist in the compression of the thorax, as well as the adjustment of the glottis, the elevation and depression of the larynx, and the contraction of the pharynx.

(770.) The elementary articulate sounds of a language consist of vowels and consonants. Vowels are continued sounds, produced when the passage of the air through the fauces is uninterrupted, the fauces being only more or less narrowed. Each vowel requires a different elevation of the tongue or contraction of the lips. Thus the sound of the broadest pronunciation of the letter *a*, which occurs in the word *awe*, results from the lowest position of the tongue, giving its greatest depth to the cavity of the mouth. The ordinary sound of *a*, as in the word *age*, is produced by a certain elevation of the tongue, reducing considerably the capacity of the mouth. The vowel *e*, pronounced as in *eve*, is sounded by raising the tongue still more, so as to leave a more contracted channel for the exit of the air. The positions for *o* and *oo*, are obtained by placing the fauces in the position first described, namely, that for *au*, and then approximating the lips.

(771.) The pronunciation of consonants is effected by interruptions to the passage of the air in some part of the cavity of the mouth, by various motions of the tongue and lips, which, when applied to the palate or the teeth, narrow or close the channel for its exit.

[1] *Philosophical Transactions* for 1832, p. 299.

(772.) The following experiment is mentioned by Mr. Mayo[1] as having been made by M. Deleau, demonstrating that the articulation of vocal sounds takes place in the fauces. He introduced through the nostrils into the pharynx a flexible tube, and, by means of a gum bottle, impelled air through it into the fauces; then, closing the larynx, he threw the fauces into the different positions requisite for producing articulate sounds, when the air impelled from the gum bottle became an audible whisper. Dr. Bennati repeated this experiment, allowing at the same time laryngeal sounds to pass into the fauces, when each articulated letter was heard double, in a voice at once, and in a whisper.

(773.) Consonantal sounds may be divided, first, into *aspirates* and *sonants*, or, secondly, into *continuous* and *explosive*.

(774.) The aspirates are those which may be rendered audible without a vocal sound, as is the case with *p*, *t*, *k*, *h*, *f*, *th*, *s*, and *sh*. The sonants are those which, without any appreciable difference in the shape of the fauces from the form required for the pronunciation of the preceding to which they are allied, are not heard without a vowel sound, either previously uttered, as in *b*, *d*, *g*, *v*, *z*, and *l*, or subsequently, as in *g*, or in conjunction with it, as in *r*.

(775.) Continuous consonants are pronounced when the vocalized air passes through some part of the organ, previously rendered very narrow. Explosive consonants are those which are produced by the interruption to the current of air occasioned by the entire closing of the passage, and its being allowed to burst out with some force by the sudden opening of the same passage.

[1] *Outlines of Human Physiology*, p. 354.

(776.) The nasal consonants, *m*, *n*, and *g*, are distinguished from the rest by the peculiar character of their articulation arising from the breath being allowed to pass through the nostrils; whilst in the pronunciation of the others, the soft palate being raised closes the posterior nostrils, and prevents the sound from diffusing itself in that direction.

(777.) We refrain from entering into any further details with regard to the position of the fauces, tongue, and lips, in the pronunciation of the different consonants, having already treated of this subject at some length, in the article Deaf and Dumb, to which we shall therefore refer our readers.[1]

(778.) The low pitch of the voices of men compared with those of women and boys, arises both from the greater general size of the larynx, and also the greater length of the chordæ vocales, which has been found to measure nearly double that of the latter. In attempting to utter high notes, voices, naturally grave, assume the character of the *falsetto*. This, Mr. Willis supposes, may result from the shortening of the vocal chords; but Mr. Wheatstone is disposed to ascribe it to the tension given to the windpipe being such as to reinforce the laryngeal sounds by subdivisions.

(779.) Some curious observations on the mechanism of the voice during singing have lately been given by Dr. Bennati,[2] who states, that the compass of his own voice extends to three octaves. He concludes from his inquiries, that it is not merely the muscles of the larynx which modulate the sounds, but those also of the os hyoides, and the other neighbouring parts. He mentions that, on removing

[1] See also Haller's *Elementa de Physiologiæ*, ix. 4; Dr. Young's *Lectures*, ii. 276; and the work of Mr. Mayo, already quoted.

Annales des Sciences Naturelles, xxiii. 32.

part of the tonsils, the operation was followed by the raising of the voice half an octave, without altering its compass. Mr. Mayo supposes this effect to result from the cicatrix stretching the mucous membrane of the larynx, and thus giving increased tension to its inner surface.

CHAPTER XVIII.

GENERATION.

SECT. I.—GENERAL VIEWS.

(780.) As far as we are permitted to scan the designs of the Almighty Creator in the formation of organized beings, they appear destined to a mode of existence characterized by perpetual mutation. Their living state is made to consist of a perpetual series of actions and reactions, in which nothing is intended to be permanent, not even the materials of which the combinations constitute the substance and organs of the body. All is subject to displacement, alteration, renewal, and renovation, during a certain definite period, which varies in each species, according to the primordial law of its constitution; and all must bend, when that period is exceeded, to the imperative law of mortality, to which every individual endowed with life is subjected.

(781.) But the same counsels which prescribed these limits, and decreed the extinction of life, and the dissolution of the frame in which it had resided, have providently ordained most ample means for the continuance of the race, and the indefinite multiplication of its numbers. Individuals perish, but the species is preserved in endless perpetuity by means of GENERATION; a function of paramount importance in the economy of nature, and for which the most ample provision has been made, and the greatest solicitude manifested to secure the accomplishment of its purposes. Nutrition and generation, indeed, constitute the only functions which can be said to be universally exercised by all organized beings, whether belonging to the vegetable or the animal kingdom, or whatever rank, from the lowest to the highest, they may occupy in the scale of nature.

(782.) But although the purpose is thus manifest, and the provisions for its execution thus effective and even exuberant, the immediate agency by which one living being is rendered capable of giving rise to another similar to itself, is enveloped in the most profound and most hopeless obscurity. No means within the compass of our understanding, no combination of the powers of matter which we can possibly conceive, no process of which the utmost stretch of human imagination can give us the most remote idea, has ever made the least approach towards the solution of this most inexplicable of all enigmas,—the production, nay, the apparent creation, of a living plant or animal by powers inherent in the organization of a similar being. We must content ourselves, in studying this inscrutable mystery, to observe and generalize the phenomena, in silent astonishment at the marvellous manifestation of design and of power exhibited in this department of the wonderful works of the Almighty.

(783.) Various plans of reproduction are exhibited in the different classes of animals, but they are all reducible to three general heads, which may be designated by the titles of *fissiparous*, *gemmiparous*, and *sexual* reproduction. Many physiologists, however, have been disposed to admit the existence of a fourth mode of reproduction, which they have termed *spontaneous*, or *equivocal generation*. It is contended by the advocates of this hypothesis, that in many of the lower tribes, instances occur of the formation of animals without the intervention of any parents, and produced by the spontaneous union of certain elements, which might fortuitously be found in juxtaposition, in collections of the decomposing materials of other organized structures, after the extinction of their life. Although this opinion was at one period the generally prevailing doctrine, it is now, in consequence of the more extensive knowledge which has been obtained of the procedure of nature in the multiplication of animals, very generally exploded. The principal arguments in its favour were, in the first place, those drawn from the existence of intestinal worms, and other parasitic entozoa, in the bodies of animals, the germs of which appear neither to be introduced into the system from without, nor to have any assignable origin from within; secondly, those derived from the rapid appearance of infusory animalcules in all infusions of decaying animal or vegetable matter that are exposed for a short time to the air. But the analogy of every other department of the animal and vegetable kingdoms is directly opposed to the supposition that any living being can arise, unless it has originally sprung from an individual of the same species as itself, and of which it once formed a part. The difficulty which the hypothesis of the spontaneous production of infusory animalcules professes to remove, consists in our inability to trace the pre-existence of the germs in the fluid where these animalcules are found to arise, and to follow the operations of nature in these regions of infinite minuteness. But the recent discoveries of Ehrenberg relative to the complete organization of these beings, in which he in many instances detected the presence of generative organs, has very much diminished the difficulty of conceiving the possibility of their ova, so minute as to be wholly imperceptible, existing in great numbers in the fluid, or even in the atmosphere, and giving rise to all the observed phenomena.[1]

(784.) *Fissiparous generation*, the simplest of all possible modes in which the species can be multiplied, consists in the spontaneous and gradual division of the body of an individual animal into two or more parts, which, when the division is completed, separate, and each soon assumes the form, and grows to the size of the parent, and becomes capable of performing all the functions which originally belonged to the undivided animal. The most common form of this mode of generation is met with in some of the simpler of the infusoria, as the monas, the gonium, the cyclidium, the vorticellæ, and the volvox. In the instance of the volvox, however, we find an approach to the next order; for the young are seen forming within the body of the parent, which is, in course of time, reduced to a mere membranous vesicle, and then bursts, and is torn into shreds, setting free the enclosed young, each of which immediately begins to execute its independent movements in the fluid.

(785.) *Gemmiparous generation* occurs when a new in-

[1] See Bridgewater Treatise, *on Animal and Vegetable Physiology*, vol. ii. p. 591, note.

according as the male and female organs are both contained in the system of the same individual, (as occurs in *monœcious* plants and hermaphrodite animals,) or exist separately in different individuals, (as in *diœcious* plants, and all the higher classes of animals.) In the former case, self-impregnation may take place, either by the required seminal access being effected internally in each individual independently of any other; or, in other cases, by the concurrence of two individuals in sexual union which reciprocally impregnate one another, (as is exemplified in the leech, the earth-worm, and the snail.) In the second division, where the male, or fertilizing organs, are possessed exclusively by one individual, and the female organs, or those producing the germ, by another, impregnation of the ova may take place either after their exclusion from the body of the female parent, by their contact with the male semen ejected on them when thus excluded, (as happens in the case of fishes and batrachian reptiles,) or within the body of the female; for which latter purpose, a new function, that of *copulation*, becomes necessary. This last mode of procedure is had recourse to by nature in by far the largest portion of the animal kingdom, including all the tribes of insects, nearly all the mollusca, and all warm-blooded vertebrated animals.

(790.) All the subsequent phenomena relate to the developement of the embryo thus brought into existence; to the supply of nourishment for its growth; and to the advantages of situation, of warmth, and of protection, which are necessary for the favourable procedure of the vital powers in the progress of this developement.

(791.) Various plans are resorted to for conducting these processes of developement of the fecundated ovum. In that which is termed *oviparous generation*, the ovum, during its passage through the oviduct, receives the addition of a considerable quantity of nutritious matter, sufficient for the supply of all the materials requisite for its growth, until the period when it is capable of procuring food for itself; and it also acquires a capsule, or substantial covering, frequently of a calcareous nature, fitted for its protection under the circumstances in which it is to be placed. When thus formed it constitutes an *egg*, or complete ovum; and in this form it is either excluded from the body of the female parent, and hatched, if already fecundated, by the influence of external warmth; or if not previously fecundated, this change is accomplished by the seminal fluid of the male being shed upon it. The former case, which implies sexual congress, is exemplified in all insects and birds: the latter, which requires no such congress, obtains in fishes, and many of the reptilia. Both are comprehended under the term *oviparous animals*.

(792.) In a few instances the eggs, previously fecundated within the body of the female, instead of being expelled, remain in the oviducts until they are spontaneously hatched, and the young are then brought forth alive. This phenomenon, which is exhibited by many cartilaginous, and a few osseous fishes, by several reptiles, and by some gasteropodous mollusca, insects, annelida, and entozoa, has been called *ovo-viviparous generation*.

(793.) In *mammiferous generation*, on the other hand, the ovum, which is not perfected in the same degree as in the two former cases, remains within the female, and is attached, by the medium of a substance called *the placenta*, to the inner surface of an organ termed the *uterus*, where it receives nourishment from the maternal system, and where it remains until it is capable of independent life, and it is then brought forth. This retention during growth in the uterus is termed *utero-gestation*, and its subsequent exclusion is termed *parturition*. The young of mammalia after birth, although they cease to be organically connected with the mother, continue to derive from her a certain quantity of sustenance in the form of milk, which is a secretion from certain glands termed *mammæ*, the possession of which is the characteristic feature of this class of animals. An exception occurs in the case of marsupiate animals, in whom the young leaves the uterus at a very 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 a pouch, termed the *marsupium*, formed by a folding of the integuments of the lower part of the belly; and a short time after it has been deposited there, it is found attached by its mouth to one of the nipples of the mammæ, which are concealed within the marsupium, and there receives its nourishment until it has acquired sufficient size and strength to quit its habitation. *Monotrematous generation*, which is peculiar to the ornithorynchus and echidna, is not yet perfectly understood. The generative organs, and the ova within the ovaries, in these animals, partake in a great degree of the oviparous type; but they are also combined with the presence of mammary glands, which perform the office of lactation, as in the strictly viviparous class of animals.

(794.) The following table, which is nearly that given by Dr. Allen Thomson,[1] exhibits a synoptical view of the

[1] *Cyclopædia of Anatomy and Physiology*, by Dr. Todd, article Generation, p. 438, to which article we are largely indebted in the compilation of this chapter.

various forms of the reproductive process occurring in different classes of animals :—

Modes of Reproduction.

- **Non-Sexual,**
  - *Fissiparous*, .
    - A. The parent splits into two or more parts, each part becoming a new animal.
      1. By transverse fissure.
      2. By longitudinal fissure.
      3. Irregularly.
    - B. The parent bursts, and the included young are discharged.
  - *Gemmiparous*, .
    - A. *Buds* sprouting from the parent stock.
    - B. *Gemmæ*, or Sporules, formed—
      1. In all the parts of the body.
      2. In one part only.
- **Sexual,**
  - *Monœcious*, or Hermaphrodite,
    - Both sexual organs contained in the same individual.
      1. By self-impregnation.
      2. By mutual impregnation.
  - *Diœcious*, .
    - A. *Oviparous ;* eggs laid, and afterwards hatched.
      1. Eggs fecundated externally.
      2. Eggs fecundated internally.
    - B. *Ovo-viviparous ;* eggs hatched within the maternal body.
    - *Mammiferous ;* the parent suckling the young by mammæ.
      1. *Monotrematous.*
      2. *Marsupial.*
      3. *Placental,* or strictly *viviparous.*

(795.) A wide range of inquiry is here opened to us, comprehending, if we were to include in its field the whole of the animal kingdom, an immense multitude of facts, to the complete study of which the labours of a whole life would be inadequate. We are, however, to confine ourselves, at present, to the view of human physiology ; but even here the great extent of the subject obliges us to reduce within a narrow compass the account we have to give of this important and interesting department of the science. For this purpose, after a short description of the circumstances relating to the unimpregnated ovum, we shall proceed to the physiology of the male and female systems respectively, bringing its history to the period of the fecundation of the ovum. This latter subject wil lead us to consider some of the most celebrated theories of generation; after which we shall briefly consider the phenomena of utero-gestation and parturition, which are functions belonging exclusively to the female parent, but which accompany and are accommodated to the successive changes attending the developement of the fœtus. Of these latter changes, relating to the system of the new individual, it will be more convenient to give the history separately.

SECT. II.—UNIMPREGNATED OVUM.

(796.) Much difficulty is necessarily experienced in obtaining direct evidence of the early changes occurring in the process of human generation, from the scanty opportunities allowed us of direct observation of those changes, and from our being precluded from resorting to the most instructive fountain of knowledge, namely, experimental research. Whilst, therefore, we obtain occasional views of the actual phenomena which occur in man, we must content ourselves with filling up the chasms in the continuous history of his generation, by the observation of those which are presented in the lower animals that most resemble him in the mode in which this function is conducted, and by remoter analogies derived from other classes.

(797.) It is well established, from these combined sources of information, that the essential part of the female system concerned in generation is the *oviary*, or *ovarium*, of which there is one, situated on each side, in the cavity of the pelvis. The ovaries are small capsular bodies, of an oblong, or oval, and somewhat flattened shape, which are enveloped in the fold of the peritoneum, forming the broad ligaments of the uterus. They are composed of a white and loose cellular texture, in which we discover several minute vesicles, or cysts, filled with a transparent fluid, and termed, from the name of De Graaf, who first observed them, the *Graafian vesicles*. Their number is generally from fifteen to twenty in each ovarium, and they vary in size, the largest being about one-third of an inch in its longest diameter. The fluid which is contained in these vesicles is slightly viscid and albuminous, inclining to a yellow colour in the most turgid vesicles, containing numerous granules of an irregular shape, and a few globules of oil, but being otherwise pellucid.

(799.) Besides the peritoneal covering already described, the ovarium has a cellular coat proper to itself. Each of the Graafian vesicles has a double investment; the outer coat consisting of a close filamentous texture; and the internal layer being thicker, softer, and more opaque than the outer, from which it is readily separable after maceration, and having a slightly villous inner surface. The membrane immediately containing the granular fluid above described, also exhibits the appearance of being studded with granules, and is on that account styled the *membrana granulosa*. Within the granular fluid is found a body, composed of closely coherent granules, which has been denominated by its discoverer, Baer, the *discus proligerus*, and which he represented as having a flattened or discoid form, and as forming the bed in which is placed the minute vesicle of the *ovulum*, or germ of the unimpregnated *ovum*. The later researches of Dr. Martin Barry, of which he has given an account in a paper communicated to the Royal Society of London, have thrown further light on this branch of Zoology. The following is a summary of the principal conclusions at which he has arrived on this subject.

(800.) The ovulum of all vertebrated animals, and of many of the invertebrata also, is contained in a vesicle, called by some authors the *chorion*, but which Dr. Barry thinks it desirable, wherever found, to call an *ovisac*. He considers the Graafian vesicle of the mammalia, and also the capsule, or *calyx* of oviparous vertebrata, as an ovisac which has acquired a covering; which covering is the "*couche externe*" of the "*capsule de la vesicule de Graaf*" of Baer. The *perfect* Graafian vesicle of the mammalia has been shewn by preceding physiologists to be analogous to the perfect capsula, or calyx of the bird; but the analogy is found by Dr. Barry to be much more remarkable between the ovisacs of these two classes of animals, before these additional coverings have been acquired; and this analogy may also be extended to those of amphibia and fishes, so that, in fact, the surfaces of all the vertebrata are in their original structure essentially the same; a conclusion which Dr. Barry is disposed to extend also to the ovisacs of many of the invertebrata.

(801.) The ovisac, being originally an independent structure, can be better studied in this state than at a later period, when it has become the lining membrane of the Graafian vesicle or calyx. Thus, while the perfect Graafian vesicle of the mammal, and the perfect capsule of the bird, are obviously corresponding structures, there yet exists this difference, that there is a space, filled with a large quantity of fluid in the former, not present in the latter; a difference which does not exist in the early stages of formation, when ovisacs in general appear in this respect to be essentially the same. The structure of the ovisac may be examined, in some mammalia, when it does not exceed in length the 600th, or even 1200th part of an inch; so that in the latter case, a cubic inch would contain 1728,000,000.

(802.) The ovisac of the vertebrata, and perhaps of other animals, is at first of an elliptical form. In the mammalia and birds, myriads of ovisacs and ovula are formed, which never reach maturity. Many of these are formed in the substance of the proper membrane of larger ovisacs, and are therefore termed by Dr. Barry *parasitic ovisacs.*

(803.) The ovisac is formed in a cavity proper to itself, with which it does not appear to have any organic connexion. The granules found in the fluid of the ovisac are very characteristic in their appearance, and imply the presence of albumen in a concentrated form. A stratum of these granules, found on the internal surface of the proper membrane of the ovisac, constitutes, as Baer remarks, a distinct membrane. But the mass of granules described by that anatomist as being discoid, is believed by Dr. Barry to be of a spherical form. This latter observer finds that the ovulum of vertebrated animals is, when first formed, situated in the centre of the fluid of the ovisac, and more or less obviously held there by a flake of granules; and has at first no proper envelope of granules. In the mammalia, there forms around the ovulum a granulous covering of a spherical form, which Dr. Barry terms the *tunica granulosa*; but it has no discoid mass of granules proper to it. At a certain period, the ovulum of the mammalia passes from the centre of the ovum to the periphery; and there, while invested by its granulous tunic, it penetrates the membrana granulosa, leaving behind it a flake of granules. Here it lies quite in contact with the proper membrane of the ovisac, is more or less imbedded in the membrana granulosa, and is supported behind by a mass of granules, sometimes presenting the appearance denominated by Baer the *cumulus*. But this cumulus does not belong to the proper granulous covering, or tunica granulosa, of the ovulum; for it may in some animals be separated from this covering, in the form of what Dr Barry calls the *petasiolus granulosus*.

(804.) After the ovulum has reached the periphery, its tunica granulosa may, at least in some animals, by contact with the membrane of the ovisac, become attenuated, or may even disappear at one side; which circumstance, together with the great transparency of this tunic, may have been the cause of Baer's assigning to it a discoid form. This approximation of the ovulum to the exterior surface of the ovisac, is doubtless for the purpose of exposing it to the action of the fecundating seminal fluid, which reaches it while it is in this situation, and still in the ovary. The next step being now the application of this fluid, we are brought to the next stage of our inquiry, namely, into the series of apparatus and of functions provided for the preparation of the semen, its introduction into the female organs, and its transmission to the surface of the ovulum.

SECT. III.—THE MALE SYSTEM.

(805.) The preparation of the seminal fluid is the office of the two glandular bodies called the testicles, or *testes*. They are suspended in a portion of common integument having the form of a sac, termed the *scrotum*, by a round band, called the spermatic cord, which pursues a very serpentine course; a plexus of veins, the assemblage of which has received the name of *corpus pampyriforme*, consisting of the spermatic artery, a plexus of absorbents, a plexus of nerves; and lastly, the *vas deferens*, or excretory duct; and they are further supported by a sub-cutaneous layer of muscular fibres, termed the *dartos*. The scrotum is divided into two chambers, one testis being lodged in each, by a membranous partition, or *septum*. Each testicle is loosely contained in a sac, formed by an external serous membrane, the *tunica vaginalis*, derived from the peritoneum, which forms a cavity for its reception similar to that of other serous membranes. This tunic is reflected, like those of other cavities, over the body of the organ; and the reflected portion, which is called, from its white colour, the *tunica albuginea*, forms the proper capsule of the testis. When this latter tunic is divided, the testis is found to consist of a flattened oval substance, to the upper, outer, and back part of which a narrow and flat slip of substance, called the *epididymis*, is found adherent.

(806.) The substance of the testicle is extremely vascular, and the ultimate branches of its spermatic arteries are collected into small bundles of fine convoluted vessels, separated from one another by *septulæ*, or membranous partitions. From these the *vasa seminifera*, or beginnings of the excretory ducts, take their rise, and gradually unite to form a smaller number of canals of larger diameter, but exceedingly tortuous in their course. On arriving at the surface and back part of the testicle, they suddenly become straight, assuming the name of the *vasa recta;* they, however, again subdivide, and their branches have very numerous communications with one another, composing the net-work of tubes called the *corpus highmorianum*, or the *rete testis*. From the rete testis arise the ducts denominated the *vasa efferentia*, which, after being again contorted into numerous convolutions, form the conical bodies called *coni vasculosi;* these again, alternately join to form the epididymis, already mentioned, and which consists of one slender tube, of enormous length, coiled upon itself into a small compass.[1] The epididymis at length emerges, in the form of a tube of larger diameter, which is the *vas deferens*, and which ascends along the spermatic cord towards the abdomen. On tracing these ducts into the pelvis, we find them passing up by a circuitous route through the spermatic passage, and on reaching the pelvis, again descending by the lower side of the bladder, to the under part of its cervix. Each duct is here connected with an oblong membranous bag, called the *vesicula seminalis*, which is a long blind sac, folded many times upon itself; its open extremity entering the vas deferens at an acute angle. These sacs are supposed to be receptacles for the retention and accumulation of semen, until the time when it is required to be expelled. But Hunter remarked that the fluid contained in them is somewhat different from that obtained from the seminal ducts of the testicle itself; and he therefore supposed that these vesicles secrete a peculiar fluid which may perhaps dilute and add to the bulk of the semen. He even contended that the proper office of these cavities is not that of reservoirs of semen; supporting his opinion by arguments derived from comparative anatomy, which furnishes many examples where no direct communication exists between them and the vas deferens, and others where these vesicles are entirely absent. Notwithstanding these analogies, the prevailing opinion is

[1] The whole length of the excretory vessels of the testes is very extraordinary. Their diameter has been stated to be no greater than the 200th part of an inch; and it has been estimated that the total length of the vessels which compose one of the testes amounts to more than 500 feet.

in favour of the vesiculæ seminales in man being reservoirs of the seminal secretion.

(807.) From the vesiculæ seminales and the vas deferens, the semen is occasionally discharged through a duct common to both, and about half an inch in length, which perforates a body called the *prostate gland*, and then opens on each side into a canal, termed the *urethra*, which is continued from the urinary bladder, close to a small eminence in that canal, termed the *verumontanum*, or *caput gallinaginis*. The prostate gland is of the size of a small chesnut; in shape it resembles a heart, with the apex directed forwards. Its texture is firm and tough; it is divided into two lateral lobes, and one anterior lobe, and contains a great number of follicles, into which a white opaque viscid fluid is secreted. This secretion is discharged by ten or twelve excretory ducts opening obliquely into the urethra, in a furrow at the side of the verumontanum.

(808.) The urethra is a canal, lined by a mucous membrane, serving the double purpose of discharging the urine and the semen. As it proceeds forwards from the neck of the bladder, it passes through the prostate gland, on emerging from which it becomes more contracted in its diameter, and passes under the symphysis pubis. At this part, for the length of about an inch, it is supported only by firm cellular and ligamentous membranes; this part of the canal is termed the *membranous portion* of the urethra. It is then dilated into what is called the *bulb*, or *sinus* of the urethra; and it afterwards receives the ducts of several mucous glands, which have been denominated the *glands of Cowper*, and which are generally very minute, but sometimes have the size of peas. One of these is placed on each side of the membranous portion of the urethra, below which they are united by an isthmus; and the duct of each, about three inches in length, opens by perforating the mucous membrane lining the spongy body of the penis. Mucus is also furnished to various parts of the canal by *lacunæ* provided for that purpose. At its bulbous part, the urethra takes a considerable curve forwards, and is surrounded in the rest of its course by a peculiar erectile texture, denominated the *corpus spongiosum urethræ.* This substance is expanded, at the extremity of the penis, into what is termed the *glans*, which is covered by a fold of the skin called the *prepuce.* The *corpora cavernosa* are the cylindrical bodies which compose the chief bulk of the penis. They arise by two *crura*, one from each ascending ramus of the os ischii, and are chiefly composed of the peculiar structure, termed the *erectile tissue*, (see § 434.) At its extremity, the urethra is considerably narrower than where it passes along the corpus spongiosum.

(809.) These parts, namely, the glans and corpora cavernosa penis, and the corpus spongiosum urethræ, consist principally of large convoluted veins, which in the last named part are particularly dilated and branched, and are bound together and crossed in various directions by ligamentous bands and fibres. This arrangement, by obscuring the connexions which the veins have with one another, as well as their tortuous course, has led to the mistake that has so long prevailed among anatomists, of ascribing to these bodies a cellular structure. These bands appear to have been provided for the purpose of limiting the distention of the vessels, and adding to the rigidity occasioned by the accumulation of blood in the venous convolutions during erection. The means by which the blood is made to pass from the small arteries into these convoluted veins, is not clearly understood. Professer Müller[1] has lately discovered a remarkable set of minute dilated and ramified branches, which he terms *arteriæ helicinæ*, and which are 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, and which he represents as projecting into the interior of the veins, and pouring their blood into them; a mechanism which must doubtless have some direct relation with the process of erection. Dr. Houston[2] has described some muscles, under the name of *compressores venæ dorsalis penis*, to the contraction of which, and the consequent impediment to the return of the blood from the penis, he attributes the erection of that organ. It is more probable, however, that this effect is produced principally by an altered action of the blood-vessels themselves, and is analogous to the turgid state of the vessels which occurs in blushing, than is owing to any mechanical cause. The purpose served by the dilatation, elongation, and rigidity of the male organ, effected by this vascular action, is obviously that of enabling it to penetrate to a sufficient distance into the female organs during coition, for the conveyance of the semen to those parts of the latter whose office it is to carry it on to the ovulum which it is intended to fecundate. With this view, the secretions from the testes, vesiculæ seminales, prostate gland, and the glands of Cowper, are poured together into the bulb of the urethra, and thence expelled with force by the action of the muscles called the *ejaculatores seminis*.

(810.) The seminal fluid, which acts so important a part in the process of generation, has at all times attracted much attention. It is found to be considerably heavier

[1] *Archiv. für Physiol. &c.* 1835. pp. 27 and 220.
[2] *Dublin Hospital Reports*, vol. v.

than water, and to have a peculiar odour, which increases on keeping; to exhibit alkaline properties, and to give off ammonia when heated. From the analysis of Vauquelin, it appears that human semen contains six per cent. of animal mucus, three of phosphate of lime, and one of uncombined soda; the rest being water. The phosphate of lime is deposited in crystals when the fluid is at rest. But the most remarkable circumstance in its composition is, the constant presence of an immense number of microscopic animalcules, the form, appearances, and size of which are different in almost every different animal; but in each species of the more perfect animals, the kind of animalcules, like that of the entozoa, is constant and determinate. Leeuwenhoek claims the merit of having first discovered them; but the priority of this discovery is assigned by Haller to Ludwig Hamm, who, when a student at Leyden, is said to have observed them in the year 1677. Another claimant of the discovery is Hartsoeker,[1] but apparently on no good grounds. An account of the controversy that arose on this subject, is given by Dr. Bostock.[2] Doubts were at one time entertained of the fidelity of the representations of these singular beings given by Leeuwenhoek; but they have been wholly removed by the later researches of Spallanzani, and the still more recent inquiries of Prevost and Dumas. These animalcules have a definite figure, consisting of a flattish rounded head, from which proceeds a long tail, exhibiting constant undulatory movements. They are accordingly classed by naturalists under the title of *spermatozoa*, as a species of the genus *cercaria*, among the infusoria.

(811.) It would appear from the elaborate researches of

[1] *Essai de Dioptrique*, art. 88, p. 227.

[2] *Elementary System of Physiology*, p. 642, note.

Prevost and Dumas, that these spermatic animalcules are 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 in which they exist are fit for procreation. They are almost always present in the fluid secreted by the testicles, and very often in that of the vesiculæ seminales, into which they have doubtless been introduced along with the fluid derived from the testicles. Hence it has been concluded, that their presence is intimately connected with the power of propagation; and may even be essential to that process. Wagner infers from his observations, that these animalcules are subject to remarkable changes of form at different periods, and that they even go through a regular gradation of developement; and phenomena leading to the same conclusion have been observed by Dr. Allen Thomson.[1]

(812.) It is not until the period of puberty that the generative organs are fully developed, and become capable in either sex, of exercising their proper functions. Prior to this period, the physical character of the two sexes is nearly the same: there is the same delicacy of complexion, the same high pitch of the voice, and the same slightness of figure. But the developement of the sexual organs appears to exercise a peculiar and specific influence over the system at large, affecting the growth of the rest of the frame, and modifying both its physical and mental powers. The attainment of this condition is more tardy, by two or three years, in the male than in the female; and the age at which it takes place, differs in different climates, and in persons of different temperaments, modes of life, and circumstances of

[1] *Cyclopædia of Anatomy and Physiology*, art. Generation, p. 460.

physical and moral education. It occurs at an earlier age in southern than in northern climates; in this country generally appearing in the male between the ages of fifteen and eighteen years; and in the female from that of thirteen to sixteen; but in the hottest regions of the great continents, girls are said to arrive at puberty at ten, or even at nine years of age; and in the northernmost parts of Europe, not till that of from fifteen to eighteen. The arrival of this period is retarded by habits of active bodily exertion.

(813.) The characteristic changes induced by puberty in the male besides the developement of the genitals, and the secretion of the seminal fluid, are the enlargement of the larynx, which changes the quality of the voice; the growth of the beard on the chin, upper lip, and cheek, and of an increased quantity of hair on the rest of the body, and especially on the pubes; the enlargement of the chest and shoulders; an increase of physical activity and power; a greater capability of enduring fatigue; an exaltation of the active powers of the mind, and of the qualities of courage and resolution.

(814.) The act of sexual union is prompted by instinctive feelings, experienced by both sexes, and which generally depend on the condition of the body, and of the genital organs in particular, which are then in a state of high excitement. This mental feeling, and the local affection appear to be intimately associated together, and mutually produce one another. According to the doctrines of phrenology, the cerebellum is supposed to be that particular part of the encephalon which presides over the sexual function; and to be, in a word, the sensorium commune of the feelings relating to it; that is, the part to which impressions of a sexual kind proceed, and from which all sexual desire emanates; and to be the source of that power by which the generative organs execute their appropriate functions. Dr. Allen Thomson, after enumerating the proofs alleged in favour of this hypothesis,[1] observes, that he is not inclined to adopt it as established on sufficiently accurate and extensive data; and remarks, that the comparative anatomy of the brain, (in which, rather than in experiments on animals, he would be 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 phrenological doctrine, and furnishes several facts which militate strongly against it. (See the article PHRENOLOGY.)

SECT. IV.—THE FEMALE SYSTEM.

(815.) The female generative system of organs, having to perform the offices of receiving, conducting, and applying to the ovulum the seminal fluid, of conveying the ovum into a situation where it can be evolved and properly nourished, and of bringing it forth at the appointed period into the world, is necessarily much more complicated and elaborate than the male system. The part performed by the male is quickly accomplished, while the female has to execute a long series of processes, which require a considerable time, and are connected with important changes in the economy.

(816.) The ovaria, of which we have already described the structure and offices, are connected with a hollow muscular organ, termed the *uterus*, *matrix*, or *womb*, by two ducts, called, from the name of the anatomist who first de-

[1] *Cyclopædia, &c.* p. 444.

scribed them correctly, the *Fallopian tubes*. They commence by a trumpet-shaped mouth, opening from the abdominal cavity, and of which the edges are fringed or jagged with irregular filaments, or *fimbriæ*, as they are termed.[1] The mouth of the Fallopian tubes are endowed with the power, on certain occasions of venereal excitement, of attaching itself to the adjacent ovarium, and of firmly grasping it. The tubes, each of which is about five inches long, in their progress towards the uterus, soon contract in their diameter, and become exceedingly narrow at their termination in the upper and lateral corner of the triangular cavity of that organ. They are enclosed in the folds of the peritoneum which form the broad ligaments of the uterus.

(817.) The uterus itself is a compact, dense, membranous, and fleshy organ, provided with a copious supply of blood-vessels, lymphatics, and nerves. It has the shape of a flattened pear, and is situated in the pelvis, between the rectum and the urinary bladder. The outer surface of the uterus is covered with a reflected portion of the peritoneum, which, in passing from the sides of the uterus to the sides of the pelvis, forms the broad ligaments already mentioned, or the *Alæ Vespertilionis*, as they have been called. It is also provided with round ligaments, connecting it with the external parts of the pubes. The inner surface of the uterus is lined with a mucous membrane. The existence of muscular fibres in its substance has been called in question by many anatomists, and it is certainly difficult to demonstrate their presence; yet the extraordinary mechanical force which this organ exerts during parturition can scarcely be ascribed to

[1] This part has also been termed the *morsus diaboli*.

any power but a muscular one.[1] The parts of the uterus are distinguished into the *fundus*, which is the broad end turned towards the abdomen, the body and the *cervix*, or narrow end. The channel of the cervix uteri, which proceeds from the lower angle of its triangular cavity, leads into the *vagina*, which is an elastic membranous canal, opening externally, and surrounding at its upper part the cervix uteri, which forms a protuberance in its cavity, called the *os uteri*, or *os tincæ*, from its supposed resemblance to the mouth of a tench.

The membrane which lines the vaginal cavity is continued from the mucous membrane of the uterus, but is thrown into numerous folds and wrinkles, admitting of occasional dilatation of the canal. This is surrounded by a tissue, of an erectile structure, termed *plexus restiformis*, or *corpus cavernosum vaginæ*.

(818.) The external parts are the *mons veneris*, which is formed by an accumulation of adipose substance on the upper part of the *symphysis pubis*. Below this are the *labia pudendi*, forming in their progress towards the anus, from which they are divided by the *perinæum*, what was called by the French anatomists *fourchette*. Between the labia is the *fossa magna*, in the upper part of which is lodged the *clitoris*, a small, round, and spongy organ, which is analogous to the penis in its erectile structure, being composed of two *corpora cavernosa*, arising from the tuberosities of the os ischii, and terminating in an impervious glans, furnished with a prepuce. The *meatus urinarius*, or orifice of the urethra, which in the female is very short, opens immediately below

[1] Dr. Bostock has given in his *Physiology* an enumeration of the authors who have written on both sides in this controversy, p. 648, note.

the clitoris. From this part, on each side of the fossa, extends the *nymphæ*, or *labia minora*, which are membranous and spongy folds. The *vulva*, or orifice of the os externum, is in part closed by a transverse membrane, of a crescentic form, called the *hymen*, the remains of which, after it has been lacerated, compose the folds called *carunculæ myrtiformes*.

(819.) The changes which the female system undergoes at the period of puberty are on the whole as considerable as those of the male, although many of the external characteristics of the state of childhood are still retained, such as the delicate texture and inferior developement of the general frame, the large proportion of subcutaneous fat, smooth skin, and want of prominence in the muscles of the trunk and limbs. But the genital system undergoes a considerable and rapid developement at this period, the breasts enlarge, the pelvis becomes more capacious, and a peculiar periodical secretion, from the inner surface of the uterus, consisting of a certain quantity of sanguineous fluid, is established. This process, which is termed *menstruation*, recurs at periods nearly equal to a lunar month, and continues, with certain intermissions, determined by the occurrence of pregnancy, and the performance of the function of lactation, as long as the organs are capable of bearing progeny, which is, on an average, a term of thirty years. The fluid thus discharged is generally believed to contain less fibrin than blood, and to be less prone to putrefaction; it evidently contains a large proportion of the colouring particles of the blood, and is very seldom found to coagulate. The secretion amounts, on an average, to six or eight ounces, and usually continues for about four or five days, beginning and leaving off gradually, and being most abundant towards the middle of the period. The discharge in general takes place slowly, or drop by drop.

(820.) The effectual fecundation of the *ovulum*, which is by this change converted into an *ovum*, and its removal to a situation where the *embryo*, then first brought into existence, can be perfectly developed, constitute the process of *conception;* but the exact nature of this process, as well as the precise circumstances which must concur for its successful accomplishment, have been but very imperfectly ascertained. The investigation of these phenomena in the lower animals, however, has rendered it extremely probable that Graafian vesicles are continually being produced in the ovarium, and come forwards at intervals, during the whole period of female fertility, and that they burst in succession, and shed the contained ovula, whether sexual intercourse take place or not, although there is reason to believe that their maturity is hastened by this act. The consequence of the bursting of one of these vesicles is the escape of the ovulum or ovum, as the case may be, and its passage down the Fallopian tube into the cavity of the uterus. The lacerated membrane of the vesicle closes, leaving a scar; the internal coat becomes thickened, and a yellow substance is deposited in its cavity, giving rise to the appearance which has been termed a *corpus luteum.* The presence of this substance is a certain indication of the previous bursting of a Graafian vesicle.

(821.) Much discussion has arisen on the question as to the precise time when, and place where, the ovulum is impregnated. There seems now, however, little reason to doubt that the semen, immediately on its reception into the uterus, is conveyed by the Fallopian tubes to the ovarium itself, and then comes in contact with the exposed ovulum, which is ready for fecundation. On the bursting of the vesicle, the ovum is conveyed down the Fallopian tube, and arrives at the uterus, where the changes it next undergoes will be the subject of future inquiry.

SECT. V.—THEORIES OF GENERATION.

(822.) Having thus stated the provisions which have been made by nature for the fecundation of the ovulum, by the concurrent offices of the two sexes, we may here examine various speculations and opinions which, from time to time, have been entertained relative to the nature of this marvellous and mysterious process; speculations which, although for the most part exceedingly hypothetical, and often completely visionary, have been dignified with the appellation of *theories of generation.* This it is our intention to do very briefly, and to notice only the more important of these theories; for the total number of hypotheses which have been advanced on this subject is so great, that their mere enumeration might occupy many pages. Drelincourt, who lived in the latter part of the seventeenth century, collected from the writings of his predecessors as many as two hundred and sixty-two "groundless hypotheses" concerning generation; and "nothing is more certain," observes Blumenbach, "that Drelincourt's own theory formed the two hundred and sixty-third"

(823.) These theories may be arranged according as they relate to the action of the parent organs, or to the changes in the egg occurring during the formation of the new animal; and Haller divided the first of these classes into three divisions, according as the offspring is supposed to proceed; first, exclusively from the organs of the male parent, which is the theory of the *Spermatists;* or, secondly, entirely from those of the female, which is that of the *Ovists;* or, thirdly, from the union of the male and female products, which is the theory of *Syngenesis*. The second class, again, may be arranged under two heads, according as the new animal is supposed, first, to have its parts rendered visible, by their being expanded, unfolded, or evolved from a previously existing though imperceptible condition of the germ, which is the theory of *evolution*; or secondly, to be newly formed from amorphous materials at the time when it makes its appearance in the ovum, which constitutes the theory of *Epigenesis*.

(824.) The theory of the *Spermatists* regarded the male semen as furnishing all the vital parts of the new animal, the female organs merely affording the offspring a fit receptacle and suitable materials for its nourishment, until it could exist by the independent exercise of its own functions. One of the earliest supporters of this hypothesis was Galen; but its modern revival dates from the period of the discovery of the seminal animalcules, which were regarded by Leewenhoek as the proper rudiments of the fœtus. They were even considered by some to be miniature representations of men, and were styled *homunculi*; one author going so far as to delineate in each, the body, limbs, features, and all the parts of the grown human body. Even Leewenhoek describes minutely the manner in which they gain the interior of the ovum, and are retained after their entrance by a valvular apparatus.

(825.) The Ovists, comprising some of the older philosophers, such as Pythagoras and Aristotle, maintained that the female parent affords all the materials necessary for the formation of the offspring, the office of the male being merely to awaken the dormant formative powers residing in the female products. Malpighi and Harvey asserted that the rudiments of the fœtus are derived principally from the female ovum; an opinion which was also elaborately defended by Vallisneri.[1]

(826.) The theory of *Syngenesis*, or of the simultaneous combination of products derived from both sexes, which after sexual intercourse, are supposed to unite together to form the germ, is also of very ancient date. In connexion with this theory may be mentioned that modification of it which may be termed the theory 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 hypothesis of Buffon, which was eagerly adopted by Needham, who conceived that certain molecules which they termed *organic*, and which they believed universally to pervade plants and animals, were all endowed with productive powers, which enabled them, when placed in suitable situations, to attract one another, and to compose by their union living organized bodies. They imagined, that in the process of generation the superabundant portion of these organic molecules were accumulated in the generative organs, and there constituted the rudiments of the offspring.

(827.) The hypothesis of *evolution*, or of pre-existing germs, coincides with that of the Ovists, in considering the fœtus as solely the production of the female; but it farther assumes that it already exists, with all its organs, in some part of the female system, previous to the sexual intercourse; and that it receives no proper addition from the male semen, the action of which is merely that of exciting the powers of the fœtus, and of endowing it with vitality.

[1] *Della Generazione*, part 2.

The observations of Haller with respect to the gradual enlargement or evolution of the chick during the process of incubation, were conceived to lend great support to the advocates of this theory, of whom the most strenuous and enthusiastic was Bonnet. This naturalist, so celebrated for the boldness of his speculations, contended, not only that the whole of the parts of the fœtus pre-exist in the ovum, before they actually make their appearance, but that the germs of all the animals which are in future to be born, also pre-exist in the female parent; so that the ovaries of the first parents of any species of animal, contained the germs of all their posterity, included the one within the other, like a nest of boxes; from which comparison he termed his theory that of "*emboitement.*" This extravagant notion was adopted by many physiologists, principally from its affording some kind of explanation of what no other theory seemed in the least adequate to solve. Spallanzani, in particular, was a zealous defender of the hypothesis of pre-existing germs. It appears, however, to be totally irreconcileable with the phenomena of hybrid productions, and of the resemblance which, in so many instances, the offspring bears to its male parent.

(828.) We have already mentioned that Harvey and Malpighi ascribed the formation of the fœtus principally to the powers of the female. This opinion gave origin to the modern theory of *Epigenesis*, first clearly promulgated by Caspar Frederick Wolff,[1] who not only described a successive production of organs, of the previous formation of which there existed no trace; but showed also, that after parts are first formed, they undergo many important changes in their

[1] In his inaugural dissertation, entitled *Theoria Generationis*, published at Berlin in 1759.

shape and structure, before arriving at their finished state. The more recent researches, aided by delicate microscopical observation, of Meckel, Pander, Baer, Rathké, Oken, Purkinje, and Valentin; Serres, Rolando, Dutrochet, Prévost and Dumas, Coste, and others, have demonstrated that the theory of Epigenesis, or superformation of parts, is much more consistent with the observed phenomena than that of evolution. The facts which have thus been brought to light, are of peculiar interest with reference to the plans of nature, into which they give us a more extended insight, by exhibiting new and unexpected affinities between remote families and classes of animals; by showing that at one period the type of their formation is nearly the same, and by explaining the seeming caprice of nature in instances of monstrous and defective formation. But to attempt adducing the proofs and illustrations of these positions, would engage us into details requiring an extensive survey of the whole animal creation, to enter into which would occupy more space than is compatible with the limits of the present treatise. We must, therefore, content ourselves with referring, for more ample elucidation of this subject, to the Bridgewater Treatise *on Animal and Vegetable Physiology*.[1]

SECT. VI.—UTERO-GESTATION.

(829.) On the arrival of the ovum in the cavity of the uterus, to which we have traced it in a preceding chapter, the first object of nature is to effect its attachment to a portion of the inner surface of that organ. A provision for this purpose has already been made, even whilst the ovum

[1] Part iv. chap. ii. on *Organic Developement;* and chap. iv. on *Unity of Design*. Vol. ii. pp. 599, 625.

was contained in the ovarium. A vesicle, first noticed and described by Dr. Barry, is formed around the ovum; the granules of the *tunica granulosa* become less densely aggregated together, and gradually pass into the state of fluid albumen; oil globules appearing for the first time to take their place on the surface of the ovum. This fluid he supposes to correspond to the yolk of the eggs of birds; and the membranous vesicle above mentioned, in which it is enclosed, and which thus forms after impregnation, he considers as the rudimental chorion, by which the ovum is afterwards attached to the uterus.

(830.) It results from these views, that mammalia differ from oviparous animals in the circumstance, that those parts of their ovum which are last formed, have a more internal origin; thus, the first portion of the albumen and the chorion of the ovum in mammalia, originate, not in the oviduct, but in the ovary; for which purpose, chiefly, there is provided the very large quantity of albuminous fluid in the Graafian vesicle; a provision which may be presumed to have especial reference to the developement of the embryo within the body of the mother. The chorion, being formed in the ovary, it is an *ovum*, and not an *ovulum*, that is expelled from that organ in mammalia. On the other hand, in birds it is an *ovulum*, and not an *ovum*, that leaves their ovary; and it becomes an ovum, and receives an addition of the albumen, or yolk, and the shell membrane in their oviduct, and then becomes analagous in all its parts to the ovum of the mammal when the latter leaves the ovarium. The albumen, in the form of granules, lines the ovisac, constituting the *membrana granulosa;* and in the form of the *flake* it supports the ovulum in the centre of the fluid of the ovisac, and afterwards supports it at the periphery of the latter, sometimes in the form of the *petasiolus granulosus*, or *cumulus* of Baer. It closely invests the ovulum in the form of the *tunica granulosa;* it forms, in the rabbit at least, and probably in other mammalia, two bands or ligaments, termed the *chalazæ*, which are conspicuous in birds; and finally, it also provides the granulous bands by which, in some instances, too sudden a discharge of the ovum of the Graafian vesicle is prevented.

(831.) Dr. Barry finds that the ova of the rabbit of five or six days, when in the uterus, are in bulk about eight thousand times that of the ovulum in the ovary, and have three concentric membranes; namely, first, an outer vesicle, (the villous chorion,) originating in the ovary; secondly, the primitive membrane of the yolk, distended so as to fill the chorion; and, thirdly, an inner vesicle, or membrane, which has been called the *blastoderma*, or germinal membrane, presenting in its substance a central spot, which is the germinal spot, or *embryo*. Dr. Allen Thomson has seen this spot very evident in the ova of a rabbit, on the sixth day after impregnation. It corresponds exactly with the part called the *cicatricula* in the egg of a bird, which there lies immediately on the surface of the yolk, imbedded in a disc of granules. In the centre of the cicatricula, a dark round spot is seen, termed the *colliquamentum*, which contains a minute vesicle, discovered by Purkinje, and which bears his name. This vesicle, which is seen in the ovulum, afterwards bursts, and leaves in its place a thin and tender transparent membrane. In the centre of this transparent spot, may be perceived, seven or eight hours after the commencement of incubation, with the aid of a magnifying glass, a small dark line. This line, or *primitive trace*, as it has been termed, is swollen at one extremity, and is placed in the direction of the transverse axis of the egg. The rounded end is towards the left, when the small end of the egg is turned from us.

(832.) Having traced thus far the changes occurring in the ovum before it becomes attached to the uterus, we shall defer the consideration of the subsequent stages of its evolution to a future section, and here attend to the changes which have in the mean time taken place in the uterus, with a view to prepare it for the office it has now to perform.

(833.) A change has already taken place in the uterus, preparatory to the reception of the ovum, and before its arrival in that cavity. An increased flow of blood is directed towards that organ. A substance consisting of lymph, or organizable fibrin, exudes from its interior surface, furnishing it with a soft flaky lining, which, when the ovum is received, is reflected over that body, so as to give it a double covering. These two folds, the one being in contact with the uterus, and the other with the ovum, constitute the two layers of the *membrana decidua;* the former portion being termed the *decidua vera*, and the latter, the *decidua reflexa*. This membrane soon becomes organized, and highly vascular. The vessels in the progress of growth, are in some parts much dilated, so as to form sinuses, which are ultimately intermingled, though by no means continuous, with the blood-vessels of the fœtus. These latter blood-vessels, consisting of the umbilical arteries and veins, of which the trunks are collected in the umbilical cord, have passed to the chorion, which by the end of the first, and during the second month of pregnancy, has acquired a villous external surface. At the end of this period, the branches of these vessels penetrate and ramify in these villi, which become thoroughly vascular; and this thickening and vascularity is concentrated on one side of the chorion, generally on that which is adjacent to the fundus of the uterus, forming the body called the *placenta*. This body is of a flattened oval shape, from six to eight inches in breadth, and from an inch to an inch and a quarter in thickness at the middle part, becoming thinner towards the edges. It occupies about a fourth part of the chorion, and at birth is about a pound in weight. In ruminant quadrupeds, the substance corresponding to the human placenta, is confined to a number of circular and spongy elevations, varying in number from thirty to one hundred, which are termed *cotyledons*. The human placenta is evidently formed of a structure essentially the same, composed of many lobes consolidated by contact into one organ. It has very generally been supposed that the placenta is of a cellular structure, and that the arteries and veins of the uterus communicate with its cells; but the recent researches of Dr. Robert Lee,[1] renders it very doubtful if these inter-placental cells really exist.

(834.) In proportion as the fœtus grows, the uterus enlarges, and about the fifth month it rises out of the pelvis, and rests against the front of the abdomen. As it enlarges, the distinction between the body and the cervix is lost; the os tincæ is flattened, and forms only a small rugous hole, not easily discernible; and it is closed by a tough glutinous matter, which is fixed in the irregularities of the surface.

SECT. VII.—PARTURITION.

(835.) The ordinary period of utero-gestation is forty weeks; on the expiration of which the uterus takes on itself

[1] *Philosophical Transactions* for 1832.

a new kind of action; its contractility, which had lain dormant for so long a time, is now suddenly and powerfully excited. A mucous discharge takes place from the vagina, the external passage is relaxed, and slight pains are felt in the back and loins, which usher in the real pains of labour. These are occasioned by powerful contraction of the uterus, accompanied by a strong action of the diaphragm and abdominal muscles; and they are repeated at short intervals. Impelled by this pressure, the membranes of the fœtus project into the vagina, and dilate the os tincæ; on their bursting, the liquor amnii escapes, and at the next pain the pressure of the uterus falls directly on the fœtus. The head of the fœtus gradually descends, urged on by succeeding spasms, the occiput foremost, the long axis of the head being disposed obliquely across the lesser basin of the pelvis. The occiput, as the external parts yield, glides off the inclined surface of the ischium, presenting at the orifice of the vulva, and bringing at the same time the long diameter of the shoulders to correspond with the greatest breadth of the pelvis, and the head being thus disengaged, the trunk follows. After a short time, fresh pains return, and the placenta and membranes being detached from the uterus, comes away. In the majority of natural births, labour is completed in from four to six hours. The uterus then very slowly and insensibly contracts, so as to diminish the ample cavity which has been rendered vacant, and at the same time its volume is reduced by absorption. During the return of the uterus to its former state, a discharge, at first tinged with blood, and afterwards of a whitish colour, termed the *lochia*, ensues, which lasts for several days.[1]

[1] The above account of parturition is for the most part extracted

content ourselves, therefore, with a brief outline of the principal phenomena, and with referring to works professedly treating on this subject, for more copious information on this highly curious department of physiology.[1]

(839.) On the outer surface of the serous layer, or that most distant from the yolk, there are raised two parallel ridges, which, joining along their upper margins, form a canal; in this canal, according to Baer and Serres, a semi-fluid matter is deposited ; this matter, acquiring consistence, becomes the spinal chord, with a pyriform extremity, which last is the rudiment of the future head. Roland, Prévost, and Dumas, on the other hand, suppose that the primitive trace is itself the spinal cord and brain, in their rudimental state.

(840.) When the layers of the germinal membrane have so far expanded as to cover nearly one-third of the yolk, they no longer retain their flat and uniform appearance, but begin to exhibit various folds, which afterwards become the different cavities of the body. Those of the mucous layer turn downwards, and whilst its remote expansion includes within it the yolk, as in a sac, the inner folds close inwards, and by the union of their margins form two tubular cavities, one at each end of the embryo, communicating in the middle with each other, and also, by a common opening, with the cavity of the yolk. This tube is the nascent alimentary canal.

(841.) The first rudiment of the heart is perceptible at

[1] The reader will meet with much instruction on these subjects, in Dr. Allen Thomson's papers on *Embryology* in the *Edinburgh New Philosophical Journal;* in the *Cyclopædia of Anatomy and Physiology*, by Dr. Todd ; and also in Mr. Mayo's *Outlines of Human Physiology*, chap. xv. sect. ii. We would also beg to refer to the summary contained in the Bridgewater Treatise *on Animal and Vegetable Physiology*, vol. ii. p. 599. The greater part of the summary given in the present article is abridged from Mr. Mayo's work.

the anterior part of the vascular layer, which, as we have already stated, is developed between the serous and mucous layers. In the mean time, the surrounding disc of the cicatricula, which continues to expand, exhibits, in the circumference of the transparent area, which now becomes thicker and more spongy, numerous irregular points and lines of a dark yellow colour. These lines gradually extend, unite together, first into small groups, and then into one net-work, which composes the *vascular area*. The space they occupy is terminated, on each side, by a circular vessel, of larger size than the rest, the *sinus* or *vena terminalis*, into which the smaller ramifications of the vessels open at the circumference, whilst towards the central part they unite into a vessel on each side, the two *omphalo-meseraic arteries*, which penetrate into the vascular layer of the embryo.

(842.) Simultaneously with these changes, all the important organs of the body are formed in rapid succession. The spinal cord and brain, of which we have noticed the first traces, are quickly developed; the former, appearing first as a membranous tube, the latter, as three vesicular bodies; and both being gradually filled with opaque nervous substances of two kinds, the one being uniform, the other filamentous. The nerves next appear, but whether they are generally formed in their entire length at once, or are growths from the brain or spinal cord, or are first produced at their farthest extremity, and afterwards extended towards the central organ, are points not yet determined. Some, however, as the optic, auditory, and olfactory nerves, are certainly productions from the cerebrum. The muscles become visible in the human embryo at the third month; they are then soft and gelatinous, transparent, of a light yellow tint, and not distinguishable from their tendons. Each muscle is formed at once in its whole length, with its attachments perfect. The eyes are formed at a very early period, and their growth is rapid; they are situated at first at the sides of the head, as in quadrupeds, and subsequently move forwards. The iris has no central aperture, the place of the pupil being occupied by the *membrana pupillaris*, which disappears completely before birth. The organ of hearing is formed soon after the eye. The substance of the bones is at first an homogeneous jelly, enclosed in a membrane, and exhibiting no divisions into joints. This jelly gradually becomes cartilaginous, the conversion taking place from the surface inwards. It is gradually replaced by ossific matter, which grows from the interior, resembling a process of crystallization. Ossification begins in the human embryo in the seventh week.

(843.) The integument is the outermost fœtal product of the serous layer, which gradually spreads like a mantle over all the other structures, and does not acquire proper strength till the middle of the fœtal period. At the end of the fifth month the body is covered with short, whitish, and silky down, which, however, disappears in the seventh month. The hair of the head and of the eye-brows, and the nails, are formed in the sixth month. About the fifth month there appears on the body a yellowish-white greasy substance, at first thinly, and afterwards more thickly spread, and termed the *vernix caseosa*. The limbs are formed originally below the skin, which they reach, pushing out like little globular shoots, in the sixth week. They originally grow straight out from the trunk. The upper arm is next laid against the breast, the fore-arm drawn upwards; the thigh is bent up to the belly, the leg drawn backwards towards the thigh, and the feet turned in, and crossed, with the soles turned inwards. When the fingers are first formed, they are contained in a common mitten of skin, which, gradually becoming thinner between them, forms a web, which is finally absorbed.

(844.) Another product of the serous layer is one still more external than the integument of the fœtus, and consisting of a sac formed by a membrane reflected from the sides and from either extremity of the embryo, so as to enclose a space behind its body. This is the *amnios*, which forms a loose bag filled with a liquid *(the liquor amnii)* in which the fœtus floats, suspended by the umbilical cord. As the walls of the trunk close in front, the circular edge by which the amnios is attached to the body of the embryo becomes proportionably contracted; and it is finally limited to the umbilical opening, hereafter to be noticed.

The communication which we described as being left between the intestinal tube and the cavity of the yolk bag, or *vitelline sac*, and which in birds continues open, soon becomes closed in mammalia, the sac assuming the form of the *intestinal vesicle*, discovered as such by Bojanus in the ovum of the sheep; though it had been before seen and known by the name of *vesicula alba*; it disappears by the third month.

(845.) The glandular organs which communicate with the alimentary canal are formed by the extension of its mucous membrane in the form of tubular productions, shooting into small masses of matter lodged in its neighbourhood; the blind ends of the tubes being often dilated into spherical pouches. The gall bladder is, in like manner, formed by the extension of a tube, which not being received into a mass of elementary matter, enlarges into a simple sac.

(846.) The lungs are regarded as another expansion of the mucous layer of the germinal membrane, growing from the back part of the œsophagus, and gradually advancing on either side of the aorta, so as at length to surround it.

(847.) The kidneys are preceded in the embryo by a substance first noticed by Wolff, and called after him the *Wolffian bodies*, or *false kidneys*, which originally extend the whole length of the spine, from the heart to the end of the intestines; but they become afterwards shorter, and, after a time, diminishing by absorption, wholly disappear. They appear to be subservient to the developement both of the true kidneys and of the testes and ovaria. The bladder and urethra, on the other hand, together with the external genitals, are formed partly out of a developement of the extremity of the intestine, and partly by fissure and folding of the integument, in the following manner.

(848.) There is first the production of a bag of considerable length, called the *allantois*, from the intestine, or that part of it which may be considered as the *cloaca;* subsequent contractions of the sides of this sac, at different parts, next divides it into two cavities, the proper allantois and the urinary bladder; and the lower contraction is elongated into the canal of the urethra. The separation between the two former afterwards closes, and the coalesced membrane forms the ligament termed the *urachus*. The urethral tube never closes.

(849.) The testes and ovaries appear in mammalia about the same time at the inner and fore part of the Wolffian bodies, attached to them by a fold of the peritoneum. From each testis or ovary there descends to the internal ring a membranous process, which in the male is called the *gubernaculum*, and in the female constitutes the *round ligament*. It passes, in either sex, along the spermatic passage to the filamentous tissue of the scrotum or labium. The ovaries descend to the brim of the pelvis ; the testes pass through the ring into the scrotum.

(850.) Every organ begins to be formed without either blood, or blood-vessels; the circulation in them being established solely for the purpose of subsequent growth and perfection. Even the heart is formed and shaped, and its texture has acquired some degree of consistency, and it displays an undulatory motion, before the blood has reached it. We have already described the formation of vessels and of blood in the vascular area ; but the blood is at first motionless. It afterwards finds its way from thence by the omphalo-mesenteric veins to the heart, whence it is expelled along the aorta, and thence again carried into the vascular area ; thus establishing a simple circulation. In a few days arterial branches extend from the aorta, and venæ cavæ are formed, establishing the systematic circulation. Five pair of branchial vessels are formed from the aorta in the neck, the œsophagus being between the branches on each side, and there are also four openings in the neck of the embryo on each side. This single heart, branchial arches, and openings, are permanent parts of the structure in fishes. In the mammalia, these branchial clefts soon close ; the heart becomes separated by the growth of partitions in each ventricle and auricle, into two separate cavities, and the artery is divided, in like manner, into an aorta and pulmonary artery. Some of the arches then disappear ; others become permanent aortic, and others permanent pulmonary branches ; and the fœtus is becoming prepared for pulmonary respiration.

(851.) The amnios, closing upon the shrunk urachus, forms with the umbilical artery and veins, and a connecting gelatinous tissue, the *umbilical cord*, or navel-string ;

connecting the fœtus with the placenta, which, as we have before seen, is formed by a thickened portion of the chorion. The umbilical vein distributes part of its blood to the liver, and then, under the name of the *ductus venosus,* joins the inferior cava, through which the mixed blood of the placenta and of the inferior part of the body is carried into the right auricle of the heart. Part of this blood passes directly from the right to the left auricle through the *foramen ovale,* which is an aperture in the yet imperfect septum of the auricles; the remainder, with the exception of the small quantity transmitted to the yet imperfectly developed lungs, passes from the pulmonary artery, through the *ductus arteriosus* directly into the aorta. The offices of the placenta are supposed to be those, first, of introducing nourishment, transmitted by imbibition from the maternal to the fœtal blood, through the membranes of the interjacent vessels of the mother and the fœtus; and, secondly, of oxygenating the blood of the fœtus by imparting to it oxygen from the same source. It has been supposed by many that the fœtus derives sustenance from the liquor amnii which surrounds it, and which might be introduced through the mouth into the stomach; but this opinion is now very generally abandoned. It is true, however, that the stomach of the fœtus usually contains a considerable quantity of ropy mucus, but without albumen. This last substance is found in the contents of the duodenum,[1] and the great intestines contain a green matter termed *meconium,* which has the appearance of being the refuse of a kind of digestion. It has been conjectured that the *thymus gland* has some relation to the function of fœtal assimilation.

[1] See a paper by Dr. Robert Lee, in the *Philosophical Transactions* for 1829.

CHAPTER XIX.

PROGRESSIVE CHANGES IN THE ANIMAL ECONOMY.

(852.) We have now traced the history of the changes which the human system undergoes, from the earliest rudimental state in which it exists in the embryo, through the period of its fœtal life, to the epoch of its birth; when it is ushered into the world, with organs fitted for maintaining a comparatively independent existence, yet still requiring the most tender offices and most fostering care of that parent, of whose system it had so long formed a part, and from which it has been so recently dissevered. To follow the narrative of the successive alterations which take place during the growth of the system, the proportional developement of its several organs, and the acquisition of its various powers, both corporeal and mental, during all the subsequent epochs, filling up the interval between the cradle and the grave, composes a long chapter in human physiology, and would occupy too large a space for the present treatise. All that we can pretend to attempt must be a faint sketch of the outlines of this "strange eventful history."

(853.) The greatest of all the changes which occur in the animal existence of every human being, is its emergence from the state in which it was dependent for its immediate supply of nourishment and of oxygen on the blood which is circulating in the vessels of its parent. On its birth, which cuts off the placental circulation, all these ties are at once dissevered. A new element surrounds it, from which it is in future to derive the principle that maintains its vital energies. The placental supply is superseded by respiration; and the first gasp of air received by an instinctive effort into its lungs alters at once the whole character of its organic constitution. It is now a breathing animal; and all the channels and passages, which had till then been adapted to a different mode of being, have now become useless, or rather worse than useless, and they must give way to a new order of processes, and a new mechanism of the hydraulic functions. The ductus venosus, the foramen ovale, and the ductus arteriosus are superseded in their functions, and must be speedily closed and obliterated, in order to give place to new courses of circulation and a new order of functions.

(854.) Besides these changes, which, being consequent on the sudden exercise of the new function of respiration, are immediate, the whole organization rapidly conforms itself to the great alteration of the circumstances in which it is now placed. As the growth of the fœtus had been progressively becoming more and more rapid in proportion as the term approached when it was to be ushered into the world; so, on the other hand, the growth of the body is greatest in the earliest periods of its extra-uterine life, and becomes more and more slow in proportion as it advances to the full dimensions it is destined to attain. The principal anatomical changes which follow birth, besides those already stated, are, the gradual obliteration of the thymus gland, and of the renal capsules.

(855.) The natural term of lactation is succeeded by that of teething; the first set of teeth, or the *milk teeth*, being furnished by nature as temporary structures, until instruments of greater dimensions can be constructed in the enlarged jaws. The appearance of the teeth is an intimation that the organs of assimilation are prepared for the digestion of solid food; and that the proper period for weaning is arrived.

(856.) From this period an accurate observer may perceive that the intellectual education keeps pace with the physical; whilst the active exercise of the limbs consolidates the bones, and gives firmness to the muscles, that of the senses is continually adding to the store of ideas, and calling forth the latent powers of the understanding. The moral faculties are developed much earlier than is generally imagined; and the future character of the individual often receives a permanent impress from the events of infancy. No one can have watched its varying aspect at this tender age, without recognising how early its affections are called forth towards its protector and fosterer; how quick is the distinction it makes between kind and unkind treatment, and how keen is its sense of the least injustice which it may have either to bear or to witness.

(857.) To the periods of infancy and childhood succeeds that of puberty, which we have seen is attended in either sex with remarkable changes, both physical and moral. During the period of increase the powers of assimilation are in full activity in furnishing a sufficiency of materials for growth; the circulation is vigorously employed in applying them to that purpose; and the supply is even more abundant than the consumption. When, however, the fabric has attained its prescribed dimensions, the total quantity of nourishment furnished and expended being nearly balanced, the vital powers are chiefly exerted in consolidating and perfecting the organization of every part, and qualifying them for the continued exercise, during a long succession of years, of those functions of which we have given the history in the preceding part of this treatise.

(858.) But, in the mean time, the process of consolidation, begun from the earliest period of developement, is still advancing, and is producing in the fluids both greater thickness, and a diminution of their total quantity. By the gradual conversion of their gelatin into albumen, all the textures acquire increasing solidity ; the cellular substance becomes firmer and more condensed, and the solid structures more rigid and inelastic. The contractile power of the muscles is also impaired ; and the limbs no longer retain the elastic spring of youth. All these progressive modifications of structure tend slowly, but inevitably, to disqualify the organs for the due performance of their functions. Their vascularity gradually diminishes ; for a large proportion of the arteries which had been actively employed in building the fabric, being now thrown out of employment, contract, and, becoming impervious, disappear. The parts of the body, having acquired greater rigidity, oppose a gradually increasing resistance to the propelling force of the heart, which is itself, in common with all the other vital powers, slowly diminishing. The absorbents are now active in removing the parts which have become useless or superfluous. Old age steals on by slow and imperceptible degrees, which, even when obvious to others, are unknown to ourselves. But nature kindly smooths the path along which we descend the vale of years, and conducts us by easy stages to our destined place of repose. When death is the simple consequence of old age, we may perceive that the extinction of the powers of life observe an order the reverse of that which was followed in their evolution. The sensorial functions, which were the last perfected, are the first which decay; and their decline is found to commence with those mental faculties more immediately dependent on the physical conditions of the sensorium, and more especially with the memory, which is often much impaired whilst the judgment remains in vigour. The heart, the pulsations of which gave the first indications of life in the embryo, generally retains its vitality longer than any other organ; but its powers being dependent on the constant oxidation of the blood in the lungs, cannot survive the interruption of this function, and on the heart ceasing to throb, the death of every part of the system may then be considered as complete.[1]

[1] For more ample details on the subject of the changes which take place in the progress of age, see the article Age in the *Cyclopædia of Practical Medicine*, and also the chapter on the Decline of the System in the Bridgewater Treatise *on Animal and Vegetable Physiology*, vol. ii. p. 619.

CHAPTER XX.

TEMPERAMENTS.

(859.) In the natural and healthy condition of the system, all its functions are nicely adjusted and proportioned to each other, so as to produce the most perfect harmony. Yet within the limits of health variations are admissible in this balance of functions, according as some predominate over others in regard to energy and activity; or rather, according as there prevails a tendency to such predominance, which, though it does not actually overset, may yet endanger the preservation of that balance which constitutes health, and may thus give at least a proneness to disease. This peculiar state of the system, depending on the relation between its different capacities and functions, by which it acquires a tendency to certain modes of action, is called its *Temperament.*

(860.) Much attention was paid by the ancients to the subject of temperaments; and the nomenclature they established to express the various combinations of peculiarities in the constitution, corresponding with the definition above given, has continued in general use even to the present day. They described four temperaments, corresponding to the four qualities of hot, cold, moist, and dry, ascribed to the human frame by Hippocrates, and which were supposed to confer the specific characters to the four ingredients of which the blood was thought to be composed; namely, the red part, the phlegm, the yellow, and the black bile respectively; and hence were derived the names of the sanguine, the phlegmatic, the choleric, and the melancholic temperaments, as indicating an excess of each of these principles.

(861.) In modern times the ancient doctrine of temperaments was adapted to the humoral pathology, by which all the deviations from the standard of health were attempted to be explained. Boerhaave, reasoning on these principles, and considering the several temperaments as being formed by different combinations of the four cardinal qualities, increased their number to the eight following: namely, the warm, cold, moist, dry, bilious, sanguine, phlegmatic, and atrabilious. Darwin, endeavouring to found his doctrine of temperaments on varieties in the vital actions of the system, which he had classified as referring to the four heads of irritation, sensation, volition, and association, formed four temperaments in conformity with this arrangement, in which these functions were conceived respectively to predominate.

(862.) Most of the modern physiologists, however, following the example of Cullen, have adopted the four temperaments of Hippocrates, which are characterized by the following peculiarities:

(863.) The *Sanguine* temperament is distinguished by a full habit and relaxed frame of body; by a greater vascularity, softness and delicacy of skin, in which the veins are of considerable size, and are particularly conspicuous by their blue colour, as seen through the thin layers of the skin. The surface of the body generally, and more especially the face, exhibits a florid and ruddy colour. The hair is generally of a light brown; but has often a yellow, and sometimes a reddish hue. Persons endowed with a sanguine temperament are acutely sensitive, and highly irritable: their pulse is frequent, indicating the general rapidity and energy of the circulation. Both the secretions and excretions are abundant, and little liable to obstruction. The disposition is free and open; the temper cheerful, and rather disposed to levity.

(864.) A remarkable contrast to the temperament just described is presented by the *melancholic* temperament, which is marked by a firm and robust frame, and a spare habit of body; by an integument of greater thickness, and of a brown and swarthy hue; and by an abundance of dark or black hair, which being particularly conspicuous in the eye-brows and beard, and being conjoined with a black colour of the iris, imparts to the countenance a stern and sombre aspect. In persons endowed with this temperament the pulse is habitually slower than the average condition; the blood is thicker and more sluggish; the secretions and the excretions are less copious, and more apt to be morbidly deficient than with the generality of men. The nervous system is, on the whole, less sensitive and excitable; but the mind, although not readily moved, when once set in motion, is remarkably retentive of its impressions, and tenacious of its purposes; persevering and indefatigable in action, ardent and constant in its affections; possessing great capacity of understanding, with a fondness for contemplation, and for speculative inquiries demanding profound thought. The temper is naturally grave, and often gloomy; the fancy imaginative, and of a poetic turn, but tinctured with melancholy, and betraying a proclivity to madness; when happily tempered, it exhibits that fortunate combination of genius and industry from which have resulted the noblest achievements of the human intellect.

(865.) The *Choleric* temperament would seem to occupy a place intermediate between the two former, as partaking of some of the qualities of both. The frame is more relaxed, the senses more excitable, and the mind more irascible than in the melancholic temperament. The complexion is less ruddy than in the sanguine temperament, and the pulse stronger and more frequent; the secretions are more copious, and the skin fairer and less hairy than in the melancholic temperament.

(866.) The *Phlegmatic* temperament is denoted by a relaxed and feeble frame, prone to obesity; a pallid complexion, a smooth integument, with but few hairs, that on the head being of a light colour. The circulation generally is languid, the pulse slow and weak, the blood-vessels less capacious, the fluids more bland and watery. The functions of digestion, secretion and excretion, are performed slowly, and are liable to frequent impediments. The mind is dull, sluggish, disposed to indulge in sleep; not easily moved, timid, inclined to fear, and prone to avarice.

(867.) Dr. Gregory has added to these four temperaments a fifth, which he denominates the *nervous* temperament, and which owes its peculiarities to the sensibility of the nervous system existing in an undue proportion to the contractility of the muscles; conjoining the qualities of excitability and of debility. Such an union of qualities, however, is compatible with the characteristics of other temperaments, but occurs more commonly in the sanguine, whether existing in its purest form, or blended with the phlegmatic; and it is found exemplified chiefly among those whose occupations are sedentary, and who lead a life of ease and luxury.

(868.) These several temperaments are found variously modified by occasional intermixture in different degrees with one another. Thus, the phlegmatic is often conjoined with the sanguine, and sometimes with the melancholic temperaments; and observation will readily suggest examples of other similar combinations. The predominance of each of these temperaments varies at different periods of life. At an early age the system inclines more to the sanguine; in middle life, to the choleric; and at a more advanced age, to the melancholic temperament. They admit also of being variously influenced and modified by climate, habits, and education; and accordingly each is found to prevail amongst particular tribes and nations, and in particular regions of the globe.

CHAPTER XXI.

VARIETIES OF THE HUMAN SPECIES.

(869.) It has been a question much agitated amongst naturalists, whether the differences observable in the complexion, features, and the intellectual and moral endowments of different tribes and nations which are found scattered over the surface of the globe, are sufficiently great to mark an original diversity of species, or whether they correspond merely to the character of varieties taking place in a single original race, analogous to those we behold in many domesticated animals, such as the dog, the horse, and the sheep, and therefore affording no objection to the hypothesis that every individual composing the human race belongs really to one and the same species. To Blumenbach belongs the merit of being the first who entered with a philosophical spirit into the investigation of this great problem. The generally prevailing opinion at present is, that all mankind are the descendants of the same original stock; and are therefore to be considered as members of the same family.

(870.) It is a matter of considerable difficulty to establish an accurate classification of the different varieties into which the human race should be divided. Blumenbach, who, from having devoted to it much labour and attention, is justly considered as the highest authority on this subject, has fixed the number of these varieties at five; though, as Mr. Lawrence observes, these five races ought perhaps rather to be considered as principal divisions, each of them including several subordinate varieties. M. Bory de St. Vincent, in his *Treatise on Man*, extends the number of primitive varieties to fifteen. Cuvier, on the other hand, is inclined to refer all the varieties in the race to three principal heads, considering the others as merely modifications of these.

(871.) The five varieties which Blumenbach has pointed out, are designated by the terms *Caucasian*, *Mongolian*, *Ethiopian*, *American*, and *Malay*. He regards the Caucasian race as the primitive stock, or as the standard and type of the rest. It appears, indeed, to occupy an intermediate place between the Mongolian race, on the one side, and the Ethiopian on the other, which latter races are the most widely different from each other. The American variety has been considered as intermediate between the Caucasian and the Mongolian; and the Malay race as intermediate between the Caucasian and the Ethiopian. The various intermixtures which have taken place between these several races, in different parts of the world, render it very difficult, at the present day, to draw those precise lines of distinction which have probably, in remoter times, characterized the primitive races now enumerated. Thus, in Asia, we find considerable mixtures of the Caucasian with the Mongolian races; whilst in Africa, the Caucasian race has in various instances been blended with the Ethiopian. The following are the circumstances by which these several varieties are characterized:—

(872.) 1. The *Caucasian races* are distinguished by the general whiteness of the skin; the fairer complexions exhibiting a roseate tint, particularly conspicuous in the cheeks, and derived from the abundance of blood circulating in the vessels, and the darker races inclining to a brown, and by the abundance and softness of the hair, which is either black, or of a lighter chesnut colour, occasionally inclining to red. The cranium is large and oval, and developed especially about the forehead; the face comparatively small, and falling perpendicularly underneath the forehead. The features are distinct from each other; the nose narrow, and frequently aquiline; the mouth small; the front teeth in both jaws have a perpendicular direction; the lips, particularly the lower one, are gently turned outwards; the chin is full and rounded, and the general contour of the face has an oval form, and is broader in the upper than in the lower portion. This is the race in which the moral and intellectual energies of man have risen to a higher degree of excellence than in any other; and it is the race which has at all times been the most susceptible of cultivation and improvement. The hope may indeed be entertained that it is yet far from having arrived at the highest point in these respects which it is destined to attain.

(873.) 2. The *Mongolian* races are characterized by a complexion approaching to an olive colour; the eyes being black; the hair also black, strong, and straight; the beard thin and scanty; and the head of a form somewhat square; the cheek bones large and prominent; the forehead low; the face broad; the features flattened, and running together; the nose small and flat; the aperture of the eyelids narrow, and the orbits situated obliquely; the lips thick; the chin slightly projecting; the ears large. The stature of most of the nations belonging to this raee is, in general, inferior to that of Europeans.

(874.) 3. The *Ethiopian* or *negro race* is marked by the lateral compression of the skull, which is elongated forwards; by the prominence of the cheek bones, the narrowness and projection of the jaws, and the recession of the chin. The forehead is low, and very slanting; the eyes prominent; the nose broad, thick, and flat; the lips, the upper one especially, thick; the upper front teeth are oblique; the hair black and woolly; the legs are long and slender; the calf espeeially is small, and the knees are bent inwards; the arms are longer than in the other races.

(875.) 4. The *Aboriginal American race* is remarkable for the red eolour of the skin, the strong and straight black hair, the scanty beard, and low forehead, the deeply sunk eyes, and the round and prominent cheek bones. The mouth is large, the lips thick, and the faee in general broad and square; charaeters which assimilate this race with the Mongolian, from which, however, it is sufficiently distinguished by the colour of the skin, and the projection of the features, especially of the nose.

(876.) 5. The *Malay variety* of the human species varies considerably in the colour of the skin, from a light tawny brown, to one approaching to black. The head is narrow; the bones of the face are large and prominent; the mouth large; the nose full and broad at the point. The hair is black, and more or less curling.

The following account of the filiation of the different raees, and of their distribution over the globe, is given by Cuvier.

(877.) The Caucasian race has been so named from its presumed origin in the western part of Asia, in the neighbourhood of the Caucasian chain of mountains, which are situated between the Caspian and the Black Seas; whence it has spread as from a centre to the adjacent parts of the Asiatic, European, and African continents. The present inhabitants of these regions, namely, the Circassians and the Georgians, are reputed to be still the handsomest race on earth. The principal ramifications from the primitive stock, may be most satisfactorily traced by following the analogies of the languages of the nations which have proceeded from it. Thus, the Armenian, or Syrian branch, proceeded southwards, and gave rise to the Assyrian and Chaldean nations; and also to the Arabians, who, after the era of Mahomet, aspired to the empire of the world. The Phœnicians, Jews, and Abyssinians may be regarded as Arab colonies, to which class also the Egyptians may probably be referred.

(878.) The branch giving origin to the *Indian*, *Germanic*, and *Pelasgic* tribes was far more widely spread, and became subdivided at a much remoter period of antiquity. Amongst the four principal languages which prevailed among the nations composing these races, namely, the Sanscrit, the ancient Pelasgic, the Gothic or Teutonic, and the Sclavonic, we may trace the most multiplied affinities. The primitive Sanscrit is still preserved as the sacred language of the Hindus, and is the model on which all the existing languages of Hindustan have been formed. The Pelasgic is the primitive source of the Greek, of the Latin, and of many other tongues now extinct, but from which most of the present languages of the south of Europe have been derived. The Teutonic has given rise to the languages of the northern and the western nations of Europe, such as the German, the Dutch, the English, the Danish, the Swedish, together with their various dialects. From the Sclavonic tongue are derived those of the north-east of Europe, namely, the Russ, Polish, the Bohemian, and the Vendean.

(879.) It is amongst this latter extensive race that philosophy, sciences, and the arts, have been most assiduously cherished, and have been carried to their highest states of perfection. This race had, in Europe, been preceded by the Celtic tribes, which originally came from the north, and were formerly widely spread, but which are now confined to very narrow spaces in the west of Europe and Africa, and are nearly effaced by continued intermixture with the numerous races which have supplanted them.

(880.) The ancient *Persians* have a similar origin with the Indians; and their descendants at the present time, bear the strongest marks of affinity to the modern European nations.

(881.) The *Scythian* or *Tartaric* branch, first directed itself towards the north and north-east, and composed the wandering tribes which traversed the immense plains of Tartary. In later times, become more numerous, they returned to spread devastation amongst the flourishing establishments of their more civilized brethren. The irruptions of the Scythians in Upper Asia, of the Parthians, who overthrew the domination of the Greeks and Romans in those regions; of the Turks, who destroyed that of the Arabs, and reduced to subjection the miserable remnant of the Greek nations in Europe; all proceeded from the overflowings of the northern swarms from this common race. The Finlanders and the Hungarians, which belong to this race, may be regarded as stragglers from these swarms, amidst Sclavonic and Teutonic tribes. On the northern and eastern coasts of the Caspian Sea, the original cradle of these races, there are still found tribes which have the same common origin with the former, and which speak a similar language; but they are variously intermixed with a great number of other smaller tribes, differing from them both in language and in origin.

(882.) The *Tartarian* tribes have remained more free from mixture, along the whole of that extensive tract whence they long defied the power of Russia, but to which they have at length been forced to submit; namely, from the mouths of the Danube, to the countries beyond those of the Irtish. But the conquests of the Mongols have led to considerable blending of the two races amongst the Tartarian nations.

(883.) The *Mongolian* race inhabits the remoter regions of Asia, extending from the eastern parts of the continent, where the Tartar branch of the Caucasian race terminates, to the Eastern Ocean. The different branches of this Mongolian race, such as the Calmuc Tartars, and the Kalkas, have no settled residence, but are wandering tribes over the extensive deserts of Eastern Asia. Thrice have their ancestors carried far and wide the terror of their arms; first, under Attila; next under Genghis Khan; and, lastly, under Tamerlane. The Chinese are an ancient branch of this family, which was very early trained to a high degree of civilization; at a period, indeed, apparently more remote than that to which our most ancient histories extend. The Manchew Tartars, who have recently achieved the conquest of China, are a third branch of the same Mongolian race. The Japanese, the Coreans, and almost all the hordes which extend to the north-east of Siberia, under the dominion of Russia, belong also to the same division of the human species.

The original seat of this widely-spread race appears to be the chain of the Altai mountains, the central ridge of Asia; in the same way that the race to which we belong was derived from the inhabitants of mount Caucasus; but it is quite impossible to unravel the complicated filiation of these various tribes. The history of these wandering people is as evanescent as their establishments; and even that of the Chinese, confined as it is to the limits of their empire, supplies only brief and unconnected notices of the surrounding nations. The affinities of their languages are too imperfectly known to afford any clue for our guidance in this mighty labyrinth.

(884.) The languages of the north of the Indian peninsula, beyond the Ganges, as well as that of Thibet, have some relations with the Chinese language; at least they resemble it in their monosyllabic structure. There is also a general resemblance of features amongst all these Mongolian tribes. But the southern division of the same peninsula is inhabited by a different race, namely, *Malays*, distinguished from the former by their greater symmetry of form, and by a peculiar language. This race is spread over the coasts and islands of the Indian Archipelago, as well as those of the Southern Pacific. In the largest of the Indian Islands, however, we meet with a much more barbarous race of men, with dark woolly hair, with black skins, and with the negro features, and savage and ferocious in their dispositions. They are known by the name of *Papuans*, and are principally met with in the Islands of New Guinea, and the New Hebrides. It has been conjectured that this singular tribe was descended from negroes accidentally cast on the shores of these remote islands.

(885.) The inhabitants of the northernmost regions both of the old and new continent, comprising the Samoides, the Laplanders, and the Esquimaux, possess many peculiar features, and have been classed by some naturalists under the Mongolian races, but are considered by others as degenerated scions from the Scythian and Tartaric branches of the Caucasian race.

(886.) The aboriginal American Indians have never been satisfactorily assimilated to any one of the races of the ancient continent; yet they scarcely possess any precise or well marked distinctive characters, which may entitle them to be regarded as one of the primitive races of mankind. The copper hue of their skin is certainly not of itself sufficient to establish such a distinction. Their dark hair and scanty beard would incline us to refer them to the Mongolian race, were it not that their well-defined features, and prominent nose, are opposed to such a classification. Their languages are as diversified as their tribes are numerous; and no analogy has yet been traced either amongst one another, or with any of those of the old world.

(887.) The analogy of what we observe in the inferior animals, affords the strongest grounds for believing that natural causes are perfectly adequate to explain the diversities which occur in the several varieties of the human race, on the supposition of their having originated from a common stock. The variations in size, colour, and even forms, which take place amongst different kinds of dogs, characters which are transmitted from the parent to the offspring with as much constancy as those of the human race, are no less considerable than the differences observable between the European and the negro, and yet are admitted by naturalists to be perfectly compatible with the unity of the species, and with a community of source. Of the causes which originally produced the peculiarities in the several varieties of the race, and which have become permanent, we can have no certain knowledge ; nor can we even supply the want of precise information by any rational conjecture. The common hypothesis which ascribes the black colour of the negro to the more powerful influence of the solar rays in tropical climates, will not bear the test of close examination ; no permanent effect of that kind having ever been produced by the same cause operating for any length of time on the complexion of Europeans. Different opinions have been entertained with regard to the natural and original complexion of the human race. Dr. Prichard contends that it was black, and that the Ethiopian form was the primitive type of the race ; the successive changes produced being that from the imperfect to the more perfect form, and from barbarism to refinement ; terminating at length in the Caucasian race, in which it has attained the greatest state of improvement compatible with its nature, accompanied by the highest degree of capability of civilization, and of intellectual and moral excellence.[1]

(888.) In opposition to the doctrine of the unity of species in all human races, it has been contended by Rudolphi, Virey, Desmoulins, Bory St. Vincent, and others, in the most positive manner, that these races were originally different. The arguments on each side of the question are fully discussed in the work of Dr. Prichard referred to.

[1] See his *Researches on the Physical History of Mankind.* Third edition. London, 1806.

CHAPTER XXII.

COMPARATIVE PHYSIOLOGY.

(889.) We purpose, in giving an account of the most important facts relating to the physiology of the animal creation, to take as the standard of comparison the mode in which the functions of the human body are conducted. The history we have given of the animal economy in man will easily enable us to refer all the facts relating to comparative physiology to this standard type; and this view of the subject, besides the interest which naturally attaches to it, will have the further advantage of reflecting light on various subjects of human physiology, which, as we formerly remarked, must ever receive important elucidation from a comparison with that of the lower animals.

(890.) Conformably with this design we shall take a review of the different divisions of the animal kingdom; first pointing out the general characters of organization and of function which are common to each class and order; and noticing, in the next place, the peculiarities that are most worthy of remark in the several species included in those divisions. By thus following the logical order of descending from generals to particulars, we shall avoid the numerous repititions that would otherwise be requisite, and comprise in the smallest space the greater number of particular facts relating to the science

SECT. I.—COMPARATIVE PHYSIOLOGY OF MAMMALIA.

1. *Peculiarities in the Human Conformation.*

(891.) Since man, in his zoological relations, must be comprehended in the class of mammalia, it is evident that the general characters of this class must consist of those possessed by the human species in common with quadrupeds, and even with the other families of mammalia still farther removed from man in their external conformation. Whilst the points of resemblance are so numerous, the easiest mode of instituting a comparison between them will evidently be by pointing out, not the features which they possess in common, but those in which they differ. We shall begin then with an account of the peculiarities which distinguish the human structure from that of the lower animals, and more especially from that of the quadrumanous tribes, which approach the nearest to him in their conformation.

(892.) The great distinctive features which characterize the human conformation, as compared with that of all other mammalia, have reference to the superiority of his intellectual powers, and to his maintenance of the erect position. In the number and excellence of his mental faculties, and in his capabilities of improvement, he leaves all other animals behind by an immeasurable distance. The faculty of speech is a consequence of this developement of intellectual power, which is favoured, indeed, by the conformation of the larynx; but the organization requisite for the uttering of articulate sounds would have been in vain conferred unless it had been placed under the guidance of the mental faculties; thus to the parrot the gift of the organs of articulation, without the mind which is to use them as expressions of thought, becomes a comparatively unprofitable boon.

(893.) The superiority of the human intellect is accompanied by a much greater developement of the cerebral hemispheres than is found in any other animal. Hence also the great magnitude of the cavity in which it is contained, together with that part of the skull which protects it, when compared with the face, which is composed of the organs of the principal senses, and of the apparatus for mastication. The mass of the brain bears also a large proportion to the size of the cerebral nerves. The cerebellum is entirely covered by the hemispheres of the brain. The forehead in man is particularly distinguished by its elevation, and the beauty of its convex arch. The shortness of the lower jaw, and the prominence of its mental portion, are particularly remarkable. The elephant is the only quadruped in which the lower jaw is equally short in proportion to the size of the head; but this animal is still deficient in the projection of its lowest point, so that the possession of a chin seems to be peculiar to the human race.

(894.) In every particular connected with the mechanism of the fabric, man enjoys the most decided advantage over those mammalia which are most nearly allied to him in their physical conformation. Man is the only species amongst the mammalia whose body can maintain itself for any length of time in an erect position, and in whom the office of supporting the trunk is entrusted solely to the lower extremities. We find that every part of the osseous fabric, as well as the disposition of the principal organs of sense, are in obvious conformity with this design. The lower limbs, being the great instruments of support and progression, are larger, and of greater strength, compared with the body, than in most quadrupeds, the only exceptions being met with among those which are formed expressly for leaping, as the hare, the jerboa, and the kangaroo. In the monkey tribes the lower limbs are comparatively much weaker than in man; and in other quadrupeds the disproportion is still greater, the thigh bone being short, and almost concealed by the muscles which connect it with the trunk of the body, whilst the rest of the limb is very slender, and not covered by any considerable mass of muscle. In man the articular surfaces of the knee-joint are very broad, and admit of greater extent of motion than in quadrupeds, and the two portions of the limb can be brought into the same straight line, thus constituting firm perpendicular columns of support for the body. The long neck of the thigh bone allows of more complete rotation of the limb at the hip-joint; and this, together with the greater breadth of the pelvis, which affords an ample basis for sustaining the trunk, are circumstances peculiar to the human frame. The heel in man forms a greater projection than in other animals; and by its being extended so as to touch the ground, it forms, as we have seen, one of the points of support, by which, in conjunction with the toes, a much larger base is comprehended. The muscles which raise the heel, and which compose the calf of the leg, are of greater size and strength than in monkeys, besides acting with the mechanical advantage arising from the long lever which the heel affords for the insertion of their united tendons; and by the direction of the foot, which forms a right angle with the leg.

(895.) The form of the chest exhibits similar differences. In quadrupeds the thorax is compressed laterally, and is deepest from the spine to the sternum; a structure which allows the front legs to come nearer together, and to support with more effect the front part of the trunk. But in man the thorax is flattened anteriorly and extends more in width, that is, from side to side, thus throwing out the shoulders, and giving a more extensive range to the motions of the arms.

(896.) That the erect posture is natural to man is strongly indicated by the position of the head with respect to its articulation with the spine, which takes place at the middle of its basis; and thus, by the great extension of the occiput, its weight is more nearly balanced than it is in the monkey. The cervical vertebræ of the monkey have very long and prominent spinous processes, evidently adapted to give greater purchase to the muscles sustaining the head, of which the front part considerably preponderates, in consequence of the elongation of the jaws, and the backward position of the centre of motion.

(897.) The same design may be traced in the position of the eyes, the mouth, and the face in general; and is so obvious as to have been noticed by Ovid, while describing the formation of man, in the following celebrated lines:

> "Pronaque cum spectant animalia cætera terram,
> Os homini sublime dedit: cœlumque videre
> Jussit, et erectos ad sidera tollere vultus."

(898.) All the internal organs have been regulated by the same intention. The human heart is placed obliquely in the chest, and rests by a flat surface on the diaphragm, to which its investing membrane, the pericardium, is firmly attached. In quadrupeds, no such attachment exists; but the heart is situated more perpendicularly with the apex directly downwards, and cannot be felt, as in man, striking on the left side of the ribs at each contraction of the ventricles.

(899.) The fore legs of quadrupeds are in general appropriated solely to the support and progressive motion of the body. In some instances, indeed, they are employed, besides, in other actions; such as seizing and securing their prey, raking and digging up the earth, or climbing and laying hold of the branches of trees; but it is only in a few species, and chiefly amongst the monkey tribes, which resemble man in their form, that they are instrumental in carrying food to the mouth, or even in grasping weapons of offence. But in man the superior extremity being entirely released from the office of maintaining any portion of the weight of the trunk, is at liberty to be employed for a great variety of purposes; and the exquisite structure of the human hand, which has already been noticed, renders this exemption of still greater value, and constitutes unquestionably one of the great perfections which mark the human structure, as compared with that of the brute creation. The arm and hand are thus rendered an organ at once of prehension and of touch, for both of which purposes it is admirably adapted by the great latitude and variety of movements it is capable of executing. One of the chief sources of perfection in the hands is the structure of the thumb, which is furnished with muscles of so great a power, compared with those of the fingers, as to enable it to oppose and balance their united strength. Hence it is enabled to grasp a spherical body, and to retain firm hold of many objects, which otherwise could not have been held without the united efforts of both hands. This conformation is peculiar to man; for the paw of a monkey cannot exercise the same force and readiness of prehension, in consequence of the thumb being inferior in strength to the other fingers.

(900.) The great perfection of the organs which modulate the voice and produce so great a variety of articulate sounds, is another striking instance of the high destination to which the human structure has been adapted. In those tribes of monkeys which come nearest to the human conformation, the power of uttering articulate sounds is prevented by the interposition of two sacs connected with the larynx, which receive part of the air when the animal uses any effort to expel it from the lungs.

(901.) The structure of the digestive organs in the human species is similar to that of many quadrupeds, and has generally been regarded as intermediate between that of the carnivorous tribes, and of those that live altogether on vegetable food. Man may very justly, and almost exclusively be entitled to the appellation of an omnivorous animal; being equally capable of subsisting on different kinds of aliment; and also of using at the same time a great mixture of different sorts of food. No other animal is capable of so great a versatility of powers in this respect. It has also been remarked, amongst the characteristic circumstances of the human race, that whilst other animals are contented with food in the state in which nature offers it, man alone employs artificial processes for improving its flavour, and rendering it more fit for digestion. Man is the only animal that is known to practise the art of cookery; an art which indeed appears necessary to enable the stomach to extract from his usual food all the nutriment it is capable of yielding.

(902.) The teeth of man are distinguished from those of all the other mammalia by their being arranged in either jaw, in a uniform unbroken series; and also by the circumstance of their being all of the same length. The cuspidati, or eye-teeth, as they are called, which correspond to the canine teeth in quadrupeds, are, perhaps, at first a little longer than the others, but their sharp points are soon worn down to a level with the rest. In all the monkey tribes, these teeth are long and prominent, and are separated by an interval from the neighbouring teeth. The cutting teeth in the lower jaws slant backwards in the monkey, and the jaw itself has the same direction ; but in man these teeth are perpendicular, and in a line with the front of the jaw, which descends to form the prominence of the chin, a part of the face which does not exist even in the orang utan. The tubercles on the surface of the grinders are different in their shape, both from the ridges of enamel on the crowns of the teeth of herbivorous animals, and from the sharp-pointed eminences on the grinders of carnivorous animals.

(903.) The human brain is not only larger in its relative proportion to the body than in any other of the mammalia, but its absolute size is greater, if we except only that of the elephant, and of the whale. With these few exceptions, all the larger animals with which we are more commonly acquainted, have brains absolutely, and even considerably smaller than that of man. Besides the prodigious expansion of the hemispheres, we may remark in the human brain a more elaborate structure, and a more complete developement of all its minuter parts. There is no part of the brain found in any animal, which does not exist also in man ; whilst several of those which are found in man are either extremely small, or altogether absent in the brains of the lower animals. Soemmerring has enumerated no less than fifteen visible and material anatomical differences between the human brain and that of the ape. The proportion of medullary to cortical substance is greater in the human brain than in that of other animals.

(904.) Although the negro race is a branch of the great family of man, and although the peculiarities which distinguish the conformation of that race rank only as varieties in the species, it yet cannot be denied, that in almost every one of the circumstances in which it differs from the type of the Caucasian race, it exhibits an approach to the structure of the monkey or quadrumanous tribe of animals. In nothing is this approximation more remarkable, than in the proportion between the size of the face as compared with that of the brain. One of the most convenient methods of roughly estimating this proportion is that invented by Professor Camper. Drawing a line from the most prominent part of the frontal bone, to the anterior point of the upper jaw bone, just at the roots of the incisor teeth, which is called the facial line, it is to be intersected by another line, drawn from the external orifice of the ear to the inferior edge of the aperture of the nostrils. The angle formed by these two lines is the *facial angle* of Camper, which determines by its magnitude the degree of preponderance of the bones of the cranium, in which the brain is contained, over those of the face, which contain the organs of sense.

(905.) In man the facial angle is greater than in other animals; it differs, however, in different varieties of the human race, and appears to indicate with tolerable exactness the comparative degree of intellectual excellence appertaining to each variety. In the Caucasian variety the facial angle is between 80° and 90°; in the Mongolian, 75°; in the American Indian, 73½°; in the Negro it is only 70°. Pursuing the application of this test to the lower mammalia, we find it in the orang utan reduced to 65°; in the baboon, 45°; in the mandrill, one of the most ferocious of that tribe, only 30°. The mastiff has a facial angle of 41°, the bulldog of 35°. In the feline tribe it is still farther diminished; being only 28° in the leopard. In the sheep and hare it is 30, in the horse it is only 23°.

(906.) The varieties in the magnitude of the facial angle have thus been traced through a number of gradations amongst different tribes of mammalia and also of birds, till we arrive at its almost total obliteration in the snipe and the woodcock, animals which are reputed to be extremely deficient in intelligence.

(907.) The projection of the bones of the face, which tends to diminish the facial angle, is universally considered as expressive of stupidity or ferocity. An ample and projecting forehead, on the contrary, is associated in our minds with the idea of superior intelligence. It was probably for that reason that the owl was selected by the Athenians as the emblem of wisdom. In the statues of their divinities, the Greek sculptors have exaggerated the facial angle, making it as much as 100°, which is considerably greater than it is ever found in the human form. The Italian painters, also, in their representation of saints, have often given them a facial angle of 95°.

(908.) But in applying this method to some of the most sagacious species of animals, such as the horse, which, as we have seen, has a very small facial angle, we meet with great and striking exceptions. We arrive at more correct determination of the proportional developement of the face and brain, by comparing, as proposed by Cuvier, the areas respectively occupied by each in a longitudinal vertical section of the head. But in the elephant all these criteria, but especially the admeasurement by the facial angle, fail, in consequence of the great projection of the frontal bones, which are raised to a considerable distance from the brain by the interposition of large cells, or frontal sinuses, and which give an undue proportion to the size of the forehead.

(909.) Daubenton proposed, for the comparison of different skulls with one another, what he called his *occipital lines;* the one passing from the posterior margin of the great occipital foramen through the lower edge of the orbit; the other, taking the direction of the opening itself, beginning at its posterior edge, and touching the articular surface of the condyles. The angle formed by the intersection of these lines is his *occipital angle.* But the variations of this angle are too inconsiderable to furnish sufficient criteria of the character of the head.

2. *Peculiarities in the Conformation of other Mammalia.*

(910.) The bones of quadrupeds appear, as Blumenbach observes, to possess a less fine and delicate texture than those of man. Their fibres are more easily loosened by maceration, and are of a coarser grain; this is more particularly observable in the jaw-bones and the ribs.

(911.) The spine is formed of the same classes of vertebræ as in man, namely the cervical, dorsal, lumbar, and sacral. In all quadrupeds belonging to the class of mammalia, the number of cervical vertebræ is constantly seven, as in man. The length or shortness of the neck has no influence on their number, though it has a material one, of course, on the comparative length of each individual vertebræ. The cameleopard, whose neck is extended to so great a length, and the mole, in which it is so short, have each of them seven cervical vertebræ. An apparent exception to this general rule occurs in the three-toed sloth, in which Cuvier found nine vertebræ of the neck instead of seven; but it has since been found that the two last of the cervical vertebræ, which appeared to be supernumerary, ought properly to be classed amongst the dorsal vertebræ, of which they possess the distinctive characters.[1]

(912.) The number of dorsal vertebræ depends principally upon that of the ribs, which differ in different quadrupeds, and are usually more numerous than in man. Their transverse and spinous processes are generally longer than in man, for the purpose of affording a broader surface of attachment to the powerful muscles which support the head and neck.

The number of the lumbar vertebræ is various in different quadrupeds. There are only three in the elephant; five in the ass; six in the horse; and seven in the camel. Still greater differenees are met with in the number of component parts of the sacrum.

(913.) Most quadrupeds have a prolongation of that part of the skeleton which corresponds to the os eoccygis of man, and which in them composes the tail, and eonsists of a great number of imperfectly formed vertebræ.

(914.) The thorax of quadrupeds is, as we have already noticed, more compressed laterally, but deeper from the spine to the sternum, than it is in the human skeleton. The scapula is constantly found; but in most tribes there is no clavicle whatever, and in others only a short rudiment of that bone, connected merely with the muscles. In other respects the number and connexions of the bones of the extremities are generally very similar to the human conformation; we may observe, however, that the os femoris is usually much shorter than the tibia, and being covered by the large muscles which attach it to the trunk, appears to belong to that

[1] See a paper by Mr. Thomas Bell, *Philosophical Magazine*, third series, iii. 376.

division of the body. The bones of the carpus and tarsus, together with those of the fingers, are in many cases exceedingly compressed, and some of them are so consolidated together, as not to be distinguishable as separate bones.

(915.) In all the mammalia we find a peculiar bone, called the *intermaxillary bone*, interposed between the two upper jaw-bones, and locked in between them; its office appears to be to contain the upper incisor teeth, when these teeth exist; but it is also met with when there are no incisor teeth.

(916.) The number, form, and internal structure of the teeth is exceedingly diversified in the different tribes; and afford excellent characters for the distinction of orders and genera of the class mammalia. As these characters have a strict relation to zoological classification, we shall abstain from entering here into the details of this subject.

(917.) In proceeding to notice the peculiarities of structure in the mammalia, we shall next examine the organs of the functions of assimilation, to which that part of the skeleton we have just adverted to, namely, the jaws and teeth, are subservient.

(918.) The tongue of quadrupeds is, for the most part, more narrow, long, and slender than that of man. Except in the genus simia, we do not meet with any structure corresponding to the uvula. The œsophagus has two layers of muscular fibres, which have a spiral course, and cross one another. This structure gives it greater power of propelling its contents into the stomach; a power which is the more required, inasmuch as the food has often to ascend considerably in passing along this canal.

(919.) The conformation of the stomach presents very considerable diversities, apparently determined by the habit of the animal and the nature of its food. From the simple structure it exhibits in the purely carnivorous tribes, we may observe a gradually increasing complication as we pass to those that feed on fish, and on vegetable aliment. In the latter orders of mammalia, and especially in the ruminants, we meet with a very complicated apparatus for digestion. But these diversities will come more properly to be noticed in the examination of the orders and families to which they relate. It will be sufficient here to remark, that the stomach is often divided into several distinct portions, such as the cardiac and pyloric; and often presents several intermediate subdivisions, and expansions into separate pouches, so as to exhibit the appearance of a multiplicity of cavities or stomachs. They differ also considerably as to the degree in which the glandular structures attached to their coats are developed in different parts.

(920.) Similar varieties are met with in the structure of the intestines of different mammalia. As a general rule, to which, however, there are several exceptions, it may be remarked, that the intestinal canal is much shorter, and more contracted in its diameter, in carnivorous animals than in those which feed on vegetables. This probably depends on the more rapid assimilation of animal than of vegetable materials; the latter requiring a more complicated apparatus, more capacious cavities, and a more extensive surface both for secretion and absorption. It has been observed that the canal of the intestines is longer in the domesticated breed than in the wild animal of the same species. Thus, in the wild boar, the length of the intestines is to that of the body in the proportion of nine to one; but in the tame animal the proportion is as thirteen to one. In the domestic cat it is as five to one; in the wild cat as three to one. It may also be remarked that in the class mammalia, the comparative length of the intestinal canal is greater than in any of the other vertebrated classes; and diminishes successively as we compare it in birds, reptiles, and fishes.

(921.) The liver in the mammalia generally, is divided into a greater number of lobes, and the divisions penetrate deeper into its substance, than in man. In a great many instances, as in the horse and the goat, there is no gall-bladder, the bile being carried at once by the hepatic ducts into the intestine. Occasionally when the gall-bladder is present, there exist also hepato-cystic ducts which convey the bile directly from the liver into the gall-bladder, and not by a retrograde course, as in man.

The mammalia is the only class of animals provided with omentum, which, in some, as in the racoon, is particularly large and stored with fat.

The kidney generally presents a lobulated appearance; sometimes to such a remarkable degree, as to bear a resemblance to a bunch of grapes, being composed of numerous small and distinct portions, connected together by their blood-vessels and excretory ducts. The urinary bladder is more capacious in herbivorous than in carnivorous quadrupeds.

The heart of the mammalia corresponds in every essential particular of its structure with the human conformation; but it differs in its position with regard to the other organs, being situated more longitudinally, and resting on the sternum, which is below it, and not on the diaphragm, as in man. Hence, also, the direction of its axis is not so oblique, and it is placed more in the centre of the chest; and the pericardium is scarcely at all connected with the diaphragm.

(922.) In many quadrupeds the thoracic duct is double, and forms more distinctly than in man the enlargement which has been termed the *receptaculum chyli.* The mesenteric glands are frequently collected into a considerable mass, called the *pancreas of Asellius.*

(923.) From the consideration of the organs of nutrition we pass on to those of the sensorial functions, and shall for this purpose revert to the osteology, in as far as relates to the bones which protect the brain and principal organs of the senses.

(924.) The divisions of the cranium of quadrupeds into separate bones, differs but little from that of the human skull. The os frontis is frequently found divided into two lateral portions by the prolongation of the sagittal suture forwards to the root of the nose. Sometimes, again, the sagittal suture is obliterated by the consolidation of the two parietals into a single bone; in other cases, these bones are united with the occipital. We often find, also, a bone, distinct from the temporal, termed the *tympanic bone,* provided for containing the tympanum of the ear. But it may be observed, in general, that the sutures present fewer indentations, and less irregularity in their course in the skulls of quadrupeds than in man, a circumstance which is naturally explicable by the smaller developement of the brain, and consequent diminution of the general size of the cranium. From the position of the head in the quadruped the occipital foramen is situated less anteriorly in the basis of the skull than in man, and is for the most part nearly vertical in its position. The tentorium sometimes contains within the laminæ of the dura mater which compose it, several strong plates of bone, and the same thing has also been observed in the falx.

(925.) The brain of quadrupeds is considerably smaller, when compared with the size either of the spinal cord or the cranial nerves, than in man. The cerebral hemispheres are also much smaller compared with the cerebellum. This arises in a great measure from the absence of the posterior lobes of the brain, which, in man, when viewed from above, conceals the cerebellum; whereas in quadrupeds the cerebellum is brought immediately into view in removing the upper bones of the skull. In the proper quadrupeds the anterior lobes of the brain extend forwards into two large processes, called the processus mamillares, which give origin to the olfactory nerves, and which contains a cavity on each side, communicating with the lateral ventricle, being in fact its anterior prolongation. On the other hand, this ventricle has no posterior prolongation, there being no posterior lobe.

(926.) Every part of the organ of smell is developed in quadrupeds in a degree corresponding to the greater extent and acuteness in which they enjoy this sense, compared with man. The æthmoid bone is much more complicated in its structure, as well as larger in its dimensions; the turbinated bones are considerably larger, more intricate in their formation, and present a much more extensive surface, being composed either of a great multitude of arborescent laminæ, or of numerous spiral convolutions. The internal nasal cavities are also generally enlarged, and particularly the frontal sinuses.

(927.) The organ of hearing also frequently presents a greater complication of structure than in man. A cavity, called by Soemmerring, the *bulla ossea*, communicates with that of the tympanum, and corresponds with the mastoid cells in the human subject. In the aquatic mammalia the external meatus is furnished with a valve for the purpose of excluding water from the passage. In these animals, also, as well as in those that live under ground, the external ear is altogether wanting. The structure of the internal parts of the organ agree in all essential points with those of the human ear. The cochlea sometimes makes an additional turn in its spiral convolution.

(928.) The eyes of mammalia exhibit considerable variety as to the position of their axes with respect to the general direction of the head. They are generally separated to a greater distance, and directed laterally. The figure of the globe is nearly spherical, as in man; but in several quadrupeds the sclerotic coat is much thicker and firmer at its posterior than at its anterior part. The choroid coat is distinctly divisible into two layers, of which the internal bears the name of the *tunica Ruyschiana*, and which often exhibits at the back of the eye the most brilliant colours. This coloured portion of the choroid is known by the name of the *tapetum*.

(929.) Several quadrupeds have an additional lacrymal gland, besides that which corresponds to the one in man; and also another gland, situated near the nose, and termed the *glandula Harderi*. The globe of the eye in quadrupeds is also provided with an additional muscle, the *suspensorius oculi*, for the purpose of supporting its weight. Many quadrupeds also possess a third, or internal eye-lid, called the *nictitating membrane*, which is very large and moveable in the cat, and all the animals belonging to the same genus.

(930.) The panniculus carnosus is a muscular expansion, situated immediately under the skin, and subservient to the movements of the integuments, which it suddenly corrugates and throws into wrinkles, thereby driving off insects, or shaking away any other offensive matter, is peculiar to quadrupeds, not being found in man; unless the platysma myoides of the neck be considered as a muscle having an analogous function with relation to the skin of the neck.

(931.) In many quadrupeds some of the sebaceous glands of the integuments are very much developed. In some predacious animals, a gland exists in the orbit, described by Nuck, and of which the excretory duct opens near the last tooth of the upper jaw. It appears referable to the class of salivary glands. Another gland, particularly noticed by Professor Jacobson, and of which the use is wholly unknown, is generally met with in the anterior and lower part of the cavity of the nostrils: this he has called *the nasal gland of Steno.*

3. *Quadrumana.*

(932.) We have already had occasion, when describing the distinctive marks by which the human structure is characterized, when compared with that of the monkey, to point out several circumstances which are deserving of notice in the anatomy of this tribe of mammalia. Of all the animals of the family of the quadrumana, the orang-utan *(simia satyrus*, Geoff.) is that species which makes the nearest approach to the human conformation. This approximation is observable in the position of the great occipital foramen of the skull, which is placed farther forwards than in other kinds of apes; in the distinctness and serrated form of the sutures of the cranial bones; in the absence of the intermaxillary bone; in the eyes being directed forwards; in the smallness of the os coccygis, composed, as in man, of five imperforated bones; in the possession both of a cœcum and an appendix vermiformis; and in the oblique position of the heart with respect to the cavity of the thorax.

(933.) A still more remarkable peculiarity of structure in the orang-utan is that discovered and described by Camper; namely, two membranous sacs, which communicate with the glottis, and deprives the animal of the power of giving utterance to sounds.

(934.) In other species of this order we trace still further deviations from the human structure. The laryngeal sacs are found in many species of baboons; these are either single or double, and communicate with the larynx by openings between the os hyoides and the thyroid cartilage. The simia seniculus, and the simia beelzebub, have a large dilatation of the middle of the body of the os hyoides, which is expanded into a spherical bony cavity. This cavity, instead of interfering with the sonorous vibrations, adds to their strength, and gives the power of producing those loud intonations which are peculiar to this tribe, and from which they have obtained the name of *howling apes.*

(935.) The mandrill baboon has seven instead of five lumbar vertebræ. The appendix vermiformis of the cœcum is not met with in many species of apes. The crest of the occipital bone, though very large in the baboon of Borneo, is scarcely perceptible in most monkeys. The central foramen of the retina discovered in the human eye by Soemmerring, has been seen in the eyes of many animals of this order.

(936.) In the lemur tardigradus, and in the sloth, a singular structure has been observed by Sir Anthony Carlisle, with regard to the distribution of the arteries of the limbs. The trunks of these arteries suddenly subdivide as they enter the limb into a great number of parallel branches, which are again re-united when they arrive at the remote end of the first division of the limb; that is, about the joints corresponding to the elbow and the knee in man. After their re-union into single trunks, these arteries proceed to ramify in the usual manner.

4. *Chiroptera.*

(937.) In the bat tribe we have to notice the strictly hinge-like nature of the articulation of the lower jaw with the skull, which limits its motion to mere opening and shutting, and excludes all lateral movements. The zygomatic arches are expanded and raised, so as to allow room for the large and powerful muscles which close the jaw. The parietal bones are united into a single bone. The sacrum is composed of four bones consolidated together. Four clavicles are met with, and they are of extraordinary length. The ulna is deficient in the fore-arm, or exists only in a rudimental state, as a slender sharp-pointed process of the radius. The phalanges of the anterior extremities are enormously lengthened for the purpose of supporting the thin membrane which is stretched between them, and which serves the office of wings. The tongue of the bat is covered with sharp-pointed horny papillæ.

(938.) The vespertilio noctula is remarkable for the shortness of the intestinal canal, which is only twice the length of the animal's body. In the vampire bat, on the contrary, and in the vespertilio caninus it is seven times as long. In all bats, not only is the appendix cœci vermiformis wanting, but also the cœcum itself. The epiglottis is also wanting in most of the animals of this tribe. In many the tongue is slender, and prolonged into an organ of suction. The pectoral muscles are of enormous size; and the sternum has a prominent erest for the purpose of affording an extensive surfaee for their attaehment. The eye is remarkably small; but the imperfeetions which probably exist in the sense of sight are amply eompensated by the singular acuteness of that of hearing, the organ of whieh is exeeedingly developed; and also by the extreme sensibility of the expanded membranes of the wings, which is such as to enable the bat to direet its flight through the most intrieate passages without the aid of the sight, and without striking against obstaeles purposely placed in its way.

5. *Insectivora.*

(939.) Among the animals arranged by Cuvier in this family, the mole presents the most remarkable peeuliarities of conformation, both as regards the skeleton and the internal organs. The sternum has the same crested proeess as in the bat, and apparently with the same design of enlarging the surface of attachment to the powerful muscles employed in digging. But the anterior extremity of this erest is still farther prolonged into a sharp proeess, having the figure of a plough-share, whieh is situated under the eervieal vertebræ, and resembles the keel-like projeetion we shall have oeeasion to notice in the sternum in birds. The eervieal vertebræ are remarkable for having no spinous processes. The ligamentum nuchæ is partieularly strong, and is almost wholly ossified. The elaviele is of a singular shape, being nearly eubical. The humerus is very slender in the middle, and remarkably expanded at both its extremities. The fore-paw is provided with a bone of a peeuliar shape, ealled the faleiform bone, plaeed at the end of the radius. The phalanges have numerous proeesses, and are furnished with sesamoid bones; struetures whieh, by giving eonsiderable meehanieal advantage to the muscles that move them, contribute greatly to increase their power. The great muscles of the trunk, the pectoralis major, the latissimus dorsi, and the teres major, are of great size, and give the animal great facility in digging the ground, and throwing up the earth as it proceeds.

(940.) The æthmoid bone is of very complicated formation in the mole, especially in the numerous convolutions of its turbinated processes, by which a very large surface is given to the Schneiderian membrane which lines every portion. This structure indicates the possession of a very acute sense of smell. The remarkable developement of the internal parts of the ears, is also conclusive evidence of the delicacy of the sense of hearing in this animal, although it has no external ear whatever. The eye is so minute, that even the existence of that organ has been denied by some naturalists ; it is, in fact, not larger than the head of a pin. The cavities in which they are placed are so very superficial, as scarcely to deserve the name of orbits. The zygoma is not arched, but straight, and as slender as a thread.

6. *Plantigrada.*

(941.) Animals of the plantigrade family have a long but narrow intestinal canal, unprovided with any cœcum or appendix, and consequently not presenting any marked distinction between the small and the large intestines.

(942.) To this family belongs the bear, remarkable for possessing supernumerary canine teeth, which are small, and situated behind the principal ones. The stomach is divided into two portions by a slight contraction in the middle ; the intestines are furnished with remarkably long and numerous villi ; the kidneys are conglomerated ; the tentorium is bony ; the nasal cartilages are extremely mobile.

(943.) In the racoon, another animal of this tribe, the valve of the colon is wanting, and the omentum is very large, consisting of innumerable lines of fat, disposed in a reticular form, and connected by an extremely delicate membrane having the appearance of a spider's web. The skin of the neck is very loosely connected by cellular substance with the subjacent muscles.

7. *Digitigrada.*

(944.) The cœcum is wanting in the greater number of the animals of this tribe. It is met with, however, in the ichneumon. Many have anal glands and follicles, which prepare a strongly odoriferous secretion. This is the case with the skunk, pole-cat, and several others. When these animals are pursued, they pour out this fetid matter, the odour of which is so offensive as to deter their pursuers from approaching them. The civet has also similar glands that secrete the peculiar perfume which derives its name from that animal.

(945.) The stomach, in the weasel tribe, is a simple cylindrical canal, having no expanded extremity to the left of the cardia; but the œsophagus enters at one end, and the intestine proceeds from the other, so that the food may pass quickly through it.. In the stomach of the sea otter, Sir Edward Home describes a remarkable glandular structure near the pylorus. The receptaculum chyli, in this animal, sends two trunks to form the thoracic duct, which have frequent communications, so that there are sometimes three, frequently four, and never fewer than two branches of this duct, running parallel to one another. In two instances the foramen ovale of the heart was found open, but the ductus arteriosus was closed.

(946.) In the dog a row of mucous glands, corresponding to the labiales and buccales in man, is found opposite to the molar teeth, having several small openings into the mouth. A large salivary gland also exists under the arch of the zygoma, covered by the masseter muscle. Its duct is nearly equal in size to that of the parotid, and opens at the posterior extremity of the alveolar margin of the upper jaw. What is called the *worm* in the dog's tongue, is merely a packet of tendinous fibres, passing longitudinally the whole length of its tongue, and lying loose in a membranous sheath, unconnected with any of the muscles. It has been supposed to assist in lapping up fluids in the peculiar way in which dogs are observed to drink. There is a popular, but wholly unfounded idea, that the extirpation of this pretended worm, is a preservation against hydrophobia. The anal glands are of considerable size.

(947.) The thoracic duct is double in the dog, and forms a large receptaculum chyli. The crista occipitalis varies considerably in its degree of prominence in the different breeds of dogs. In all, the tympanic bone is distinct from the temporal bone, being separated from it by a suture. The urethra passes along a groove in a cylindrical bone. In the hyæna, however, which in other respects is very similar to the dog, this bone is not found. The extremities of the rings of the trachea, in the hyæna, overlap one another, and admit of being much compressed; a circumstance which has been considered as connected with the shrill and piercing cry which this animal is capable of uttering.

(948.) The genus felis, of which the lion affords the most remarkable example, resembles the dog in many circumstances of conformation. We find the same set of mucous glands about the mouth, and at the extremity of the rectum. The tongue is beset with sharp prickles, the points of which are directed backwards; they are of such strength as to tear off the skin from any part which the lion may lick. The stomach is divided by a slight middle contraction, into a cardiac and a pyloric portion. The ductus choledochus forms a pouch between the coats of the intestine for receiving the pancreatic duct. In all animals of this genus the tentorium is bony. The zygoma is arched, and very large and prominent. The long bristly hairs which constitute the whiskers, receive very considerable nervous filaments, and appear subservient to the sense of touch in a very remarkable degree. Two delicate membranes are met with lying under the ligaments of the glottis, and are probably the cause of the piercing sound peculiar to animals of this tribe. The retraction of the claws into a sheath is matter of familiar observation in the cat. The pupil of the lion is circular, but that of the cat has the form of a vertical slit when closed; and the motions of the iris appear to be partly voluntary.

8. *Amphibia.*

(949.) Whiskers having the same properties are likewise found in the seal, an animal of aquatic habits, and whose conformation is modified with reference to the element it is intended to inhabit. The feet act as fins, adapted for swimming; the radius and ulna are flattened; the spine is very flexible; the pelvis very narrow. The bones have no medullary cavities. Neither the parotid nor the sublingual glands are met with in this or any other animal of the order of amphibia, belonging to the class mammalia; and the teeth are adapted chiefly to the seizing and detention of objects, and are scarcely capable of serving the purpose of mastication. The stomach is a straight cylinder, having no cardiac expansion. The intestinal canal is of great length, thus forming an exception to the general rule of its being comparatively short in carnivorous animals. The renal veins form a kind of net-work, the reticulations of which intersect the furrows between the mammary processes on the outer surface of the kidneys. The proportional size of the brain of the seal is greater than in most mammalia.

(950.) The eye of the Greenland seal is peculiarly formed, having, according to Blumenbach, the anterior segment of the sclerotica, or that immediately behind its junction with the cornea, thick and firm; its middle circle thin and flexible; and its posterior part very thick and almost cartilaginous, while the cornea itself is thin and yielding. The whole eye-ball is surrounded by very strong muscles capable of shortening the axis of the eye, and of adapting it, according to circumstances, to distinct vision in air; while in their ordinary state of relaxation, the axis of the eye being lengthened, the animal when under water is still enabled to see objects distinctly.

(951.) The walrus, another animal of this order, is remarkable for the form of its teeth and tusks, part being external; but these fall more within the province of the naturalist. The zootomist may notice in this animal the smallness of the intermaxillary bone, and the total absence of the gall bladder.

9. *Marsupialia.*

(952.) The marsupial family of mammalia compose an interesting group of animals, which present many remarkable singularities in their internal conformation and economy. The principal of these is the apparently premature birth of their young, which come into the world at a period of their developement corresponding to that to which the fœtuses of mammalia have arrived only a few days after conception. Nearly the whole extent of the integument of the fore part of the abdomen forms a kind of sac or pouch for the reception of the fœtuses in their early state, and whilst they present only a shapeless mass, destitute of external members, and totally incapable of locomotion. They become attached to the nipples of the mammary glands, situated under the integument of the pouch next to the abdomen of the mother; and they remain in this situation for a long time, imbibing nourishment from these glands, until they acquire a growth equal to that which the young of other animals attain in the uterus before birth. Two bones, peculiar to these animals, and therefore called the marsupial bones, are expressly provided for the protection of the abdominal viscera, lying in the horizontal position of the trunk above this extraordinary pouch, which performs the function of a supplementary uterus. It is farther remarkable, that the same bones occur in the skeleton of the males, where, of course, there are no pouches; and also in those species where the fold forming the pouch is scarcely perceptible. The uterus communicates with the vagina, not by a single opening, but by two curved lateral tubes. This has been called the *uterus anfractuosus*, to distinguish it from the ordinary form, which is the *uterus simplex;* the *uterus bicornis*, which has two horns, either straight or convoluted; and the double uterus, or *uterus duplex*, which has the appearance of two horns opening laterally into the vagina, as in the mole, the hare, and the rabbit. The Fallopian tubes, in marsupial animals, are much enlarged at their extremities.

(953.) In the oppossum, the cardiac and the pyloric openings of the stomach are placed very near one another. The anal glands are large. The tongue is covered with pointed processes.

(954.) The kangaroo has a stomach composed of three pouches, but in consequence of the power which different portions of it possess of contracting separately, it is occasionally divided into a much greater number of portions.

(955.) The phascolome, a species of rat from Australia, which possesses an abdominal pouch, is remarkable for possessing, in common only with man, and the orang-utan, both a cœcum and an appendix vermiformis.

10. *Rodentia.*

(956.) In this order of mammalia, we find the incisor teeth furnished with enamel only in front; the frontal sinuses are absent; the os frontis is divided into two bones by a middle longitudinal suture, and the tympanic bone is distinct from the temporal. The brain presents no appearance of convolutions on its surface; the eyes are placed on the side of the head, so that the direction of their axes is completely lateral; and the orbits are not separated from the temporal fossæ; the cœcum, in particular, is exceedingly voluminous, so as often to exceed the stomach in size. The dormouse, indeed, presents an exception to this rule, being destitute of any cœcum.

(957.) The beaver has a remarkably strong and prominent zygoma. A peculiar glandular body is found near the upper orifice of the stomach, full of cavities, apparently for the purpose of secreting mucus. The urethra terminates in the rectum, thus constituting a kind of *cloaca;* a structure which, as we shall find, prevails universally in birds. The direction of the axes of the orbits is upwards.

(958.) The common rat has no cœcum; its zygoma has its convexity turned downwards; the testes are capable of being retracted within the abdomen. A similar circumstance occurs in the hamster, the squirrel, and the guinea-pig.

(959.) The mus typhlus is remarkable for having its eye covered over with the common integument of the face, which, together with the hair growing on it, completely intercept light, and must destroy the use of the eye as an organ of vision.

(960.) Cheek pouches are met with in many species of this genus; as in the case of the hamster and marmot. In the ear of the latter of these animals, a portion of bone is described by Cuvier as passing between the crura of the stapes, from one side of the fenestra ovalis to the other, the use of which conformation is entirely unknown.

(961.) In the hare, the following peculiarities are met with. The coronoid process of the lower jaw is almost entirely wanting. The transverse processes of the lumbar vertebræ are remarkably large. The stomach may be distinguished into two portions, differing in the structure of their coats; the cardiac portion being lined with cuticle, and the pyloric division having the usual villous and secreting surface. The former may be regarded as a reservoir for the food, while the latter is the part which performs the function of digestion. The undigested state in which the contents of the stomach is found in the former, and its altered appearance in the latter, corroborate this view of the different offices of these two portions of the stomach. The rabbit agrees with the hare in this conformation. The cœcum is of enormous size; it extends to a length which is greater than that of the whole animal; it is curiously convoluted, and is lined internally with a peculiar spiral fold or valve. The urinary bladder is peculiarly large in the hare

(962.) The retina exhibits very distinct and beautiful medullary striæ, which pass, for the most part, in a transverse direction. The glandula Harderi is found in these animals, and unites itself with the proper lacrymal gland, but is distinguishable by its whiter colour. Both the hare and the rabbit have a slit, opening into the lacrymal canal, which serves as a substitute for the puncta lacrymalia. Sebaceous sinuses exist on the outer side of the upper jaw, near the nasal bones ; whence a large quantity of a viscid adipose substance is secreted. Cavities are also formed in the groins, called by Pallas, *antra inguinalia*, which contain a strongly odorous substance prepared by the neighbouring subcutaneous glands.

11. *Tardigrada.*

(963.) The tardigrade mammalia are distinguished by having the same peculiar distribution of the arteries of the limbs which we have already noticed in the lemur tardigradus. They possess neither cœcum nor gall-bladder. The stomach of the sloth is complicated in its structure, being divided into several pouches ; the intestinal canal is very short ; there is also at its extremity an approach to the structure of the cloaca of birds, inasmuch as the rectum and urethra have a common termination. The zygoma is furnished with a large descending process, which comes from the os malæ.

(964.) The two-toed sloth *(bradypus didactylus)* has twenty-three ribs on each side. We have already noticed the apparent anomaly presented by the three-toed sloth, (the *bradypus tridactylus*) in its seeming to possess nine instead of seven cervical vertebræ ; this appearance being given to the two last of these vertebræ, which are, in fact, dorsal, by the ribs which are attached to them being very short, and rudimental in their conformation, (see § 911.) In the ant-eater and manis, which belong to Cuvier's family of the edentata, the six last vertebræ of the neck are anchylosed or united so as to form only one bone.

12. *Monotremata.*

(965.) The singular animals which compose this family of mammalia, instituted by M. Geoffroy, are all inhabitants of the continent of Australia, so fertile in extraordinary productions in every department of natural history. They are included in the genus ornithorhyncus, and are distinguished into the three species of paradoxus, histrix, and setosus.

(966.) Although they are not furnished with abdominal pouches like the kangaroo and other marsupial animals, yet they are provided with two bones corresponding in their position to the marsupial bones, already described (§ 952), as attached to the bones of the pubis, and supporting the abdominal viscera. The number of ribs in the ornithorhyncus is seventeen. Pouches exist in the cheek of the animal. The bill, shaped like that of the duck, is abundantly furnished with nerves, chiefly from the second branch of the fifth pair. Its teeth have no fangs which sink into the jaw, as in most quadrupeds, but are merely imbedded in the gum, and are very peculiar in their shape. In the ornithorhyncus paradoxus, there is one on each side of either jaw; it consists of a horny substance of an oblong shape, flattened at the surface, and adhering to the gum. There are likewise two horny processes at the back of the tongue, which are directed forwards, and prevent the food from passing into the throat before it has been sufficiently masticated. The tongue is very short, not an inch long, and the moveable portion not half an inch; its surface is beset with long conical papillæ. The ornithorhyncus hystrix has six transverse rows of pointed horny processes at the back of the palate, and about twenty similar teeth on the corresponding part of the tongue. The intermaxillary bones are of a very singular shape, consisting of two hooked pieces joined together at their bases.

The stomach of the ornithorhyncus hystrix is lined with cuticle, furnished at the pyloric extremity with sharp horny papillæ. There is no valve of the colon, nor is there any cœcum, although we find an appendix vermiformis. They possess a cloaca at the termination of the rectum, as in birds.

(967.) Sir Everard Home denied the existence of mammæ in the female ornithorhyncus; but these glands have been distinctly delineated by Meckel, and described by him as being largely developed. In a paper since read to the Royal Society, Sir Everard Home again asserted that further inquiry had convinced him of the non-existence of these glands; but in a paper subsequently read to that learned body,[1] Mr. Griffin describes the mammæ of the ornithorhyncus paradoxus as considerable glands, which occupy the greater part of the under surface of the animal, and have numerous excretory ducts perforating the skin in two circumscribed places, but not forming any elevations analogous to nipples. This subject has, since that period, been investigated with great care by Mr. Owen,[2] who found the structure to correspond very exactly with the account given by Meckel, and he is accordingly led to regard them as real mammæ. The falx, as well as the tentorium, contains a plate of bone. The external auditory passage is very long and tortuous,

[1] *December* 15, 1831.

[2] *Philosophical Transactions* for 1832, p. 517. See also his paper in the *Transactions* for 1834, p. 333.

and there are only two ossicula in the internal ear. A singular kind of clavicle is found in the skeleton of these animals, common to both the fore extremities, and situated in front of the ordinary clavicles, bearing some analogy to the furcular bone of birds. The conformation of the ribs also exhibits an approach to that of birds. Each rib consists of two pieces of bone; a longer one joined to the spine, and a shorter connected with the sternum; the two being united by an intermediate cartilage.

13. *Pachydermata.*

(968.) In this natural family of animals, which was established by Storr, in his *Prodromus Methodi Animalium*, the elephant first claims our notice. In addition to the thick integument common to all the animals of this tribe, we find that remarkable organ, the *proboscis*, which is a prolongation of the nose, formed of a double cylindrical tube, extremely flexible in all directions, endowed with exquisite sensibility, and terminating in an appendix very much resembling a finger, all the functions of which it is capable of performing. The motions of this admirable organ are executed by an infinite number of muscular fibres, collected into small bundles, which pass in a great variety of directions, and are continually interlaced with one another, so as to be adapted to the performance of every kind of movement. The enormous tusks which are given to the animal as formidable weapons of offence, are merely developements of incisor teeth, proceeding from the inter-maxillary bones in the upper jaw, and which on issuing from the mouth are incurvated upwards.

(969.) That part of the cranium which corresponds to the frontal sinuses is enormously enlarged; the two tables of the skull being separated to a considerable distance from one another, the intermediate space being occupied by a vast number of cells, which are full of air, and communicating with the throat by means of the Eustachian tube. Camper has very ably pointed out the advantages resulting from this structure, by the increase of surface it affords for the attachment of the great muscles of the lower jaw, neck, and proboscis, and for the augmentation of their mechanical power. The frontal and parietal bones become united at a very early period with all the other parts of the cranium, so as to form a bony cavity in which no trace of sutures can be discerned. The tympanic bone, however, is distinct from the temporal. The optic foramina commence from a single canal, which receives the two optic nerves. A rudiment only of the nasal bones is observable ; and the same remark is also applicable to the ossa unguis, or lacrymal bones ; neither can we trace the existence of any lacrymal gland, or lacrymal sac, or any passage for the tears into the nose. The foramen ovale in the base of the cranium is very large. Between the arched sides of the upper part of the cranium, a broad and deep depression is met with, having a small longitudinal crest in the bottom.

(970.) Between the eye and the orifice of the external ear, a gland of large size is situated, occasionally secreting a brown fluid, which oozes out through an opening in the skin. There are twenty ribs on each side ; and there appear to be only three lumbar vertebræ. The ligamentum nuchæ is of great size and strength, for it has to support the enormous weight of the head with its ponderous tusks and proboscis. The articulation of the thigh bone with the pelvis, is destitute of the ligamentum teres, which is found in almost all other quadrupeds. The toes are five in number, but they are almost concealed by the thickness of the skin of the foot in which they are encased. The condyles of the lower jaw are simply rounded eminences. The form and structure of the teeth are very peculiar, and afford distinctive characters of the different species of elephants, which belong more properly to natural history. In addition to the usual component parts of bones and of enamel, a third is superadded, called the *crusta petrosa*, which fills up the interstices left by the duplications of the enamel. The ivory which composes the tusks is exceedingly dense, and differs considerably in its structure from the ordinary bone of other teeth. It is distinguished by the curved lines which pass in different directions from the centre of the tusk, forming by their decussation, a regular arrangement of curvilinear lozenges. The tusk is constructed by the successive deposition of osseous matter from within, being secreted from the outer surface of the vascular pulp, which occupies the central part of the growing tusk. Hence, iron balls, fired at the animal, have been known to penetrate the latter soft portion, and to remain fixed in the interior of the tusk, till they were completely covered over, and imbedded in the successive depositions of ivory.

(971.) The stomach is simple in its structure; the intestines are voluminous, the cœcum of great size, and the colon large, long, and divided into cellular compartments. There is no gall-bladder. The ductus choledochus forms a pouch between the coats of the intestine, as it does in the cat, for the reception of the pancreatic duct.

(972.) The snout of the tapir bears a slight resemblance to the proboscis of the elephant; being, although much shorter, extremely mobile, and provided with a very complex arrangement of muscles.

(973.) The rhinoceros is furnished with a rough and slightly elevated surface of the large nasal bones, consolidated into one bone, for the attachment of the horn which is supported upon it. Such, at least, is the structure in the one-horned rhinoceros; in the two-horned species it is the front horn to which this description applies; for the posterior horn rests on a similar process of the os frontis. Like the elephant, the rhinoceros has no gall-bladder.

(974.) In the hog we also meet with a considerable developement of the frontal sinuses. The molar glands are large, and their openings very conspicuous. There are two considerable membranous bags in the throat, situated above and in front of the ligaments of the glottis. Two small flat bones are found at the base of the heart, at the origin of the aorta from the left ventricle. Their use has been supposed to be that of giving support to the valves of the aorta.

(975.) The peccari, or Mexican musk-hog, has a remarkable gland situated in the back, near the sacrum; it is composed of several lobules, the ducts of which unite into one canal, which passes through the skin, and pours out a secretion having a scent similar to musk. A singular dilatation is often met with in the aorta of this animal, as if it were affected with aneurism.

14. *Solipeda.*

(976.) This family comprehends the horse, ass, zebra, and quagga. The great interest attached to all that relates to the horse, from its utility to man, has occasioned its anatomy, the study of which is the foundation of the veterinary art, to be cultivated with peculiar zeal. The principal circumstances worthy of notice in the osteology of this animal are the following. As is the case with most quadrupeds whose necks are very long, the cervical vertebræ have very short spinous processes. The dorsal vertebræ, the number of which of course corresponds with that of the ribs, being eighteen, and sometimes nineteen, have, on the contrary, very large and broad spinous processes. The space from the first to the eighth vertebra, is called the *withers*, against which the upper part of the shoulder rests. There are six lumbar vertebræ, having strong spinous, and also broad and long transverse processes. Large lateral processes also extend from the sacrum, which is composed of five consolidated portions; and the united spinous processes of these are likewise exceedingly prominent. The tail is formed of eighteen cylindrical pieces, which, towards the extremity, have nearly the softness of cartilage.

(977.) The true ribs are, on each side, eight in number, the remaining ten or eleven being joined to the sternum by cartilage. The sternum is composed originally of seven pieces of bone united into one. Its anterior extremity is sharp-pointed, like the prow or keel of a ship. In the pelvis of the horse, denominated the *haunch*, we find the ilium, or hip-bone, extended in three directions, above, below, and behind, forming three large processes, for the attachment of the strong muscles which surround the hip joint. The ischium is much extended, forming a strong process posteriorly for a similar purpose. This elongation of the ischium has been termed, from its figure, the *processus triquetrus ischii*. By removing the point of attachment of the muscles to a greater distance from the axis of motion, it gives them the mechanical advantage of acting by a long lever. The symphysis of the pubis (or the junction of the bones of that name) is remarkable for its depth, thus affording an extensive surface for the attachment of muscles.

(978.) The bones of the extremities of the horse are constructed on the same general model as the human, though varying much in the details of their form and relative proportions; and some parts only appearing in an imperfect or rudimental state. The scapula is of an oblong triangular shape, considerably narrower and longer than the same bone in the human skeleton, and exhibiting only faint traces of the acromion and coracoid processes. Its axis is nearly in the same line with the os humeri, which latter bone is very short, and scarcely descends below the line of the chest, and possesses scarcely any rotatory motion on the scapula. The radius and ulna are consolidated together; the olecranon is much elongated. The carpus, or as it is vulgarly called, the knee, of the horse, is composed of seven, or sometimes eight, small bones, disposed as in the human carpus, in two rows; though with respect to their individual form, they have but little resemblance to the latter.

(979.) That part of the skeleton which corresponds to the metacarpus is, in the horse, consolidated into a single bone termed the *shank*, or *canon bone*, to which are united behind, and on the side, two much shorter and very slender bones, called the *styloid*, or *splint bones*, frequently found consolidated with the canon bone by ossific union. It is only the latter, or principal bone, that is articulated with the next, or *pastern bone*, which corresponds with the first phalanges of the fingers, and may be regarded as the consolidation of these five bones into one. In like manner, the second phalanges are consolidated in the horse into the next bone of the foot, which is termed the *coronet bone*, and which is articulated by a divided condyle with the *coffin bone*, of which we shall presently speak. Before proceeding, however, we must notice two or three small rounded bones placed at the back of the pastern joint, (between that and the shank bone) which correspond in their office to sesamoid bones, and which have accordingly received that appellation.

(980.) The coffin bone corresponds in situation to the third phalanx of the fingers. It supports the single hoof; from which this family of mammalia derive their characteristic name. Connected with this is a small bone, called the *shuttle bone.*

(981.) In the posterior extremity we find a very similar arrangement of bones. The thigh bone is unusually short, scarcely extending beyond the trunk of the body, when surrounded by its muscles. The glutæi muscles, and especially the glutæus medius, are particularly powerful in their action for extending the thigh backwards, and performing the motion necessary for kicking. There is a process in this bone of the horse which is not observed at all in the human os femoris; it is a strong curved spine, situated on the outside, opposite to the lesser trochanter. It has been termed the *processus recurvatus femoris.*

(982.) The *patella* of the horse is large, thick, and very prominent. From the *tibia* there arises a small spinous process, which may be considered as the rudiment of a fibula. The tarsus, or *hock*, is composed of six or seven bones, and forms a very obtuse angle with the tibia, when the horse has his foot to the ground. The astragalus differs from the human bone of that name, by having two very large and prominent condyles. The metatarsal bones correspond in every respect with those of the carpus already described.

(983.) In the skull of the horse we may observe that the temporal bone is divided by a suture into the squamous and tympanic portions. The occipital bone has a deep depression in the middle, where the cervical ligament is attached. The antrum maxillare and turbinated bones are of great size. The lower jaw-bone is also very large, and presents a very extended surface for the attachment of muscles.

The horse is provided with a large salivary apparatus of glands. Its stomach is divided into two portions; the first of which, next to the œsophagus, is lined with a cuticular membrane which terminates in a loose expansion, supposed to have the office of a valve, and to prevent the possibility of the animal's vomiting. There are generally found adhering to its coats a great number of the larvæ of the œstrus equi, and the œstrus hæmorrhoidalis, called in common language, *botts.* The intestinal canal is of great length, the large intestine alone being twenty-four feet in length. The colon is very capacious, and divided into cellular compartments. The liver is large, divided by deep indentations into lobes, and unprovided with a gall-bladder.

(984.) The peculiar sound produced in neighing is ascribed to the presence in the trachea of a delicate membrane, attached by its middle to the thyroid cartilage, and of which the two extremities pass along the external margins of the rima glottidis. The Eustachian tube opens, not immediately over the larynx, but into a sac peculiar to this tribe of animals, situated on the lateral parts of the lower jaw; and these cavities then open by a long fissure, furnished with a cartilaginous valve, into the pharynx.

(985.) The eye of the horse presents a remarkably beautiful and delicate structure in the folds of the internal membrane of the corpus ciliare. The pupil is oblong, the superior margin of the iris having a fringed appearance.

15. *Ruminantia.*

(986.) The anatomy of the ruminant family of quadrupeds, which comprises so many of those animals that man has domesticated and rendered subservient to his most urgent wants, has also very strong claims on our attention.

(987.) In their skeleton they correspond very closely with the horse, of which we have already given so detailed a description. The principal differences are observable in the terminal bones of the extremities, each limb presenting us with two hoofs, instead of one, and a corresponding division of the metatarsal bones and phalanges into two. On the other hand, the slender traces of a fibula met with in the horse, disappear in the ox and other animals of this tribe.

(988.) The whole track of the alimentary canal in these animals presents us with objects of interest. The tongue is covered with a thick cuticle, provided with pointed papillæ, which, being directed backwards, are fitted for laying firm hold of the grass, and tearing it up from the roots. The salivary glands are extremely large; the coats of the œsophagus particularly strong and muscular, in subservience to the function of rumination peculiar to this tribe. The organs provided for digestion are more complicated than in any of the animals we have yet considered. There are no less than four cavities which have been regarded as performing the office of stomachs. The first is the *paunch*, which is a capacious reservoir, abundantly supplied with secretion from its coats, which are beset with numerous flattened papillæ. The second is the *honey-comb* stomach, so named from the reticulated appearance of its inner membrane, the folds of which are disposed in polygonal lines, somewhat resembling the hexagonal margins of the cells of the honey-comb. The third stomach, which is the smallest, is termed the *manyplies*, and contains a great number of broad folds, or duplicatures of its inner membrane, which have been compared to the leaves of a book. The fourth, or the *reed*, has a pyriform shape, an internal villous coat, and a structure altogether analogous to that of the simple stomachs of carnivorous animals. It terminates in the beginning of the intestinal canal. A groove extends from the termination of the œsophagus along the edge of the three first stomachs, at the part where they communicate together; the edges of this groove are thick, so as to admit, when brought into close contact, of forming a canal for the direct communication of the œsophagus with any one of these four stomachs.

(989.) The grass which the animal takes into the mouth undergoes but a small degree of mastication, and passes, on being swallowed, into the paunch, where it undergoes maceration, and is transferred, by small portions at a time, into the honey-comb, or second stomach, which serves to perform an auxiliary office to the first. Thence it is sent up again directly through the œsophagus into the mouth, for the purpose of undergoing a second and more deliberate mastication, which the animal performs when reposing, and from which it appears to enjoy considerable pleasure. After being thus ruminated it is again swallowed, and the sides of the groove being brought into contact, so as to constitute a canal, and exclude all passage into the first or second stomachs, it passes directly into the third stomach; whence, after having been subjected to the further action of the secretions of that organ, it is transferred to the fourth or last stomach, where the process of digestion is completed. Liquids drunk by the animal pass at once into the second stomach, and assist in the maceration of its contents. But the milk taken by the calf, requiring to be neither maccrated nor ruminated, is conveyed directly from the œsophagus into the fourth stomach.

(990.) The biliary organs present us, in horned cattle, with numerous hepato-cystic ducts, conveying the bile immediately from the liver to the gall-bladder, which cyst is found in all the animals of this order, though it is absent in the horse. The urinary bladder is particularly large. In like manner, as we found in the pig, two small bones are met with also in ruminants, at the origin of the aorta; and the same purpose has been assigned to them as in the former instance. In the stag, these have been called the *bones of the heart*.

(991.) The internal carotid artery, at its entrance into the cranium, is suddenly subdivided into numerous branches, which are variously contorted, and afterwards re-united at the basis of the brain. The intention of this curious structure, which has been termed the *rete mirabile*, appears to be to diminish the impetus with which the blood would otherwise be forced into the arteries distributed to the brain; a force which would be increased by the effect of gravity when the animal stooped in grazing. The frontal sinus, and other parts connected with the sense of smell, are much developed. The lacrymal bones and ossa nasi are of considerable size. The tapetum is particularly conspicuous in the eyes of ruminants. One or two additional small bones are found among the ossicula auditus. The mastoid cells are numerous, and in the arrangement of their compartments somewhat resemble a ripe poppy head. In the ox and the sheep, the superior ligament of the glottis, as well as the ventricles of the larynx, are absent.

(992.) Ruminant animals are distinguished into two tribes, the first consisting of those which are without horns; the second, of those provided with horns. Of the former, the camel is remarkable for the great expansion of the hoof, which adapts it for treading upon sand. It has seven lumbar vertebræ. A peculiar moveable bag, glandular in its structure, exists behind the palate, probably designed for the lubrication of the throat: it has received the name of *bursa faucium*. Connected with the paunch is a large receptacle divided into numerous cells, for the purpose of holding water, as in a natural reservoir. Hence, when a camel dies in the desert, the Arabs open the stomach, and quench their thirst with the water it contains, which is found to be pure and wholesome. Like the horse, it has no gall-bladder. It has no fibula; but this latter bone is met with in the musk, which is also a hornless ruminant.

(993.) The horned ruminants have an eminence on the os frontis for supporting the horn. This process is in the stag a real bone, remarkable for the rapidity of its growth, which is annual, and for its death and separation from the skull at certain periodic intervals. The osseous bases of the horns of the ox, the sheep, the goat, and the antelope, on the contrary, are permanent, and are invested with a horny covering, which has a structure very different from bone. The camelopard, or giraffe, on the other hand, has two osseous prominences, which remain permanently covered with the integuments, and are even surmounted by a tuft of hair. But the details relating to organs so external as the horns fall more properly within the province of natural history.

(994.) The rein deer has, like several of the baboon tribe, large laryngeal sacs on the front of the neck, communicating with the larynx.

(995.) In the ox and sheep the spleen is remarkable for being of a distinctly cellular structure. In these animals we find a great developement of the salivary glands, and more particularly of the submaxillary gland, which extends along the side of the larynx quite to the back of the pharynx.

16. *Cetacea.*

(996.) From the consideration of the quadrupeds of the class mammalia, we pass now to that of a tribe of animals which, although warm-blooded and mammiferous, are formed on a model adapting them for inhabiting the water; nature having bereft them even of the rudiments of hinder extremities. The bones of the spine are continued, without being interrupted by an interposed pelvis, into the vertebræ of the tail, which terminates in a horizontal fin. The head and trunk are united by a neck, so short as to exhibit scarcely any diminution of diameter, and containing cervical vertebræ, which are extremely compressed, and the greater number of which are consolidated together by a bony union. The superior extremities are supported by bones, which have no medullary cavities, and which, compared with the analogous bones of quadrupeds, are much shortened and compressed. They do not admit of motion amongst themselves, and being enveloped by a tendinous membrane, are reduced to the office of fins. The internal organs correspond, however, with that of other mammalia. Cetacea breathe by means of lungs, their circulation is double, and they are warm-blooded. The females are viviparous, and are provided with mammæ for the nourishment of their young.

(997.) The necessity of occasionally receiving air into the lungs, whilst the animal is generally immersed in water, renders it requisite that a provision should be made for their readily rising to the surface in order to breathe. Hence the movements of the tail are from above downwards; hence in the cachalot and other kinds of whale, a large quantity of oil is accumulated round the head, which gives greater buoyancy to this part of the body. Hence, also, when the animal, in seizing its prey, takes into the mouth a large quantity of water, there is a necessity of getting rid of it, which is effected by its transmission into a sac placed at the external orifice of the nasal cavity, whence it is expelled with great force, by the contraction of powerful muscles, through a passage which conducts it to the top of the head. In this way are produced the enormous spouts of water that mark the track of the whale on the surface of the sea.

(998.) The olfactory organs are not adapted to the possession of any accurate sense of smell, being furnished neither with turbinated bones nor with any considerable nerves. The larynx rises in a pyramidal form into the posterior part of the nostrils, in order to receive the air from those passages, and convey it to the lungs, without its being necessary for the animal to extend more than the end of the snout above the surface of the water. The glottis is simple, and is not interrupted by any projecting membranes.

(999.) The stomach is composed of as many as five, or sometimes even of seven distinct pouches. There is no cœcum or appendix vermiformis; and the gall-bladder is absent in the greater number. The spleen is divided into a number of small globular lobes. The kidneys are conglomerate. The brain is large, and its hemispheres much developed. The tympanic bone is separated from the rest of the cranium, adhering to it only by ligamentous connexions. There is no external ear; the stapes is nearly solid; in the walrus it exhibits no perforation. The ossicula, semicircular canals, and other parts of the labyrinth of the internal ear are remarkably small. The external meatus is cartilaginous, and so small, that its external orifice in the dolphin will only just admit a pin. It pursues a winding course through the fat, which is of great thickness, until it reaches the tympanum. The Eustachian tube opens at the blowing hole, and is furnished with a valve preventing the admission of the water which the animal expels through that passage. The lacrymal organs are entirely wanting; the sclerotic coat of the eye is very thick at its posterior part, so that although the eye-ball has exteriorly a spherical form, the figure of the vitreous humor is very different; its structure at the back of the eye has the hardness of cartilage.

(1000.) In many parts of the arterial system of the cetacea, we find reticular plexuses, or convolutions of the vessels, the purpose of which is probably to serve as reservoirs of arterial blood, for the use of the system, when the animal is long under water.

(1001.) In the trichecus manatus borealis, or manati, a gland of the size of the human head is found between the coats of the stomach, near the œsophagus, discharging, on pressure, a fluid resembling the pancreatic juice.

(1002.) The whale is remarkable for having, in place of teeth, an apparatus apparently intended for filtration, and consisting of plates of the substance called *whalebone*, descending vertically into the mouth from the lower surface of the upper jaw, into which they are fixed by a ligamentous substance. On each side their number amounts to three or four hundred. The inner edge of each plate has its fibres detached so as to form a kind of fringe, which retains the small fishes and mollusca on which the animal feeds. The lower jaw is unprovided with any similar appendages. Although there are no teeth in the upper jaw, yet an intermaxillary bone is still present. Rudiments of teeth exist in the interior of the lower jaw before birth, lodged in deep sockets, and forming a row on each side. The developement of these imperfect teeth, however, proceeds no farther, and they disappear at an early period. The tongue, which is supported by an os hyoides of singular shape, is very thick and fleshy. The œsophagus is exceedingly narrow. The stomach is complicated in its structure. The intestinal canal is of considerable length, and contains a great number of longitudinal folds. There is a short cœcum. The mesenteric glands contain large spherical cavities, into which the trunks of the lacteals open, and where the chyle is probably blended with secretions proper to those cavities. The eye is extremely small in comparison with the size of the animal; and it occupies but a small portion of the orbit.

SECT. II.—COMPARATIVE PHYSIOLOGY OF BIRDS.

1. *General Description.*

(1003.) The whole of this class of animals exhibits great uniformity in its comparative anatomy; insomuch that the whole may easily be comprised in one general description. The structure of every part of the frame of birds is adapted to facilitate rapid progression through the air; for which purpose the anterior extremities are converted into wings, and are not employed in any other action. The support of the body when the animal is not flying, is entrusted solely to the posterior extremities; so that birds are, strictly speaking, *bipeds*. Hence we may trace some degree of approximation to the human structure in the conformation of the skeleton.

(1003.) The bones are dense in their texture, but are at the same time rendered light by having large cavities, occupied, not with marrow, as in the mammalia, but with air. There is a smaller proportion of cartilaginous to osseous structure in the skeleton of birds than in that of quadrupeds.

(1004.) The neck of birds being required to be very flexible, we find the cervical vertebræ very numerous, and freely moveable upon one another. The swan has twenty-three cervical vertebræ. Those of the back, on the other hand, are perfectly fixed and immoveable, their spinous processes being large and often united by osseous substance, so as to preclude the possibility of any relative motion. As the ribs occupy the whole of the sides of the trunk, there are properly no lumbar vertebræ. The os coccygis is short and compressed; and can scarcely be regarded as a proper tail, although it affords support to the long feathers which constitute what is usually called the tail of birds. The pelvis consists almost entirely of a broad os innominatum, the lateral portions of which are widely separated, in order to admit of space for the developement of the eggs; and for the same reason the two ossa pubis do not join to form a symphysis, but are at a considerable distance from one another. The exceptions to this general rule will be noticed afterwards.

(1005.) The number of true ribs never exceeds ten pair; the false ribs are numerous, and directed forwards. Those which occupy the middle of the body are distinguished by a flat process, directed upwards and backwards. The sternum is composed of five pieces, and is of great size and strength. From the middle of its lower surface there rises a sharp process, or spine, resembling the keel of a ship, and evidently adapted to accommodate the large and powerful pectoral muscles, which take their rise from this part of the chest, and which act in depressing the wings. The bones which connect the wings to the trunk are apparently three in number; the coracoid process of each scapula being distinct and largely developed bones, having the semblance of ordinary clavicles, whilst the real clavicles are consolidated into a single bone, denominated the *furcular bone,* from its resemblance to a fork, and which in the fowl is better known by the name of the *merry-thought.* Its extremities rest on two strong processes of the scapula. Many anatomists, considering the coracoid as the true clavicles, have regarded the furcular bone as an additional, or supplementary clavicle, corresponding to the coracoid apophysis.

(1006.) The bones of the wing are analogous in their divisions and distribution to those of the upper extremity in man: there being a humerus, radius, and ulna; two carpal bones; and two metacarpal bones, generally consolidated into one; one bone corresponding to that of the thumb and two fingers; that next to the thumb consisting of two phalanges, and the outer one, of a single bone.

(1007.) In the legs we find a femur and a tibia, to which there adheres a very slender fibula, (which is, indeed, often wanting;) one metatarsal bone, and the phalanges of the toes. The patella is often supplied by a process from the tibia.

(1008.) The muscles possess a high degree of irritability, and contract with great quickness and force. Many of the tendons become ossified in the progress of age. A remarkable arrangement exists in the tendons of the flexor muscles of the toes, by which the flexion of the knee and heel puts them on the stretch, and thus mechanically bending the toes, enables the bird to lay firm hold of the branch of a tree or perch whilst roosting. This is effected by the flexor tendons passing round over the outer side of the angle formed by each of these joints. Thus a bird, while roosting, supports itself on one leg only, by the mere effect of the weight of the body producing the necessary flexion of the toes, to enable it to preserve its hold. This remarkable provision of nature was long ago observed, and well explained by Borelli; and though the fact has been controverted by Vicq. D'Azyr, it appears to be well established. In order to give great latitude of motion to the head, the articulation of the os occipitis with the atlas is performed by a single condyle only, which procures it the advantages of a ball and socket joint. This condyle is situated at the anterior margin of the great occipital foramen. The proper bones of the cranium are not joined by sutures, but are consolidated into a single piece. The orbits for the eyes are very large, and are frequently found to communicate laterally in the skeleton, being separated, in the living animal, only by a thin membranous partition. The ossa unguis are generally very large. The upper jaw is almost always moveable upon the other bones of the head. To this bone is joined the bill, the structure of which is horny, and thus supplies the place of teeth, occupying the situation of the palate. The functions of the teeth, indeed, are not wanted, for the animal swallows its food without any mastication. The lower jaw is connected with the skull by the intermedium of a peculiar bone of irregular form, called the *os quadratum.* Another small bone resting against the palate is connected with it.

(1009.) The energy of the digestive functions in birds corresponds with that of respiration, and muscular irritability. The stomach may be considered as consisting of three cavities ; the first of which, termed the *crop,* is rather a dilatation of the œsophagus, furnished with numerous glands disposed in a regular arrangement of rows ; the second is the *ventriculus succenturiatus,* or *pro-ventriculus,* situated lower down, and just at the entrance of the proper stomach. It is furnished with a still more complex glandular apparatus ; and hence has been termed the *bulbus glandulosus.* Its form and structure vary much in different genera of birds. The third is the proper stomach, which resembles in the structure of its coats the simple stomachs of the mammalia, being thin and membranous in those birds which feed on insects and flesh. But in all granivorous birds the coats of this stomach are farther armed with a thick cuticular lining, of nearly the density of horn, which is surrounded by four immensely thick and powerful muscles, capable of exerting a strong compression on the contents of the stomach, and a slight degree of lateral motion, and thus performing the office of trituration. Such is the structure of what is called a *gizzard.* Between these opposite structures there exists, in different species of birds, a great number of intermediate gradations, corresponding to the peculiar nature of the food to which nature has adapted their organization. The trituration of the grain is assisted by small stones voluntarily swallowed by the animal, and in the selection of which the animal is directed by a principle of instinct.

(1010.) The intestinal canal of birds is much shorter than in most of the mammalia; but a similar disparity is also noticed in the former, with regard to the greater length of the eanal in birds consuming vegetable food, when compared with that of the carnivorous tribes. There is scareely any distinction in point of size between the small and large intestines; though the division between them is generally marked by the presence of two cœea. The rectum terminates in an expansion, termed the *cloaca,* in which the ureter terminates, and which therefore performs the function of the urinary bladder. Connected with the cloaca, there is an oval glandular bag termed the *bursaFabricii,* and opening into it by a narrow longitudinal aperture. The oviduct in the female also opens into the same cavity. Two blind pouches, opening into the rectum, are found near to its termination.

(1011.) The liver of birds is usually divided into two lobes; but in some birds there is in addition a third smaller lobe. Two duets proceed from the liver; the one is the hepato-cystie duet, the other the hepatic duct. The former conveys the bile into the gall bladder, the latter into the duodenum. Thus the bile is conducted into the duodenum by one hepatic duct distinct from the eystie duct, and these two alternately with two or three ducts from the pancreas, which is large, and generally consists of two distinct glands; the spleen, on the other hand, is usually round, and of small size. The gall-bladder is situated under the right lobe of the liver; but some birds have no gall-bladder. There is no omentum. The chyle is transparent; there are no glands in the mesentery; the thoracie duct is double. Magendie has denied the existenee of lymphatie vessels in birds; but they have been distinctly seen by others. The kidneys form a double row of conglobate glands, connected together, and situated on the sides of the lumbar vertebræ, in the hollows of the ossa innominata. There is no cavity corresponding to the pelvis of the kidneys of the mammalia; but renal capsules, similar to those of mammalia, are found also in birds.

(1012.) The heart of birds is furnished, as in the mammalia, with a double set of cavities; the one subservient to the general or systemic, and the other to the pulmonary circulation. The valves of the right ventricle are supplied by a strong triangular muscle, which gives additional impetus to the blood propelled into the pulmonary artery. Jacobson has discovered a singular distribution in the abdominal veins; those returning the blood from the hinder extremities being ramified through the kidneys and liver, previously to their termination in the vena cava.

(1013.) The lungs are not divided into lobes, and are fixed in their situation, being tightly braced in the cavity formed by the ribs, on each side, by a membrane, which is perforated by a number of holes. These apertures are the terminations of collateral branches of the bronchiæ, through which the air received into the chest passes out, and circulates through a multitude of cells interspersed through various parts of the body, and communicating ultimately with the central cavities of the bones. An immense surface is thus exposed to the influence of the air, which, having access to every part of the body, acts very extensively on the blood circulating in the vessels lining these air-cells and cavities. Hence the energy of the function of respiration is greater, and the temperature higher, than in any of the mammalia. There is properly no diaphragm in birds; a few muscular fibres only surround the larger air-cells, and assist in expelling the air from them back again into the lungs. The trachea is supported by a series of cartilages, which form entire rings, and overlap each other at their upper and lower margins, so as to preserve the tube open amidst the violent bendings and twistings of the neck. It is provided, at its bifurcation, with a peculiar set of muscles, which, aided by a second rima glottidis, enable this part to perform the functions of a second larynx, and to give rise to sounds; and, indeed, to be apparently the principal organ of the voice. In many aquatic birds, as in the male swan, the trachea makes a large circumvolution, which is contained in the hollow of the sternum. In other birds it is not enclosed in this bone; but there is a bony structure surrounding the inferior larynx, which tends to strengthen the voice. These convolutions and bony cells of the trachea, have been compared in their office to the turns of the French-horn, or the divisions of a basoon. This great development of the vocal organs is peculiar to the male bird.

(1014.) The brain of birds is characterized by the smallness of the hemispheres, which are not united by any corpus callosum. There is no appearance of convolutions on its surface. The optic thalami are voluminous, and are situated behind and below the hemispheres; a cavity is found in each. The crura of the cerebellum do not form any eminence at their junction with the medulla oblongata, corresponding to the pons varolii. The cerebellum is comparatively large, but has no lateral lobes, being almost wholly constituted by the processus vermiformis. The total bulk of the brain, compared with the size or weight of the body, is generally greater than in the mammalia.

(1015.) The eyes of birds are very large, in proportion to the size of the head, and appear to be adapted to a great range of vision. The adjustment of the position of the lens appears to be effected by means of a vascular and plicated membrane, called the *marsupium*, extending obliquely from the bottom of the retina, through the vitreous humor, to the edge of the crystalline. Its figure is trapezoidal; its surface is covered with the pigmentum nigrum, which of course absorbs all the rays of light that fall upon it. The anterior part of the eye-ball is, in many carnivorous birds, strengthened by a circle of bony plates, lying close upon the sclerotica, and overlapping each other. Besides the two external eye-lids, birds are always provided with a strong nictitating membrane, proceeding from the internal corner of the eye, and drawn over the cornea by a special muscular apparatus. In some birds the lower eye-lid is the most moveable, and in others it is the upper.

(1016.) There is no cartilaginous external ear; what has this appearance in the owl is formed only by the feathers; the cavity of the tympanum contains only one ossiculum auditus, and communicates with the air-cells of the skull. The Eustachian tubes have a common opening over the arch of the palate. The part corresponding to the cochlea has the figure of a cone, with scarcely any curvature, but with two scalæ. The semicircular canals are large, and project from the bone.

(1017.) The nasal organs are unprovided with an æthmoid bone; the olfactory nerves passing to them through the orbits, and being distributed upon the *bullæ turbinatæ*, which are oftener cartilaginous than osseous in their structure.

(1018.) The tongue is thick and fleshy, covered with a thick cuticle, and therefore not adapted to be an organ of taste. It is supported by an os hyoides of a singular shape, having besides the anterior and posterior processes, and the cornua, with their appendices, another bone jointed to it anteriorly, and moveable on it. This last bone, which supports the tongue, is called *the lingual bone.*

(1019.) The evolution of the chick from the egg being a subject of great interest, has long engaged the attention of physiologists. The following is an outline of the history of these changes in the common fowl. The ovulum, or first rudiment of the egg, is formed in the ovary, and consists simply of a bag containing the yolk; this afterwards becomes covered in its progress along the oviduct, by successive layers of albuminous substance, which composes the white of the egg, so called from the colour it assumes when coagulated. The white of the egg is invested with a firm membrane, which is easily divisible into two layers; and there are also other membranes dividing the mass of albumen into concentric layers. The membrane of the yolk, the *membrana vitelli,* or *yolk-bag,* is connected with that of the white, or the *membrana albuminis,* by a kind of ligament, which extends from the two ends or sides of the yolk, to those of the white; these, when partially stretched and torn by the motion of the yolk, have a flocculent appearance, and form what are called the *chalazæ.* They appear to act as ligaments to the yolk, keeping that surface uppermost in which the chick is situated, so that it may receive warmth from the hen during incubation. In the lower part of the oviduct the egg acquires a calcareous covering or shell, which is secreted by the inner membrane of that canal, and which is composed of nine-tenths carbonate of lime, the remaining portion being phosphate of lime and animal matter. Between the two membranes which line the shell, a small quantity of air is contained at the larger end of the egg.

(1020.) A small, round, milk-white spot, called the *cicatricula*, is formed on the surface of the yolk-bag during incubation. It is surrounded by two or three concentric circles, called the *halones*. Previously to the appearance of the embryo, a small shining spot of an elongated form, with rounded ends, but contracted in the middle, is seen within the cicatricula. This is called the *areola pellucida*. In the centre of this may be discerned, on the second day, a gelatinous filament, bent into a curve. This is the *primitive trace*, or earliest perceptible rudiment of the chick, in which the first organs that can be discovered are the two lobes of the brain, and the primitive filaments of the spinal cord, with the caudal dilatation. Vessels begin to appear on the surface of the yolk-bag, being spread on a separate membrane, and presenting what has been called the *figura venosa*, or *area vasculosa*, the marginal vessel at the remotest part being termed the *vena terminalis*. These veins correspond to the mesenteric veins; they are collected together, and form the vena portæ, whilst the arteries are derived from the mesenteric artery of the chick. The heart may next be perceived, as three red pulsating points, constituting the *punctum saliens*. These points are the rudiments of the auricle, ventricle, and aorta. Next, the separate vertebræ may be distinguished, then the eyes, and afterwards the stomach, liver, and intestines. Then a vascular membrane, the *allantois*, is rapidly formed, having the form of a bladder communicating with the cloaca. It soon extends over nearly the whole of the internal membrane of the shell, and is covered with numerous ramifications of arterial and venous vessels, derived from the internal iliacs of the chick; the former contain carbonized blood, and are therefore dark coloured; the latter, which conduct back the same blood after it has received the influence of the air at the surface, have a bright scarlet hue, and unite in forming the umbilical vein of the chick. Hence it is evident that this membrane performs a function analogous to that of the placenta in mammalia, and to that of the future air-cells of the lungs, or, in other words, that it is the organ of embryonic respiration. The chick is nourished by the matter of the yolk, which is partly absorbed by yellow vessels *(vasa vitelli lutea)* having a fringed appearance, and flocculent extremities, floating in the yolk, and partly by the direct passage of this matter into the intestine by means of a canal of communication, called the *ductus vitello-intestinalis.* The white of the egg also gradually disappears, being absorbed into and mixed with the yolk. Towards the latter periods of incubation, the whole of the yolk-bag is taken into the abdomen, and soon disappears. On the twenty-first day of incubation, the chick, being fully formed, breaks the shell which confines it, and enters into the world; for which temporary purpose it is provided with a hard beak, which is afterwards lost.

2. *Peculiarities in particular Families and Genera of Birds.*

(1021.) The shades of difference in the anatomy of each organ in individual genera and species of birds, are exceedingly numerous, and to enter into their detail would far exceed the limits within which we are obliged to confine ourselves in this treatise. We must not, however, pass over some of the most remarkable differences which offer themselves to our notice in a few families of birds. Amongst these none are more singular than those presented by the tribe of the brevipennes of Cuvier, comprehending the ostrich and the cassowary. These birds not being intended for flight, have very imperfectly formed wings; the sternum exhibits no carinated figure, but presents a plane and uniform surface, being destitute of an inferior spine; the pectoral muscles of the hinder extremity, on the contrary, are very large and powerful. The furcular bone exists only in a rudimental state. The pelvis of the ostrich differs from that of all other birds in being closed below by the complete junction of the ossa pubis. The cœca in this bird are furnished with a remarkable spiral valve. The feathers are also exceedingly peculiar; but as this subject belongs rather to the external characters, we cannot dwell upon it here.

(1022.) The same consideration prevents us from dilating on the varieties in the structure of the bill, and of the toes, which offer to the naturalist abundant topics of interesting inquiry. We shall only remark that the cellular bills, which are of such enormous size in the levirostres, have free communications with the air cells subservient to respiration, and may therefore be auxiliary to that function.

(1023.) The tongue of the woodpecker is provided with a singular apparatus for darting it forwards with great rapidity; this is effected by a long cartilaginous band, which passes completely over the top of the cranium, and is fixed to a groove on the right side of the upper jaw.

SECT. III.—COMPARATIVE PHYSIOLOGY OF REPTILES.

1. *Reptiles in General.*

(1024.) The class of reptiles comprehends all those vertebrated animals which breathe atmospheric air by means of lungs, but which are cold-blooded. This latter quality is a consequence of the partial extent of their respiration, the heart being so constructed as to transmit to the lungs only a portion of the circulating blood, and the remaining part being again sent into the arterial system of the body without having been exposed to the action of the air. Reptiles are distinguished by the negative characters of being destitute of either hair or feathers, and having no mammæ, organs for which there appears to be no occasion, in consequence of these animals being oviparous. The limited degree in which their blood is oxygenated appears to have a considerable influence on the whole condition of their vital functions. Not only is the temperature of the blood scarcely different from that of the surrounding medium,[1] the actions of life seem to be more sluggish and torpid, and the muscular powers less energetic; their sensations are more obtuse, and in cold climates they pass the winter in a state of torpor. The comparative smallness of the pulmonary system of vessels, and the less extent of the surfaces of the air-cells of the lungs, render them less dependent on respiration than warm-blooded animals; hence they bear submersion under water for a considerable time with impunity, although, if the interruption to respiration be too long continued, they ultimately perish, with as much certainty as any of the mammalia would do under similar circumstances.

There is ground for believing, according to Geoffroi St. Hilaire, that crocodiles and turtles possess, in addition to the ordinary pulmonary respiration, a partial aquatic abdo-

[1] The temperature of animals of this class has been shewn by the experiments of Dr. Davy, Tiedemann, Czermack, and Wilford, to be in general two or three degrees higher than that of the surrounding medium. It partakes, however, of the vicissitudes of temperature in that medium.

minal respiration, effected by means of two channels of communication which have been found to exist between the cavity of the abdomen and the external surface of the body, and also that some analogy may be traced between this aquatic respiration in reptiles, by these *peritoneal canals*, and the supposed function of the swimming bladder of fishes, hereafter to be described, in subserviency to a species of aerial respiration.

(1025.) As their vital functions do not require for their performance any elevated temperature, so we find reptiles destitute of those appendages to the integuments, such as hair, wool, or feathers, which in the other classes retain the warmth of the body. Their brain is very small compared with the rest of the nervous system, being less necessary for the exercise of the vital actions. The parts immediately instrumental in sensation are less concentrated in a particular spot, but would appear to be more diffused over the spinal cord and ganglia. Thus they not only continue to live, but even exhibit motions which have the semblance of being voluntary, though probably not so in reality, long after the loss of the brain, or even of the entire head. In like manner the irritability of their muscles is retained for a much longer time, after they have been separated from the body, than in the case of warm-blooded animals. The heart, when removed from the body, still continues to beat for several hours; and the body, thus deprived of its heart, may still possess the power of voluntary motion, in consequence of the continuance of a species of obscure circulation, which is carried on in the capillary system of vessels.

(1026.) Reptiles present a much greater variety of forms and of structures than is met with in any other class of vertebrata. The characters of the orders are derived principally from the form of their organs of progressive motion. These orders are four in number, namely, *chelonia*, *sauria*, *ophidia*, and *batrachia*.

2. *Chelonia.*

(1027.) This order comprehends turtles and tortoises, animals whose skeleton presents a trunk composed of two large plates of bone, the one derived from an expansion of the dorsal vertebræ and ribs, the other from a corresponding expansion of the sternum; these are united at the edges, and form a complete case for the thoracic and abdominal viscera, leaving apertures in front for the head and neck, together with the fore legs, and behind for the hind legs and tail. This arrangement produces a singular reversal of the positions of the scapula, the pelvis, and the muscles attached to these bones, all of which, instead of being placed externally, are situated in the interior of the ribs. The humerus is remarkably curved, especially in the tortoise, where it has nearly the form of a semicircle. The radius and ulna are distinct from each other; the carpus and phalanges are short and stunted, forming a compressed sort of hand. The vertebræ of the neck and tail are the only parts of the spinal column which are moveable upon one another.

(1028.) The cavity in which the brain is contained is very small compared with the size of the skull, the greater part of which consists of the bones surrounding the orbit, and giving attachment to the large muscles that move the jaw. There are no teeth, and the horny coverings of the jaws has some resemblance to a horse's hoof in the mode of its connexion with the bones. The tongue is short, and covered with villi, which extend also down the œsophagus; their points are all directed towards the stomach, so as to prevent the return of the food when it is once swallowed. The stomach is simple in its structure ; the intestinal canal of moderate length ; its inner membrane presenting only longitudinal folds, together with innumerable villi, which are more thickly set in the upper part of the canal than in the lower ; there is no cœcum, but occasionally small processes, or appendices epiploicæ, are attached to the outer membrane. The urinary bladder is exceedingly capacious. The lungs are voluminous, and are contained in the same cavity as the abdominal viscera. The air-cells are very large, and the general texture of the lungs is loose. Respiration is performed entirely by the muscles of deglutition; the animal in fact closes its mouth, and swallows the air received from the nostrils, which is thus poured down into the trachea, the os hyoides being alternately raised and depressed. The liver is divided into two round irregularly-shaped masses.

(1029.) The heart has two auricles, separated by a complete septum, the one receiving the blood from the venæ cavæ, the other from the pulmonary veins. The ventricle into which these veins pour their contents is single, but has two chambers of unequal size, which communicate together, so that the blood received from the lungs is more or less mixed with that returning from the body in the systemic circulation ; and it is this mixed blood which is sent through the aorta. The pulmonary artery is merely a branch of the aortic system.

(1030.) In the internal ear, we find a tympanum, Eustachian tube, and semicircular canals, together with ossicula, and also stony concretions in the vestibule. The eye has a bony ring at the anterior part of the sclerotica, as in birds.

There are large lacrymal glands, and a very moveable membrana nictitans.

3. *Sauria.*

(1031.) The various animals included in this order, or the tribe of lizards, have a heart with two auricles, with generally four feet, and a scaly integument. They are always provided with teeth, and with nails; there is invariably a tail. The ribs are very moveable, and their motions are subservient to respiration. The lungs are long and vesicular, extending far into the abdominal cavity.

(1032.) The crocodile may be taken as an example of this order. Its jaws are of immense size. The upper jaw consists of a large intermaxillary bone, which is immoveably joined with the skull, although the animal, in opening the mouth, appears to raise it independently, a circumstance which misled the older naturalists into the belief, that it was really moveable. There is an os quadratum as in birds. The sternum extends to the abdomen, and consists of seven pair of cartilaginous arches, to which ten ribs, not however reaching to the spine, are attached. There are no clavicles. The tongue is thick and flat, and attached very near its edges to the jaws, so as not to be easily perceived.

The teeth are of the simple conical kind chiefly adapted to the prehension and retention of the food; and each tooth when worn, is replaced by a fresh one, which grows underneath it; a succession which takes place several times during the life of the animal.

The œsophagus has the shape of a funnel, and leads to a stomach which resembles that of granivorous birds, in the thickness of its coats, and the approximation of its two apertures.

The liver has two distinct lobes. There is no urinary bladder. The single ventricle of the heart is divided into three compartments, which communicate together; there is one cavity belonging to each auricle, and an intermediate cavity, into which the blood from the two others is poured, and where the intermixture of the carbonized and oxygenated portions is made. There is an external meatus of the ear, which may be voluntarily closed by a species of lips. Ossicula auditus are found, as well as stony concretions in the vestibule. In the other kinds of lizards, the tympanum is on a level with the integuments, and there is no external meatus. A membrana nictitans is found in the eye. The area of the section of the cavity containing the brain does not occupy the one-twentieth part of that of the whole head.

(1033.) The chameleon has comparatively a large head; but its brain is only of the size of a pea. Its lungs have numerous projecting processes. The tongue is constructed in a manner which bears some analogy to that of the woodpecker in the mechanism by which it is darted forwards to a considerable distance from the head, and suddenly retracted. It terminates in a sort of club, which is moistened with a glutinous secretion, for seizing flies and other insects, and its upper surface is hollowed. The eyes project considerably from the head, and admit of being turned very freely in their orbits. The most singular circumstance in the constitution of this animal, is the change of colour of its skin under various circumstances of temperature or excitement. These changes appear to be connected with the variable activity of respiration, which quickly influences the colour of the blood circulating under the very transparent skin; and which is visible to a greater depth, in consequence of the ample extension of the lungs along the sides of the abdomen: when the lungs are inflated, indeed, the whole body appears as if it were semi-transparent.

(1034.) The draco volans is a remarkable instance, in this tribe, of the subserviency of the ribs, which are expanded on each side so as to support a thin membrane resembling a wing, to the purposes of progressive motion.

4. *Ophidia.*

(1035.) Serpents, being wholly without feet, are constrained to crawl upon the surface of the earth, and are, therefore, more especially entitled to the appellation of *reptiles.*

(1036.) Their skeleton presents us with the simplest possible condition of the vertebral type; for it consists merely of a simple spinal column descending from the head, and furnished only with ribs. There appears, at first sight, to be no vestige either of sternum, of scapula, or of pelvis; the body of each vertebra is articulated by a convex surface, which is received into a concave surface of the next. The number of vertebræ is often exceedingly great; being sometimes as many as three hundred. The number of the ribs corresponds with that of the vertebræ, and when acted upon by their muscles, they assist in the progressive motion of the animal, by pressing on the ground, in succession, like imperfect feet. In the rattle-snake, the last vertebræ of the tail are broad and covered with the hollow pieces which compose the rattle. Obscure rudiments of pelvic bones were found by Mayer to exist in the anguis fragilis, the anguis ventralis, and the typhlops crocotatus; and it is probable that they may be discovered in most reptiles of this order. Some serpents have external claws, which may be considered as rudiments of feet. In others they exist concealed under the skin ; and in others, again, there are cartilaginous filaments which Mayer regards as rudimental claws, connected with a series of small bones, which appear to be the rudiments of the bones of the lower extremities.

(1037.) The upper jaw-bone is detached from the rest of the skull, and admits of great latitude of motion. In most species of serpents, the jaws are so constructed as to render the mouth capable of great dilatation, and to enable it to receive objects even larger than the animal itself, and a corresponding power of dilatation exists also in the œsophagus.

(1038.) Serpents that are not venomous have usually four maxillary bones in the upper jaw, beset with small teeth, placed in two rows, widely separated from one another. The external row is not found in venomous serpents, but in their place large tubular fangs are met with, which are the terminations of the ducts from the poison bags, and which convey the venom into the wound inflicted by the tooth. This poison is secreted by glands, situated below the eyes, and surrounded by very strong muscles.

(1039.) The stomach of serpents can scarcely be distinguished from the lower extremity of the œsophagus, and is very short, compared with the great length of that canal. There is no urinary bladder, the ureters opening at once into the cloaca.

(1040.) The heart has generally two auricles, though in some genera only one is met with ; the ventricle is always single. The lungs consist of a membranous cavity, on the sides of which there are cells ; their form is exceedingly elongated. The lung on one side is often much smaller than the other. The tongue is long and slender, and forked at the extremity ; its root is contained in a kind of sheath, whence it can be protruded and retracted at pleasure. There is properly no tympanum belonging to the ear; but the long process of an ossiculum is found under the skin, and is connected with a tympanic bone.

5. *Batrachia.*

(1041.) The batrachia, (so termed from the Greek name of the frog, which may be assumed as a type of this order,) have a heart consisting of only a single auricle and ventricle; when arrived at maturity, they are possessed of two lungs; but in the earlier stages of their growth, they are wholly aquatic animals, and breathe like fishes by means of gills, which are affixed to the sides of the neck, by cartilaginous arches connected with the os hyoides. Such is the condition of the tadpole, which is the young of the frog. The aorta, on its exit from the heart, sends branches to each of the gills; whence the blood is collected by corresponding veins, that unite near the back to form a single arterial trunk, which again ramifies and distributes the blood to every part of the body, including the rudimental lungs, which are not yet developed In the process of the transformation of the tadpole into the frog, though these branchial arteries become obliterated, yet the vessels which supply the lungs remain, and are afterwards the channels of pulmonary respiration.

(1042.) In the skeleton of the frog, in place of ribs, small slender cartilages affixed to the extremities of the transverse processes of some of the vertebræ, which in the dorsal vertebræ are very broad. The spine is short, and terminates behind in a straight sacrum, which is impacted into the fork-shaped or innominatum. The scapula is thin and flat; and, together with the clavicles, are united to the sternum; but as there are no ribs, these, with the bones of the anterior extremities, are detached from the rest of the skeleton. There are properly no teeth; but the margin of the jaws is serrated. The urinary bladder exists, and is even sometimes double.

(1042.) The lungs do not collapse on opening the chest; this arises from the power which the frog possesses of distending them by the muscles of the mouth; the respiration being conducted on a plan similar to the one which has been already described in the tortoise, (§ 1027). Many species, as the pipa, have the vocal organs much developed. The tongue is of great length, and doubled back in the mouth; it is thrust forwards to a considerable distance in seizing its prey, and retracted with great rapidity. There is no external meatus to the ear; but the membrana tympani is external, and appears as part of the integument. The Eustachian tube opens at the fauces by an expanded mouth. There are two ossicula auditus; and the vestibulum contains rudiments of the calcareous bodies met with in other reptiles, and still more remarkably in fishes. The eye has two fleshy eye-lids, and also an internal nictitating membrane, which is transparent and horizontal in its direction.

(1043.) The salamander is constructed on the same model as the frog, with regard to all its internal organs; but it is provided with a tail. Its ear has no tympanum; but there is merely a cartilaginous plate laid over the fenestra ovale; there is no third eye-lid. The skeleton presents small rudimental ribs, but no sternum. This animal is remarkable for the power it possesses of reproducing the parts which have been mutilated, such as entire limbs; and even the eyes. In the newt, or aquatic salamander, the lungs have numerous processes, as in the chameleon, which terminate behind in an elongated bladder.

Müller has lately discovered that the frog, and several other animals of the same family, are provided with large receptacles for the lymph, situated immediately under the skin, and exhibiting distinct and regular pulsations, like the heart. The use of these *lymphatic hearts* is evidently to propel the lymph in its proper course along the lymphatic vessels. Their pulsations do not correspond in time with those of the sanguiferous heart; nor do those of the right and left sides take place at the same moment; but they often alternate in an irregular manner.

(1044.) The proteus anguinus, the siren, and the amphiuma, are remarkable for possessing both gills, like the tadpole, and lungs like the frog. They are, accordingly, adapted for living both in water and in air; and are the only animals that can strictly be said to be amphibious. The eye of the proteus is completely covered by the integuments, as it is in the mus typhlus.

SECT. IV.—COMPARATIVE PHYSIOLOGY OF FISHES.

(1045.) Fishes are vertebrated animals with red blood, breathing by means of water applied to the gills, or *branchiæ*, which in them supply the office of respiratory organs. Their powers of motion are adapted to progression through the medium they inhabit. This design is conspicuous in the form of their bodies, the great muscularity of the tail, the shortness of their members, which are expanded into fins, and the coverings of the body, which are smooth and scaly. The oxygenation of the blood, being effected solely by means of the atmospheric air contained in the water they respire, takes place only to a small extent; hence the temperature of the body in fishes is not sensibly raised above that of the surrounding medium, and these animals display little energy either in their vital or their sensitive powers. The brain, accordingly, is of small size, and the organs of the external senses but little developed; they scarcely possess any organs calculated to convey accurate impressions of touch. Nature has denied them any vocal organs. The circumstances in which they are placed would appear to give little exercise to the sense of hearing; and the deep recesses of the ocean, where darkness eternally reigns, afford as little to that of sight. No lacrymal organs are wanted by animals immersed in a liquid medium. The voracity with which fishes devour their prey, leaves them scarcely any opportunity of discriminating its taste; and their tongue is not adapted by its structure for receiving the impressions of this sense. Neither can the sense of smell be exercised in the same degree as in animals respiring atmospheric air, through which odorous emanations are so extensively and so rapidly diffused. Exclusively occupied in the two great objects of animal desire, that of food and of progeny, all their movements appear exclusively directed to these ends; they appear insusceptible of attachment, and incapable of any but the lowest degree of intellectual developement.

(1046.) The osteology of fishes presents a very complicated subject of study, not only from the great number of peices of which their skeleton is composed; but also from the great variety of forms exhibited in the different genera and species of this class. Fishes, with regard to their skeleton, admit of a great primary division into the cartilaginous and osseous. The former, or the *chondropterygii*, possess no real bones, but merely cartilages, having the form of bones, of a homogeneous and semitransparent substance, sometimes, however, as in the rays and sharks, presenting on its surface small calcareous granules, very closely compacted together. In a few fishes arranged under this division, as the sturgeon, and the chimera, we meet with several true bones in the head and shoulder, while the rest of the skeleton is cartilaginous. Even among the strictly osseous fishes, the density of the bones of some species is inferior to that of others, the calcareous substance, or phosphate of lime, being deposited in fibres, or layers, in the cartilage which serves as the basis of the bone. The truly osseous fishes have bones as hard and as dense as other vertebrated animals; they are even more homogeneous in their texture, and present no appearance of pores or of fibres, as are seen in the bones of the mammalia. We never find in them any medullary cavities.

(1047.) The spinal column consists of dorsal and caudal vertebræ only, those of the neck and sacrum being absent. The bodies of vertebræ have always a conical depression on both their surfaces; the double cone thus left by the junction of their margins being filled with a gelatinous fluid. These cavities generally, indeed, communicate together throughout the whole spinal column by apertures in the centre of each vertebra, at the apices of the cones. In the lamprey this opening is so wide, as to reduce the vertebral column to a mere series of rings, traversed from one end to the other by a ligament. The spinous processes are usually very long, and their roots form a canal for the passage of the spinal cord. Spinous processes are also frequently found on the opposite or abdominal side of the vertebræ; and these also form a canal for the protection of the aorta, which is admitted through it. The ribs are attached each to a single vertebra, and are frequently furnished with appendices adhering to them at one end, whilst the other end is imbedded in the muscles.

(1048.) The fins of fishes do not present much analogy with the bones of the extremities of quadrupeds, although such analogies have been sought with much eagerness. The fins are composed of parallel bones called rays, which are connected with others, called by Cuvier, *interspinal bones*, and by Meckel, *accessory spinal apophyses*. The sternum, where it exists, is composed of a series of bones, of various figures in different fishes; but which unite the lower extremities of the ribs. In the pectoral fin, or anterior extremity, are found bones somewhat analogous to the two bones which compose the scapula of reptiles; a styloid bone composed of two pieces, analogous perhaps to the clavicle and coracoid bone. The two bones corresponding to the radius and ulna are connected with a row of ossicula representing the carpus, and which support the rays of the fin itself.

(1049.) The posterior extremity, or base of the ventral fin, is composed of four bones, which may be considered as a pelvis; but these support the rays, without the interposition of any bones comparable to the femur, tibia, or tarsus.

(1050.) The bones of the head are exceedingly complex, and the mere enumeration of them would require a more lengthened discussion than can here be afforded. The bones composing the jaws, namely, the maxillary and intermaxillary, are not only moveable on the skull, but also on each other. The palatine, the pterygoid, and the tympa nic bones, have also independent motions. A row of sub orbitar bones also exists, different from what is met with in any other class. To the bones of the skull are joined also the opercular system of bones, which protect the gills, and are subservient to the motions which open and close them during respiration. The proper bones of the skull are placed in the midst of these four systems, and are very similar to those of reptiles, containing a receptacle for the brain, another for the labyrinth of the ear, and others for the eyes, and for the nasal cavities. The os frontis is composed of six pieces; the parietal of three; the occipital of five; each temporal of two; and the sphenoidal of five. Much ingenuity has been lavished in the attempt to discover analogies between these bones and the parts which compose the skeleton in the other classes of animals. Thus the opercular bones have been supposed to correspond to the ossicula auditus of mammalia; a notion which, although ably supported by Geoffroy St. Hilaire, may perhaps at first sight appear extremely fanciful and hypothetical, and which Cuvier represents as utterly unfounded.

(1051.) The teeth of fishes exhibit almost every possible variety in form, number, and situation. They may be distinguished, according to their position, into intermaxillary, maxillary, mandibular, vomerian, palatine, pterygoid, lingual, branchial, and superior and inferior pharyngean. Some fish have almost all these denominations of teeth; others a smaller number, and a few genera of fishes are entirely destitute of teeth. The teeth are generally of a conical and incurvated form, like so many hooks; sometimes the points are so small and united as to resemble a brush or file; others are round, or club-shaped; others present more flat surfaces, like a mosaic pavement. Their structure is always simple, being formed by a single pulpy membrane, which afterwards ossifies; and is, in process of time, replaced by a new tooth. This successive renewal of the teeth of fishes is continued during the whole period of their lives. The degree of mastication given to the food depends, of course, on the form and situation of the teeth.

(1052.) Deglutition is assisted by means of a membranous velum placed behind the anterior teeth. There is no appearance of salivary organs; unless we regard as such a soft and highly vascular organ found in the palate of the carp. This organ is highly irritable, and swells in a remarkable manner on the application of any stimulus; it perhaps performs the function of an organ of taste.

(1053.) The œsophagus is generally very short and capacious; it is continued into the stomach without any marked line of separation; and part of the food is often retained in the œsophagus undigested, until room can be made for it in the stomach. In a few fishes, the parietes of the stomach are muscular, so as to entitle it to be considered as a gizzard. The intestinal canal is generally very short; its internal coat is more or less villous; there is never any cœcum; the only distinction between the different portions of the canal is formed by a valve near its extremity; but this is not succeded by any dilatation.

(1054.) A remarkable structure is met with in the intestines of rays, sharks, and sturgeons; which present a spiral valve, or duplicature of the inner coat, running nearly the whole length of the canal. A great number of blind pouches, or *appendices pyloricæ*, as they are called, from their being more numerous in the beginning of the intestine, are generally found; their office appears to be to secrete a quantity of mucous fluid, probably analogous to saliva, or to the pancreatic secretion. In the sturgeon, these are short and united by vessels and cellular substance into one mass, which union becomes more close and compact in the rays and the sharks, constituting a real conglomerate gland, having a single excretory duct.

(1055.) In many fishes, namely, in the ray, shark, sturgeon, lamprey, and salmon, there are two passages opening outwards from the general cavity of the abdomen, at the sides of the termination of the intestine. The use of these passages is unknown.

(1056.) The liver is of considerable size, and placed more on the left side; great variety exists with regard to its shape and the number of its lobes in different fishes; its texture is softer than in quadrupeds and birds, and it contains a large quantity of oil. There is almost always a gall-bladder of greater or smaller size. The hepatic ducts are sometimes very numerous, and are successively joined to the cystic ducts. The mesentery is incomplete; and is often prolonged into folds containing fat, which folds may perhaps be considered as corresponding to an omentum. Although the lacteals are numerous, there are no lymphatic glands in the mesentery.

(1057.) The lymphatic vessels are very distinct in other parts of the body. Fohman has succeeded in injecting them in the gills. Several fishes have a urinary bladder, which is situated behind the rectum; in other instances there is merely a common cloaca, into which the ureters terminate. The kidneys are more voluminous than in any of the preceding classes, and are often joined together posteriorly; there are no suprarenal glands. The spleen is constantly present, and occupies various situations in the abdomen.

(1058.) The circulation in fishes is conducted upon a very different plan from what it is in reptiles. There is, as in warm-blooded animals, one complete circulation for the body in general, or a systemic circulation ; and another for the organs of respiration ; and besides this, a partial circulation for the hepatic system of organs ; but what more particularly characterizes this mode of accomplishing that function is, that branchial circulation is the only one which is effected by a muscular apparatus, that is, by a heart. The systemic circulation has no such organ for communicating to it a mechanical impulse.

(1059.) The muscular apparatus for carrying on the circulation in fishes consists of four cavities, namely, the sinus venosus, the auricle, the ventricle, and the bulbus arteriosus ; the three latter are inclosed in the pericardium, and may be said to constitute the heart, which is situated underneath the pharyngeal bones, and between the bronchial arches. The blood returning from the veins of the body and head, is collected in the sinus venosus, which transmits it by a single opening into the auricle, valves being interposed at the entrance. The auricle discharges its contents into the ventricle, which again propels it into the bulbus arteriosus, whence it proceeds along the bronchial arteries to be distributed on the gills. Thence it is returned by the bronchial veins, which unite near the spine to form a single arterial trunk corresponding in its office to the aorta, and distributing the blood, by a succession of ramifications, to every part of the body The veins from the digestive organs are collected into the vena portæ, which as usual ramifies through the liver ; and there appears also, from the observations of Mr. Jacobson, to be in addition a lesser venal circulation, independent of either of the former, and analogous to what has already been observed in birds.

(1060.) The vivifying influence of the air contained in the water which is applied to the gills of fishes, is quite as necessary for the continuance of their vital functions, as that of atmospheric air is to animals of the preceding classes; and fishes perish with equal rapidity as mammalia, when their natural element is withdrawn. This happens whether the water has been deprived of its air by boiling, or whether the absorption of air from the atmosphere is prevented by a body capable of intercepting it, placed on the surface of the water. It appears from the researches of Mr. Ehrmann, that some fishes, as the cobitis, swallow air, which passes along the intestinal tube, where it loses oxygen and acquires carbonic acid. Fishes taken out of the water are killed not so much from the want of oxygen, as in consequence of the drying of the branchiæ, which impedes the circulation of the blood through them. The water is taken in at the mouth, and after acting on the gills, which are filamentous organs, affixed in rows to the branchial arches, and protected by the operculum, is discharged through the branchial openings below. In the cartilaginous fishes there are several openings provided for the outlet of the water, at the side of the head.

(1061.) Most fishes possess a large bladder full of air, called the *swimming bladder*, placed immediately underneath the spinal column; it communicates with the œsophagus, and sometimes with the stomach, by a canal, called the *ductus pneumaticus*. In the carp, there are valves in this canal which only allow of the passage of air out of the bladder. In many fishes, especially in flat fish, no such air-bladder exists. Its figure is very various; its cavity is generally simple; but it is sometimes divided by a number of partitions. A glandular body is met with in the coats of this bladder, which probably secretes the air. The obvious intention of this instrument is to give greater buoyancy to the fish when this air is present, and to allow of a sudden increase of specific gravity by its escape. In by far the greater number of fishes, however, the air-bladder has no outlet whatever. In many fishes it is called the *sound*, and furnishes the best kind of jelly. Isinglass is the product of the air-bladder of the sturgeon. The air it contains is usually nitrogen gas, with a small proportion of oxygen and carbonic acid gases. The swimming bladder of fishes is regarded by many of the German physiologists as having some relations with the function of respiration; and as being the rudiment of the pulmonary cavity of land animals; the passage of communication with the œsophagus being conceived to represent the trachea. (See § 1022.)

(1062.) The brain of fishes is remarkable for the smallness of its size, not only as compared with the total bulk of the animal, or with that of the nerves connected with it, but also with the cavity of the cranium, which it does not by any means fill, the space left being occupied by an oily, secretion, and by loose cellular texture. The disparity is less observable in young fish; for it would appear that the growth of the brain does not keep pace with that of the rest of the body.

(1063.) The several parts which compose the brain of fishes are more detached from one another than in the higher classes, and are placed in a consecutive series. The foremost lobules give rise to the olfactory nerves, or rather appear as the bulbous enlargements of the origin of these nerves. The next in succession are solid lobes, which give origin to the optic nerves; behind these we find larger lobes containing a ventricle, with a striated eminence, at the baek part of whieh are four smaller tubercles corresponding to the eorpora quadrigemina. Behind these is the single lobulc of the cerebellum, and below are two inferior lobes. The optic nerves pass before thesc lobes, and always decussate in their eourse to the orbits. Between these nerves, and in front of the inferior lobes, is the pineal gland. Behind the cercbellum are also two lobes, whieh may be termed the postcrior lobes. There is, however, mueh differenee of opinion as to the parts in the human brain to whieh these several portions of the brain of fishes are analogous.

(1064.) Great variety is met with in the size, position, and direetion of the eyes of fishes. In general, however, they are large. There are neither eye-lids nor lacrymal organs, and the globe of the eye has but little mobility. In the ray and shark tribes, it is supportcd on the end of a moveable eartilaginous pediele, artieulated with the bottom of the orbit. The anabliss has the cornea divided into two by an opaque line, and two perforations exist in the iris, but there is only one erystalline lens, vetreous humor, and retina. The crystalline lcns is eompletely sphcrical, and of great sizc, so as to leave but little spaee for the vitreous humor. It is eomposed of eoneentrie laminæ, whieh are of greater density as they approaeh the eentre. A faleiform ligament, eommeneing at the entranee of the optie nerve, following its eurvature downwards, and eontaining vessels and nervous filaments, is observable; its extrcmity is attaehed to the eapsule of the erystalline lens. In some fish this ligament has a black eolour, likc the marsupium of birds. Thc selcrotiea is often supported by osseous or eartilaginous plates, as in birds. The pupil is ineapable of altering its dimensions; in the rays and flat fish, its border is fringed with palmated proeesses. The eornea is nearly flat, and there is but little aqueous humor.

(1065.) There is found in the eyes of fishes a peculiar body, the *membrana vasculosa Halleri*, having the shape of a horse-shoe, situated between the internal layer of the choroid eoat, or *tunica Ruyschiana*, and the middle layer; it gives origin to a vaseular membrane, called the *campanula*, whieh proeeeds towards the lens, and has some analogy with the marsupium.

(1066.) The gastrobranchus appears to be wholly destitute of any organ of vision. In the blind murena, no traee of an eye ean be pereeived externally, but a rudimental organ exists beneath the skin.

(1067.) The ear of fishes consists only of the parts belonging to the labyrinth; and these organs are generally suspended in a cavity of the eranium, which is a part of that in whieh the eneephalon is eontained. The two vertieal semi-eireular canals are suspended to the top of the skull by a vertieal ligament. The oily or macilaginous fluid which surrounds the brain has free aeeess to the cavities whieh surround the membranous labyrinth. The three semieircular eanals are dilated into ampullæ, which receive the filaments of the auditory nerve. There is an appendix to the *sinus medianus*, or principal vestibular sae, termed the *utricle*, and a smaller one termed the *cysticule*. The hard ealearcous bodies consist of one in each of these eavities, being three in number. There is no part corresponding to the eoehlea.

(1068.) In the ray there is a spiral tube, wholly within the skin, whieh terminates in a kind of finestra ovale, and appears to be the rudiment of an external meatus.

(1069.) Many fishes present the extraordinary phenomena of the developement and accumulation of electricity in large quantities, which they have the power of discharging at pleasure, so as to give strong shocks to animals coming in electric contact with them, or forming part of the circuit of the discharge. This effect is often so powerful as to benumb and paralyse their assailants. The electric fishes which are known to possess this power in a high degree are the electric ray *(raia torpedo)*, the electric eel, *(gymnotus electricus)*, and the *silurus electricus*, or *malapterurus electricus*. The first of these are met with principally in the Mediterranean Sea; the second in several rivers in South America; and the last in the Nile and Senegal rivers. Other fishes, however, are known to be electrical, although they have been less studied than those already mentioned, such as the *rhinobatus electricus*, *trichinus electricus*, and *tetrodon electricus*.

(1070.) The electrical organs of the torpedo consist of a great number of five or six-sided prisms, placed on each side of the head perpendicularly to the surface, and occupying the whole thickness of the animal. Each prism consists of a tube, with membranous sides, surrounded with nerves and blood-vessels, and containing a vast number of extremely thin plates, parallel to one another, but in a transverse position; the intervals are filled with a gelatinous fluid. Three large branches of the par vagum, and one branch of the fifth pair of nerves, are distributed to these organs on each side. The electrical apparatus of the gymnotus and silurus are disposed somewhat differently; they are two in number on each side, and extend the whole length of the fish from the head to the tail. One of these is situated deeply, and the other superficially; the two being separated by a membranous partition, and each being formed of horizontal plates, distant one-third of a line from one another, with septa passing perpendicularly between them, and directed from within outwards, and a fluid occupies the intervening spaces. Their nerves are derived from the intercostals, and are 224 in number.

(1071.) The identity of the agent called into play by these organs with electricity is beyond all doubt. The same bodies which conduct or intercept the transmission of the latter, have the same property with regard to the former; and shocks are propagated through a chain of several persons, when those at the extremities of the chain touch the fish. Electric sparks have been obtained by Walsh from the discharge of the gymnotus when passed through a strip of tin foil gummed to a piece of glass and cut through in the middle. Dr. John Davy[1] has obtained electro-magnetic effects from the torpedo, by the test of the galvanometer; and has also rendered needles magnetic by the electrical discharge from the fish.

(1072.) It appears that the power of producing these electrical discharges is quite voluntary, and dependent on the nervous influence; for it does not take place every time that the fish is touched, and it wholly ceases on the destruction of the brain, or the division of the nerves. The animal appears to have the power also of determining the direction of the discharges; and often, when irritated, it refrains from giving shocks. The destruction of the electric organ on one side does not interrupt the action of the opposite organ. Dr. Davy states, that the dorsal surface is charged with positive, and the ventral surface with negative electricity,

[1] *Phil. Trans.* for 1832 and 1834.

and that unless both surfaces be simultaneously touched, no shock is felt; and Matteuci and Colladon[1] arrived at the same conclusion by experiments made with the galvanometer, as to the direction of the electric currents. Electric fishes, when vigorous, exert this power as strongly in the air as in the water. We are quite in the dark with regard to the theory of these phenomena. Matteuei imagines that the source of electric power in these fishes is in the brain; and that the purpose served by the complex arrangement of parallel plates, with intervening fluid, which composes the structure of the electric organs, is that of mere accumulation, analogous to the property of the Leyden phial.

(1073.) What may be called the nasal cavities or nostrils of fishes, are placed generally in front of the head, and their openings are a valvular membrane or partition; behind this is found an elegantly plaited membrane, disposed in semicircular folds, on which the ramifications of the olfactory nerves terminate.

SECT. V.—COMPARATIVE PHYSIOLOGY OF MOLLUSCA.

(1074.) The class mollusca comprehends all the variety of what are commonly called shell-fish, together with the animals, such as the slug, which resemble them in their anatomical character, but which are not furnished with shells. Their comparative anatomy has been studied with great care and diligence by Cuvier, whom chiefly we shall follow in our general description of this class.

(1075.) The mollusca have neither articulated skeleton nor vertebral canal. Their nervous system does not pre-

[1] *Séances de l'Acad. des Sciences*, Oct. 1836.

sent a central spinal cord, but merely a certain number of medullary masses, dispersed in different situations in the body, and of which the largest, which may be designated the brain, is placed near the œsophagus, where it is connected with a collar of nerves that embraces that tube. The circulation is always double, like that of fishes, that is to say, the pulmonary circulation is always complete in itself, as well as the systemic. But the muscular ventricle, or heart, is not, as in fishes, placed at the commencement of the former, but of the latter; it impels the blood not into the branchial arteries, but into the aorta. The blood is either white or of a bluish colour; and it contains less fibrin than that of vertebrated animals. The veins probably perform the office of absorbents.

(1076.) The muscles are endowed with great irritability, and retain this property long after they are divided. They are attached to different points of the skin, which is smooth and moistened with a viscid liquor. The muscular actions produce contractions and inflexions of the different parts, and elongations of others, by means of which the animal is enabled to accomplish different kinds of progressive motion, whether in water or on land, without the aid of articulated members, or the advantage of solid unyielding structures, like the bones of the vertebrated classes. These movements, however, are necessarily less rapid and energetic, and less perfectly executed.

(1077.) A leading characteristic of the structure of the mollusca, consists in a muscular expansion, connected with the integument, which envelopes all the viscera, and is hence denominated the *cloak* or *mantle*. It assumes various forms in the different genera, being sometimes contracted into a flat disc, at other times being folded into a tube, or doubled into a sac, or expanded into the form of fins or oars. Most frequently we find a calcareous secretion formed on different parts of one or both of the surfaces of the mantle, which hardens and forms a layer of shell. Successive depositions take place, occasioning the enlargement of the shell in different directions; when the shell is wholly external to the animal, it serves for its habitation and protection; this is the case with the testaceous mollusca; in others, which have no such covering, (or the naked mollusca,) there frequently takes place an internal deposition of the same material, forming an internal shell. The calcareous matter is always intermixed, when deposited, with animal matter, which is sometimes in the form of a distinct membrane, and which has frequently a shining or irrideseent appearance, constituting the substance known by the name of mother-of-pearl.

(1078.) Great variety exists in the organs of the digestive functions, as will be seen by the examples we shall give in speaking of the different orders established in this class by Cuvier.

1. *Cephalopoda.*

(1079.) The various genera of sepiæ or cuttle-fish, are comprehended in this order.

In these animals, the mantle is folded so as to form a sac enveloping all the visecra; its sides being more or less extended into fins. The head alone protrudes from the sac; its form is round, furnished with large eyes, and with long processes or tentacula, flexible in every direction, endowed with great museular power, and having on the surface a great number of suckers, by which they are capable of adhering with great force to the objects to which they may apply them.

These tentacula, or feet, are employed by the animal in walking, which it does with the head downwards; in swimming, which it executes with the head turned backwards; and also in seizing hold of bodies, for which action they are well adapted. Between the basis of the feet is placed the mouth, containing strong horny mandibles, resembling in their form the beak of a parrot. The excretions pass out by a funnel-shaped aperture, situated at the mouth of the sac, and near the head.

(1080.) The pulmonary organs consist of two branchiæ situated within the sac, one on each side, and having the figure of a fern leaf. The great vena cava, on arriving near them, divides into two trunks, terminating in two muscular ventricles placed at the base of the branchiæ, for the evident purpose of propelling the blood with more force into the branchial arteries. The branchial veins corresponding to these arteries, unite in a third ventricle situated near the bottom of the sac, and which sends the blood forwards through the aortic system as usual. Thus there may be said to be three separate hearts in the cuttle-fish, one aortic and two branchial. The water respired enters at the open margin of the mouth and passes out by the funnel-shaped aperture already described.

(1081.) There is found a tongue, of which the surface is bristled with sharp horny points; the œsophagus is dilated into a *crop*, and terminates afterwards in a gizzard, equally muscular with that of a granivorous bird. To this succeeds a third stomach, which is membranous, coiled into a spiral form, and receives the bile by two ducts from the liver.

(1082.) A singular secretion is prepared by a gland in this animal, of a deep black colour, resembling ink, which, when effused, darkens the surrounding water to a considerable distance, and gives the animal an opportunity of escaping from its pursuers. The brain is large; a nervous ganglion surrounds the œsophagus. The optic ganglions are very large; and the nerves form plexuses in the abdomen and in other parts. The eye is similar in its conformation to that of the higher classes of animals; but the ear is constructed in a still simpler manner than that of fishes, having neither semicircular canals nor external meatus, but consisting merely of a membranous sac lodged in a cavity near the brain, in which a small cretaceous body is contained.

2. *Gasteropoda.*

(1083.) The mollusca which have a shell consisting of a single valve, compose a numerous order, a familiar example of which occurs in the snail. The slug, on the other hand, belongs likewise to this order, although it has no external shell. Mollusca of this description are termed *gasteropodous*, because they crawl on a flat disc placed under the belly; the back is covered with the mantle, which is of greater or less extent, and secretes the shell. The head comes out more or less from the mantle, under which it is occasionally retracted, so as to be both concealed from view, and protected from injury. A small number of tentacula, from two to six, appear above the mouth, but do not surround it. The eyes are exceedingly small, and sometimes adhere to the head, sometimes to the base, or the side, or the extremity of the tentacula; but occasionally none are found. The position and structure of their respiratory organs varies in the different families of this order; and they are always situated under the last turn of the shell when this latter has, as is generally the case, a spiral form; and they receive the water either by a broad opening under the mantle, or by a narrower aperture, and often through a tube formed by the prolongation of the mantle, which is frequently protected by an indentation or tubular process of the shell. A further protection is often afforded by a flat, horny, or calcareous plate, which closes the shell when the animal has retired within it, and which is termed an *operculum*.

(1084.) Instead of branchiæ, the pulmonary gasteropoda are provided with cavities for the admission of atmospheric air, which they respire in its gaseous form. These cavities are opened and closed at the pleasure of the animal, the mechanism of their respiration consisting in these movements.

The stomach and intestinal canal are of very various structure in the different genera. In some, as the scyllæa, we find cutting teeth implanted in the coats of the stomach itself; in the pleurobranchus there are four stomachs, like those of ruminant quadrupeds. The aplysia is provided with a very capacious crop, which leads to a muscular gizzard, armed, moreover, with a number of cartilages of a pyramidal shape ; a third stomach succeeds to this, having its inner coat lined with sharp hooks ; and a fourth, shaped like a cœcum ; and the intestines are, besides, exceedingly voluminous.

Many of the gasteropodous mollusca present the curious phenomena of the double hermaphrodite generation formerly adverted to, (§ 781.) Impregnation of the ova requires the union of two individuals, the female organs of each receiving the male organs of the other, and the fecundation being mutual. This is the case with the helix and the lymneus.

3. *Acephala.*

(1085.) The acephalous mollusca, so named from their having no head, have all the vital organs enclosed in the two folds of the mantle, which shuts like a portfolio, leaving apparent only the orifice of the mouth ; but in some cases the mouth is here prolonged in the form of a tube. In almost every case each of the two sides of the mantle is covered by a valve of shell, so as to constitute a *bivalve* molluscous animal ; in another tribe the shell is *multivalve.* The brain is situated immediately over the mouth, and consists of a certain number of small ganglions. The branchiæ have almost always a laminated form, the plates, generally four in number, being covered with a net-work of blood-vessels. The mollusca of this order are unprovided with teeth, the food brought by the water being received into the mouth, and swallowed in its original state, whence it passes into the stomach ; sometimes there are two successive cavities performing the functions of the stomach ; the intestine is of various length. The liver surrounds the stomach, and pours its secretion directly into the cavity by several apertures.

(1086.) A large fleshy process, resembling in appearance a tongue, and which has been compared to a foot, projects from the body, and by the varied movements of which it is capable, enables the animal to perform a slow progressive motion. Muscles are also provided for closing the shell, and they generally pass directly from one valve to the other ; sometimes there are two muscles, but commonly only one. The valves are separated by the force of an elastic ligament placed at the extremity of the hinge, which is called into action when the muscles that close the shell are relaxed.

(1087.) The threads, or byssus, spun by many acephalous mollusca in order to attach themselves to rocks, as a ship is moored by her cables, is another peculiarity in these animals, and particularly of the genera mytilus and pinna.

(1088.) In many mollusca of this order the rectum passes through the cavity of the heart, and this latter organ receives the blood from the veins by means of two auricles.

Some acephala are hermaphrodite; but the union of the sexual organs necessary for fecundation takes place in a single individual. This occurs in the holothuria.

(1089.) One of the most singularly constructed of the animals referred to this division of mollusca is the ascidia. The mantle and its envelope, which is a thick and cartilaginous tunic, form together a sac, everywhere closed, excepting at two orifices, the one corresponding to the termination of the intestine, the other leading into a cavity, of which the sides are the branchiæ, and at the bottom of which is placed the mouth, the principal viscera subservient to nutrition occupying a second cavity, and the heart being lodged in a third. The principal nervous ganglion is situated between the two external orifices of the sac.

SECT. VI.—COMPARATIVE PHYSIOLOGY OF ARTICULATA.

(1090.) This great division of the animal kingdom comprises all those tribes possessing what may properly be called an external skeleton; that is, a series of rings or hollow cases, of a hard texture, which enclose all the important organs of the body, and which, by their muscular connexions, allow of various kinds of movements, at the same time that they afford protection to all the softer tissues of which those organs are composed. The best idea that can be formed of this mechanical construction may be obtained by examining the body and the limbs of a lobster, in which it will be seen, that contrary to what obtains in vertebrated animals, the harder parts are external, and the muscles are within them, a construction allowing of very free movements of the limbs.

(1091.) A remarkable degree of uniformity prevails with regard to the distribution of the nervous system in all these animals. The brain, which is situated above the œsophagus, but is still in the head, as in the higher classes of animals, is exceedingly small; and after sending out filaments of nerves to the different parts about the head, is connected with a double nervous cord, which encircles the œsophagus, and runs along the under side of the animal, being joined at intervals by nodules or ganglia, from which, as from new centres, other nervous threads radiate, and are variously distributed to the different vital organs, and to the limbs. Each of these nervous ganglia appears to perform the office of a subordinate brain in relation to the system of nerves which proceeds from it, and to the parts of the body supplied by those nerves, so that when the animal is divided into several portions, each portion seems to possess its own independent vitality. The form and structure of the digestive organs is very various; but jaws are always found, and their motion is lateral instead of vertical, as in vertebrated animals.

1. *Annelida.*

(1092.) The first class of articulated animals are the annelida, or worm-shaped animals. They are remarkable for possessing red blood, which circulates in a double system of complicated vessels, without any heart, or muscular ventricles. The body is soft, more or less elongated, and composed of a great number of segments. The foremost of these, which may be regarded as the head, contains the largest of the ganglia, or brain, the mouth, and the principal organs of the senses. The branchiæ are generally external, and sometimes uniformly spread on the surface of the body; and at other times are confined to the anterior divisions. Tufts of hair or bristles supply the place of feet. The mouth is either furnished with hard jaws, or else extended in the form of a tube.

(1093.) The leech, which is referable to this class, has a very capacious stomach, nearly of the size of the whole body, or rather a series of pouches, or dilatations proceeding from each side of the central cavity.[1] Tentacula situated on the head, are their principal organs of touch; and the small black points, observable in some tribes, have been regarded as organs of an imperfect kind of vision. The earth-worm has a remarkably complicated apparatus for circulation, consisting of a great number of dilatations of the dorsal vessel, forming a series of hearts.[2]

2. *Crustacea.*

(1094.) The articulated form is more perfectly developed in the crustacea than in the annelida. Their blood is white, and is circulated by the aid of a muscular ventricle, or heart, situated in the back, propelling it through an arterial system; whence it returns by a system of veins, which collect in a trunk passing along the lower part of the abdomen. In some species the heart assumes a very elongated shape. There are always organs termed *antennæ*, or feelers, situ-

[1] See a description and delineation of this structure in the Bridgewater Treatise *on Animal and Vegetable Physiology*, ii. 103.

[2] Ibid. ii. 255.

ated in front of the head; and these are generally four in number. The jaws are of complicated structure. It is only in a few species that an internal ear is met with, and it then consists of a sac full of fluid, in which a calcareous concretion is contained. The eyes are generally two in number, often placed at the end of pedicles, and consisting of a great number of facets, each provided with a separate cornea, retina, and branch of the optic nerve; and the whole constituting what is termed a composite eye. The branchiæ are of a pyramidal form, composed of plates, or filaments, or feathery tufts, generally situated at the base of the legs.

(1095.) The larger genera of this class, as the lobster, have a horny stomach, with strong teeth implanted in its coats, for the evident purpose of breaking and bruising the shells that are swallowed. All these animals cast off their shells several times in the progress of their growth, a new shell being successively formed of larger dimensions than the preceding, and adapted to the increased size of the animal.

3. *Arachnida.*

(1096.) The third class of articulated animals, or the arachnida, have been separated from that of insects with which they had been before associated; being distinguished by the following peculiarities in their conformation and economy. They have a distinct circulation of the blood by means of an elongated dorsal vessel performing the office of a heart, propelling its blood into a system of arteries, and receiving it back again from a system of veins. They are without antennæ, but are provided with palpi. They have pulmonary cavities subservient to the respiration of atmospheric air. The head is united with the trunk without the intervention of any neck. The mouth is armed with jaws; and there are several simple eyes situated on the upper part of the head.

4. *Insects.*

(1097.) Nothing can exceed the endless variety of forms displayed by this class of the animal creation. Their internal anatomy and economy, however, present many points which are common to the whole class. There is no other trace of a heart, than a long cylindrical tube extending along the back, and termed the *dorsal vessel;* but which seems to be closed on all sides, and neither to give out, nor to receive communicating branches of any sort. This vessel appears to contain a fluid, which is irregularly undulated backwards and forwards, by a kind of pulsation, or occasional contraction of one part of the canal, and dilatation of another. It had been supposed, in the absence of any visible blood-vessels, that nutrition in insects is performed by a kind of gradual transudation, or *imbibition,* as it has been termed. Professor Carus, however, has lately made the discovery of a distinct circulation in the vessels of the larvæ of several insects, and other observers have found a system of partial circulation in even later periods of insect life. But, in general, in the last stage of transformation, all these vessels, excepting the dorsal vessel, become obliterated.[1] There being neither branchiæ nor pulmonary organs where the nutritious fluids could receive the vivifying influence of the air, a complex mode of respiration is resorted to. Apertures are found in different parts, generally along the sides of the body, and which are called *spiracles* or *stigma-*

[1] The dorsal vessel of the sphinx ligustri is delineated in the Bridgewater Treatise *on Animal and Vegetable Physiology*, ii. 245.

ta. These are the commencements of elastic tubes, which remain continually open, and which are subdivided and ramified like the blood-vessels of other animals, for the purpose of conveying air to every part of the system. These tubes are termed *tracheæ.*

(1098.) Insects are unprovided with glands for effecting secretions; that purpose being answered by means of long spongy vessels, which appear capable of absorbing the materials they require from the general cavity in which they float.

(1099.) The temperature of insects, like that of other animals said to be cold-blooded, varies with that of the surrounding medium; but is generally one or two degrees higher. In bee-hives and ant-hills, a much higher temperature prevails. This is proved by an elaborate series of experiments made on the temperature of insects, and its connexion with the functions of respiration and circulation, by Mr. Newport.[1]

(1100.) Their nervous system is formed upon the general model already described, (§ 1091.) The digestive organs admit of the greatest possible variety, according to the habits and particular kinds of food consumed. To specify all these diversities would far exceed the limits assigned to us in this work. The external organs connected with the limbs, the antennæ, the mouth, and the different functions of sense, fall more properly under the consideration of the naturalist, inasmuch as they furnish the best characters for the distinction of genera and species, and for perfecting their systematic classification. The subject is rendered infinitely more complex in consequence of the metamorphoses which the same insect undergoes in passing through the dif-

[1] *Philosophical Transactions* for 1837, p. 25.

ferent stages of its existence, from the *egg* to the *larva*, the *nympha* and the *imago*, or the perfect insect. But for the history of these changes, we must again refer to the naturalist, to whose province it more strictly belongs to record them. We must content ourselves with mentioning in this place a few of the more striking peculiarities of internal conformation which are observable in some of the insect tribes.

(1101.) The first that we shall point out is, the remarkable structure of the digestive organs of the orthoptera, an order of insects which comprehend the blatta, or cockroach, and the mantis or leaf insect, the ear-wig, the locust, the grasshopper, and the cricket. Their stomachs bear some analogy to those of ruminant quadrupeds, in complication at least, if not in office. The first stomach, or crop, is membranous ; to this succeeds a muscular stomach, or gizzard, the internal surface of which is armed either with scales, or with horny teeth. Around the pylorus there extend two or more blind pouches, furnished at their extremities with numerous vessels conveying bile. Many similar biliary ducts are inserted in the course of the intestinal canal. It has been strongly suspected that the insects in which these complex stomachs are found, actually possess the power of ruminating their food.

(1102.) The abdominal cavity of the working bee presents us with two stomachs, together with the intestine and the poison bladder. The anterior stomach in which the œsophagus opens, is the receptacle for the honey, which is occasionally returned into the mouth in order to be stored in the honey-cells, as a magazine of food for the winter. The next stomach is destined to contain the pollen, or material gathered from the antennæ of flowers. Its inner coat has a great number of circular folds. Wax is a secretion of a peculiar kind from the bee.

(1103.) The alimentary canal of the caterpillar, before transformation, consists of a straight and capacious tube, of which the anterior portion is somewhat dilated into what may be considered as the stomach; and of which the posterior portions forms a cloaca; the biliary vessels, which are four in number, and very long, are inserted very far behind. When the caterpillar is transformed into a butterfly, this alimentary canal is much diminished, both in its diameter and length; the first stomach, or crop, is situated on the side of the tube; there is next a second stomach full of irregular dilatations, a slender but long intestine, and a cœcum near the cloaca.[1]

(1104.) The nervous system undergoes corresponding changes during the transformations of insects, the ganglia uniting in several places, so that their number is much diminished.[2] The external senses of insects have for the most part a considerable range of action. Organs of vision are almost constantly present, but those of the other senses are but imperfectly known. The principal organs of touch are the *antennæ*, which probably also perform other offices relating to sensation, of which we have no certain knowledge.

SECT. VII.—COMPARATIVE PHYSIOLOGY OF ZOOPHYTES.

(1105.) The animals which occupy the lowest division

[1] These successive conformations of the digestive organs, in the *sphynx ligustri*, or privet hawkmoth, are delineated in the Bridgewater Treatise on *Animal and Vegetable Physiology*, ii. 217.

[2] Ibid. ii. 547.

in the scale of life, and constitute an approach to vegetable, namely, the class of zoophytes, present us with much simpler forms of organization than any of those which have passed under our review. Yet amongst these we may trace gradations in the mode in which the more refined organs of the animal economy successively disappear, and their functions are supplied by other parts, and also in the gradual simplification of those functions, till we appear to arrive at an approximation to mere vegetative existence. The great characteristic of the more perfect animals, the circulation of the fluids in vessels which distribute them to every part for the purposes of nutrition and secretion, is wanting in zoophytes; or if any traces of a circulation can be discovered, it is exceedingly partial and limited in degree. There is a well marked disposition in all the organs to assume a symmetrical arrangement about a common centre; being either disposed in radii proceeding from that centre, or arranged in a uniform manner round the circumference of a circle. In those instances in which a nervous system can be traced, which is the case only among the higher order of echinodermata, the disposition to assume this radiating form is particularly observable.

(1106.) Many amongst the lowest orders present us with the singular spectacle of compound animals, associated in great numbers for the purposes of a common defence and habitation, and having even nutrition in common. These more particularly constitute an approach to the vegetable kingdom.

1. *Echinodermata.*

(1107.) The zoophytes arranged in this division, which are chiefly the asterias, or star-fish, the echinus, and the holothuria, present us with some appearance of an external skeleton, or hard encasement, consisting of parts which are often articulated together, an imperfect vascular system, and the appearance of a system of nerves.

(1108.) The rays of the asterias are composed of numerous pieces, which have been compared to vertebræ, are slightly moveable upon one another, and allow of a slow flexion of the entire ray. It is hollowed below into a longitudinal groove, abounding in perforations for the passage of numerous rows of short tentacula, which perform the office of feet, for the progressive motion of the animal, and which also absorb water, and convey it into the general internal cavity for the purpose of respiration. The centre of the star is occupied by a large stomach, the entrance to which, or the mouth, is below, and which sends out two prolongations, or cœca, to each ray; these are ultimately ramified into minute vessels, suspended by a membrane which performs the office of a mesentery.

(1109.) The structure of the echinus is still more complicated. The calcareous covering of the body has a globular shape, but is composed of several angular pieces joined together, and perforated by rows of lobes, through which the short feet, or tentacula, protrude. Besides these, there are a multitude of spines articulated to the surface of the shell, and subservient to voluntary motion. The mouth is armed with five teeth, inserted in a complicated apparatus of jaws, resembling a pentagonal lantern, provided with numerous muscles, and suspended over the great opening in the centre of the lower surface of the shell. The intestinal canal is of great length, and forms a spiral tube attached to the interior of the shell by a mesentery. A double vascular system extends the whole length of this canal, and is partly spread over the mesentery.

(1110.) The holothuria resembles in its structure the echinus, but it has a cylindrical instead of a globular form. The respiratory organ is ramified like the branches of a tree, and fills and empties itself at the pleasure of the animal. The mouth has no teeth, and is only protected by a circle of calcareous plates. The intestine is very long, and makes many folds, being also attached to the sides by a mesentery. A partial circulation takes place in a double system of a very complicated arrangement of vessels, which has relation exclusively to the intestinal canal, and of which some of the branches are interlaced with the arborescent respiratory tubes already described.

2. *Entozoa.*

(1112.) Very little is known concerning the physiology of intestinal worms; the information that has been collected being chiefly of a negative kind. They have no visible respiratory organs, and no apparent nervous system or organs of sensation; and still less can we discover any traces of a circulation. The only very distinct organs are those belonging to the functions of nutrition and of reproduction. Some naturalists, indeed, allege that they have detected some filaments of nerves; but the real nature of these filaments is still very doubtful.

(1113.) The alimentary canal may in most intestinal worms be recognised without much difficulty; it is sometimes enclosed in an abdominal cavity, but at other times apparently passes through the solid parenchyma of the body. In some, as in the tænia, or tape-worm, we may discern ramified vessels for the distribution of the nourishment; but these are not seen in others. The simplest animal of this tribe is the globular hydatid, which consists altogether of a vesicular sac filled with a transparent fluid, and with an indistinct mouth; but without any other apparent external organ. This tribe of entozoa exhibit the simplest example of the gemmiparous mode of reproduction; the young appearing as gemmæ, or buds, which at certain periods spout from the homogeneous parenchyma composing the body of the parent, and by a sort of vegetative growth, gradually assume the form of the original animal, and are detached when capable of exercising an independent life.

Some of the entozoa, as the tænia, or tape-worm, are capable of being multiplied like plants, by division; each segment resulting from the division being converted into an independent animal, acquiring whatever parts may have been deficient, and after a time admitting of further subdivision, with a repetition of the same phenomena.

3. *Acalepha.*

(1114.) These are either fixed on rocks, or float in the sea; they exhibit more or less of a fibrous texture, and contain vessels which are excavated out of the substance of the body itself, and are not contained in any distinct cavity.

(1115.) The actinia, or sea anemone, is provided with numerous hollow tentacula surrounding the mouth and stomach. The space between the stomach and the outer skin is divided into compartments by vertical partitions, and the fluid contained in these compartments may be projected into the tentacula so as to render them turgid.

(1116.) The medusa has a hemispherical form, and a gelatinous consistence. The mouth, which is situated in the centre of the flat disc below, is surrounded by fringed tentacula. It leads into a singularly-shaped cavity, which is the stomach, formed of four arches proceeding like radii from the centre, and terminating in tubes which are variously divided, and the branches derived from them freely communicating with one another by anastomoses. These are apparently for distributing the nourishment which has been prepared by the stomach, but not for any real circulation. There are four large cavities in the body which appear to be subservient to respiration.

(1117.) In some species, forming the genus *rhizostoma* of Cuvier, there is no central mouth, but a canal commences by an open orifice from the extremity of each of the fringe-like processes of the tentacula, and these, uniting with others in their course upwards, form at length a single tube or œsophagus, which terminates in the central stomach already described.

Most of the animals of this order, which are found fixed on rocks, are propagated by means of spores or gemmules, constituting one of the modes by which the gemmiparous form of reproduction is effected. These gemmules are minute bodies, formed either on the surface or in some special internal organ of the parent, and which are immediately detached and swim with a spontaneous and independent motion in the circumambient fluid, by means of cilia or short filaments, which are in rapid and incessant vibration. They pursue these motions for a certain time till they find a convenient place for their future habitation, where, when they are once fixed, they generally remain ever after, growing to the dimensions and exercising all the functions of the parent animal. In the acalepha, which are not stationary, the gemmules retain their liberty of moving during the whole period of their existence.

4. *Polypi.*

(1118.) The organization of this numerous order of zoophytes, presents, in every essential particular, great uniformity, and bears a great analogy to that of the actinia. The gelatinous sac or tube, constituting the digestive cavity, is closed at one end, the opening at the other end being the mouth, which is surrounded by a circle of tentacula; and the nutritive fluid passing by imbibition through the coats of the general sac or stomach for the purpose of nourishment. The hydra may be taken as the type of this tribe of animals. It consists of a mere stomach provided with flexible tentacula for catching food and for progression. This sac may be inverted or turned inside out, without detriment to the animal, digestion being then performed by the new cavity, which is the result of the operation. These animals present the simplest examples of gemmiparous generation, (§ 777).

No further discovery can be made respecting the organization of these animals, even by applying the microscope, which shews only a semitransparent substance interspersed with opaque grains. The greater number secrete on their outer surface a calcareous or a horny substance, which serves for their mechanical support, but at the same time fixes them on the spot to which they adhere.

(1119.) The most remarkable feature in their history is their disposition to congregate together in vast numbers, so as to compose by their united architecture whole rocks and even submarine mountains, rising from the bottom of the ocean. Some of these animal republics exhibit amongst the individuals thus associated together communications of nutritious vessels, so that the materials for the sustenance of each passes into the bodies of the neighbouring polypi, and is applied to the purposes of their economy. All these fixed polypi are propagated by spores or gemmules in the manner already described in our account of the stationary acalepha.

5. *Infusoria.*

(1120.) These being all microscopic animalcules of extreme minuteness, it is scarcely possible to arrive at any exact knowledge of their internal organization or economy. Many, and probably all, are possessed of distinct organs for the reception of food, for reproduction, and for voluntary motion; but conjecture alone can fill up the imperfect outline, or suggest any plausible hypothesis as to their powers of sensation, which, however, we are unwilling to refuse to any being which appears to possess the properties and attributes of animality, especially since the splendid discoveries of Ehrenberg have made us acquainted with the complex organization observable in some of the minutest of this prodigiously diversified tribe of beings. It is remarkable, indeed, that those very animalcules, as the monads, which had been ranked by naturalists among the *agastrica*, or beings totally without alimentary cavities, are now found to have a very considerable number of stomachs, and to be entitled accordingly to the title of *polygastrica*.

It is chiefly amongst the various tribes of infusoria that the simpler modes of generation, such as that termed *fissiparous*, are exemplified. In the monas, for instance, a groove is seen to form around the equator of their globular bodies, which groove, gradually deepening, changes their form to that of an hour-glass, and the connecting ligament of the two portions being soon broken, the segments move away from one another, each commencing its independent existence, and being capable of performing all the functions of the undivided monad. In the bell-shaped vorticella, the division commences at the mouth or wide extremity of the bell, and gradually extends in a longitudinal direction towards the insertion of the stem, dividing the body into two equal portions, each being now a distinct and individual animal. The gonium divides itself into four instead of two portions, each portion being again subdivided into four others, the new animalcules assuming rapidly the dimensions and appearance of the one of which they originally formed a part. Other species are propagated by means of gemmules; and some of the infusoria are apparently oviparous.

CHAPTER XXIII.

HISTORY OF PHYSIOLOGY.

(1121.) The study of the history of any science furnishes to the mind a body of knowledge not merely ornamental or superfluous, but one that is fraught with instruction and utility, and is conducive to the just comprehension of the subject to which it relates. It is scarcely ever necessary, indeed, for the understanding of any proposition, that the student should follow the same laborious course and travel through the same tortuous mazes by which the discovery had originally been achieved; for the acquisition of any body of knowledge already systematized by the labours of our predecessors, is in general most readily attained by the synthetic method. But as soon as this point has been reached we can conceive no course of study more calculated to improve that knowledge, and to invigorate the faculties by which it may be extended and perfected, than reverting to the analytic process, and following the series of discoveries in the order in which they have actually occurred. From an historical survey of the successive steps by which science has proceeded from a rude origin to its present state of advancement, and which mark its varied progress and even occasional retrogressions at different periods, according to the prevailing disposition of the age, either to a servile submission to authority or to the hasty adoption of crude and visionary theories, we are enabled to derive most important rules for the conduct of the understanding in the search after truth.

The history of each particular branch of science may, indeed, be regarded as a separate chapter in the history of the human mind. It indicates the sources of its activity, and of its strength, and also of its weakness and fallibility; it holds out the most powerful incentives to exertion; it exhibits much to admire and to emulate, and, at the same time, discloses enough to check pride and teach humility.

(1122.) The history of physiology must necessarily comprise a large portion of the history of anatomy, which consists in the mere knowledge of the organs and minute structure of the body, such knowledge being, in fact, the foundation on which the higher science of the philosophy of life is built. It is scarcely possible, indeed, to study mere organization, without extending our views to the functions that we see performed, and to the energies that are exerted by the living organs. Our object will therefore be in the present place, to inquire how far these higher qualities of mind have been displayed by the cultivators of this department of knowledge at different periods, so as to mark the progress of the philosophy of life, as contradistinguished from the more mechanical, though equally useful labours of the mere anatomist.

(1123.) The phenomena which constitute the subjects of physiological inquiry must, indeed, have attracted the attention of mankind long before any accurate knowledge had been acquired of the structure of the organs whose actions give rise to these phenomena. Life in its different forms must have been familiar to all; and every savage and warlike people must have been conversant with the diversified aspects of death, which they inflicted in such various modes. Speculations on the nature of the vital principle, and the physiological conditions on which it is dependent for its origin, maintenance, and decay, must have been formed and pursued in every state of society, removed but one degree from barbarism; and such speculations must have stimulated inquiry into the internal mechanism with which that principle is associated, and the hidden springs which regulate its course.

(1124.) Opportunities must frequently have occurred in the rudest ages, of observing the different parts of the structure of the bodies both of men and animals. The curiosity even of the savage could not fail to be attracted by the remarkable appearance of the internal organs, in the animals which he slaughtered for food, or prepared for sacrifice. Although deterred from the actual examination of the human body, by an instinctive repugnance, or superstitious terror, various casualties occurring in battle, or arising from accidents, would occasionally afford an insight into the human frame. Human bones, and sometimes entire skeletons, would often present themselves to those who revisited the fields of carnage. Thus would the principal bones, and the most conspicuous viscera of the human body, soon become known, and they would be designated by particular names. Evidence to this effect may be collected from the rudest and most ancient languages; from which we may infer that a certain progress must have been made in this kind of knowledge, long before it had been so arranged and methodized as to deserve the name of a science.

(1125.) The prevailing custom amongst most of the ancient nations, of consigning all dead bodies to destruction by fire, was one of the greatest obstacles to the advancement of anatomical and physiological knowledge. But opportunities were on the other hand afforded of learning the structure of certain animals, by the religious rites, during the celebration of which these animals were sacrificed, and especially by the examinations which were made by the priests of the yet palpitating entrails of their victims, for the purpose of prognosticating future events. Inferences were thus drawn by analogy as to the organization and functions of the human body. The Egyptians, indeed, who composed the most ancient nation of whose manners and customs we possess any authentic records, were supposed to have acquired considerable knowledge of the human structure from the practice of embalming the dead. This operation was performed by a particular class of men, and consisted in taking out a portion of the viscera, washing them with antiseptic fluids, and filling the cavities with aromatic substances. But as this process appears to have been conducted in the rudest manner, it required no skill in anatomy, and was but little calculated to improve the science. It was in the hands of a few persons only; and such was the contempt and abhorrence in which these persons were held by their countrymen, that whatever knowledge they might have acquired by the practice of their art, was not likely to be communicated to others.

(1126.) Whatever splendour may have attended the pride of power or extent of empire in these rude and unenlightened ages, the dawn of science was coeval only with that of liberty. The same energies by which man had thrown off the yoke of tyranny, animated them likewise with the desire of knowledge; and nations had no sooner emancipated themselves from despotism, than they began to emerge from barbarism and ignorance. The Greeks, who were the most free, were also the most polished of all the nations of antiquity, and far excelled them in every species of science and of art. So great was the ardour of their philosophers in the pursuit of knowledge, that they frequently travelled into distant countries to collect useful information, and impart it to their pupils. Even in the time of Homer, the Greeks seem to have possessed much general knowledge both of anatomy and physiology, as may be collected from the writings of that poet. He relates that the stone which was hurled at Æneas by Diomed, not only crushed the thigh-bone, but also tore the ligament of the acetabulum. Merion is represented as being wounded in one of the large veins which return the blood to the heart, or venæ cavæ; and Ulysses aimed a blow at the Cyclops at the part where the liver adheres to the diaphragm. It has even been supposed that Homer has purposely often wounded his heroes that he might have opportunities of displaying by the minuteness of his descriptions, his accurate acquaintance with anatomy.

(1127.) But though curiosity was roused, and a multitude of detached facts had been observed and collected, it was long before the proper methods of investigation were known, and the true principles of inquiry established. Although it appears that the studies of anatomy and physiology were prosecuted with considerable ardour in the school of Pythagoras, yet as they were regarded merely as a part of natural history, the information relating to these subjects was not sufficiently connected or concentrated to be embodied in one science. Alcmeon and Empedocles, who cultivated anatomy, belonged to this school; but the most remarkable of the pupils of Pythagoras, belonging to the Eleatic sect, was Democritus of Abdera, a man whose eccentric manners, as well as penetrating genius, and undisguised contempt for the follies of mankind, have procured him so much celebrity. He is said to have devoted considerable time to the dissection of animals, especially with a view to discover the origin and course of the bile. His fondness for seclusion, and his perseverance in a pursuit which appeared to his countrymen to be without any rational object, led them to suspect the soundness of his intellects; and Hippocrates was sent to visit him in his solitary abode. He found the philosopher seated on a stone, under the ample shade of a plane tree, with a number of books arranged on each side, one on his knee, a pencil in his hand, and several animals which he had been dissecting lying before him. His complexion was pale, his countenance thoughtful; at times he laughed, at times shook his head, mused for a while, and then wrote, then rose up and walked, inspected the animals, sat down, and wrote again. Hippocrates, who perceived the nature of his inquiries, observed him for some time in silent admiration, proclaimed to the bystanders the importance of his researches, and declared to them his regret that want of leisure from his own professional employments did not allow him to engage in similar pursuits.

(1128.) But it was only from men whose minds are capable of enlarged views, and can perceive the bearings and connexions of the several parts of the subjects they embrace, that a powerful impulse is given to science, such as to make it almost the creation of their hands, that it is raised to its proper rank among the departments of human knowledge. Such was the vigorous mind of Hippocrates; and so great was the improvement which medicine derived from his genius, that the foundation was thus laid for the more rapid progress of all the sciences connected with it in succeeding times. Hippocrates was born in the island of Cos, in the first year of the 80th olympiad, or 460 years before Christ; an æra which is therefore remarkable in the history of medical science. It appears that at that period a knowledge of medicine had been in a great measure hereditary in certain families, amongst whom the information which had descended from the successive generations was thus retained and augmented. This was the case in the family of Hippocrates, who is said to have been the fourteenth descendant from Esculapius, on his father's side; while his maternal ancestry could be traced to Hercules. He had been instructed in all the learning of those times; but particularly dedicated himself to the cultivation of medicine, which he formed into a distinct science, collecting and arranging all the information on the subject that was then known. Not satisfied with the knowledge which he could acquire in his native place, he travelled for several years through different parts of Greece and Asia Minor. He visited the temple of Diana at Ephesus, and was at the pains of transcribing and arranging the records of cases and of successful methods of cure, which it was the custom to deposit on tablets in these temples. On retiring to his native island, after the laborious proofs he had given of his diligence and ardour, he continued to exercise his profession, and enjoyed the highest and most extensive reputation. Such was the estimation in which his talents were held, that even princes were solicitous to allure him to their courts; but he was so strongly attached to his native country, that he resisted every temptation which the splendour or the favour of monarchs could hold out.

(1129.) Excepting one or two particular treatises, which bear his name, but the authenticity of which is dubious, the writings of Hippocrates are to be regarded rather as medical than physiological; but he seems to have been the first who formed a clear conception of the value of anatomy and physiology as the basis of medical reasoning. Originality of thought, combined with accuracy of observation, forms the characteristic feature of his writings; which contain, however, many traces of the Pythagorean philosophy, with which he seems to have been early imbued. He formed the bold conception of the existence of a principle, which he calls φυσις, or nature, exercising a general direction and superintendence over all the actions and movements of the body, and endowed for that purpose with a species of intelligence directed to beneficial ends. As subservient to this great and prime agent, he imagined that the functions were carried on by means of other subordinate powers or faculties; and also that they were subjected to the influence of the stars. He regarded the body as being composed of three kinds of substances, namely, solids, fluids, and spirits, and ultimately resolvable into the four primary elements of earth, water, air, and fire, the predominance of each of which in particular individuals gave rise to the prevailing temperaments, characterised by the peculiar combinations of the four qualities of dry, moist, cold, and hot. Hence arose his doctrine of temperaments, already noticed, (§ 862). The anatomical details which are interspersed throughout his works are numerous, but do not exhibit any profound knowledge of the subject, besides being in many instances incorrect. The confession which he made on his visit to Democritus shews that he had not devoted any considerable portion of his time either to physiology or to practical anatomy. It is very apparent, indeed, that he never dissected a human body; and much could not be learned from the occasional dissection of brutes. So far was he from having any idea of the real nature of the circulation of the blood, which some have done him the honour to suppose he had discovered, that he seems to have imagined that the arteries contained air, and he was at a loss to determine whether the veins took their origin in the liver, the heart, or the brain. He includes under the same name the ligaments, the tendons, and the nerves, and makes no distinction between their respective offices in the economy. But these imperfections were more to be imputed to the unavoidable disadvantages of the times, than to his own deficiency either of industry or of talent, for wherever he had opportunities of displaying these qualities, and of exerting the whole force of his original mind, he far surpassed all his cotemporaries. Hippocrates must indeed be regarded as the father of physiology, as well as of medicine; and his name will ever be cherished by posterity, as one of the most illustrious in the annals of science.

(1130.) Amongst the Athenian philosophers who paid attention to physiology, Socrates must not be passed over in silence; since he cultivated the science with a view to establish upon it, as upon the most solid foundation, the principles of natural theology. Plato, the friend and pupil of Socrates, likewise devoted a portion of his time to the study of animal structures, and indulged in a variety of fanciful speculations concerning the uses and functions of the vital organs.

(1131.) Aristotle, the tutor of Alexander the Great, whose transcendant genius embraced the whole domain of human science, prosecuted this, as well as every other branch of the history of nature, with an ardour and perseverance that have rarely been equalled, and never surpassed. Gifted with a mind of extraordinary acuteness and comprehension, he appears to have concentrated within it all the learning of his age, which, moulded and transformed by the power of his genius, assumed new forms of arrangement, yielded new products of generalization, and spread its luminous irradiation over every department of human knowledge. At the request of his pupil he undertook an extensive treatise on the natural history of animals; he was liberally furnished with specimens of all kinds, and empowered to command the services of numerous assistants, from every part of the vast empire of Alexander. He spared no labour in the prosecution of this undertaking, and in making the most profitable use of the resources thus placed at his disposal; and contributed in no small degree to the advancement of our knowledge of the animal economy in the diversified forms of life presented by nature. Yet with all the advantages he possessed, it would appear that his knowledge of human anatomy was exceedingly imperfect. He even acknowledges that the internal parts of the human body are but little known; and points out the probable advantages that might result from the examination of animals which have the nearest resemblance to the human species, for supplying these deficiences. But his work on the history of animals, *περὶ ζωων ἱστοριας*, is unrivalled by the magnitude of the field which it embraces, and by the vast information it contains. To him belongs the merit of arranging the facts in the order, not of their zoological, but their physiological relations; referring every organ to the functions it performs in the animal economy, and thus anticipating the very principle on which, in recent times, Hunter, Blumenbach and Cuvier have founded their more rational and philosophical views of comparative physiology.

(1132.) The encouragement given by the Ptolemies, the successors of Alexander in Egypt, to every kind of learning, tended greatly to the advancement of anatomy and physiology. Permission was granted by these monarchs to dissect the human body, which none would otherwise have dared to attempt, in opposition to the prejudices of the Egyptians, which were no less violent against dissection than those of the Greeks.

(1133.) One of the earliest of the physiologists of this period was Erasistratus, the grandson of Aristotle, and the pupil of Chrysippus. Under the patronage of Nicanor, king of Sicily, he enjoyed frequent permission to dissect the bodies of those who were executed, and is even reported by *Celsus* to have had criminals delivered to him for the purpose of their being opened while alive, in order that the natural living state of the internal organs might be examined. This account, however, deserves to be regarded rather as a popular tale, which has no other foundation than irrational prejudices against dissection, and was propagated by idle credulity, and a passion for exaggerated scenes of horror. The works of Erasistratus are now lost; but from the quotations of later authors, he appears to have greatly advanced the knowledge of the structure of the human body, more especially by pointing out the circumstances in which it differs from that of other animals, whose anatomy had been previously studied as making the nearest approach to the organization of man.

(1134.) Another no less distinguished anatomist of the same period was Herophilus of Chalcedon, who also flourished at Alexandria. He was the disciple of Praxagoras, and was considered as the founder of the medical school at Alexandria. He was much occupied in the dissection of human bodies, and directed his attention particularly to the nervous system. One of the sinuses of the brain, which he is said to have more particularly described, bears to this day the name of the *torcular of Herophilus.* He is stated to have been the first anatomist who taught osteology from the human skeleton. He distinguished the nerves from tendons and ligaments, with which they had, before his time, been confounded. He also paid minute attention to the varieties of the pulse, and thus laid a foundation for a knowledge of the important function of the circulation.

(1135.) Few physiologists of any note are recorded as having flourished from the time of Herophilus to that of Galen. The names of Lycus of Macedonia; of Marinus, who lived in the reign of Nero, have been transmitted to us as the author of some elaborate treatises on the muscles; and also of Rufus Ephesius, who wrote a work entitled *Onomasia,* which was considered as the best system of anatomical knowledge extant at that period.

(1136.) Galen, the most celebrated and indeed the last of the physiologists of Greece, was born at Pergamos, in Asia Minor, about 131 years before the Christian era. His father was imbued with the love of letters, and was anxious that his son should receive the benefit of a learned education, which the early promise he gave of superior talents shewed that he was well qualified to turn to advantage. He was placed under the tuition of the best philosophers of the time, and studied in all the schools with extraordinary diligence. His father died long before he could form any probable anticipation of the future fame of his son. It was two years after this event, that young Galen, who was now in his nineteenth year, first turned his attention to medical pursuits, of which he soon became passionately fond. As

Alexandria was still the most celebrated school of medicine in the world, he travelled thither with a view of prosecuting his studies; in order to reap every advantage which foreign countries could afford, he visited in succession different parts of Asia Minor and the islands in the Ægean Sea. Anatomy was ever his favourite pursuit; but being debarred from the advantage of examining human bodies, the dissection of which had then been prohibited, even at Alexandria, he had recourse to that of such animals as were supposed to have the greatest resemblance in their structure to man. He has written very fully on every part of anatomy; so that his works may be considered as a system, exhibiting every thing which was known on the subject in his time. He was much impressed with the importance of anatomy as the basis of medicine and surgery, and enforces his opinion with singular acuteness and energy. This is evinced by the following passage in his second book of Academical Administrations:

"What can be more useful in wounds which are received in battle, in the extraction of darts, excision of bones, the reduction of luxations, the opening of fistulæ, than to be well acquainted with the anatomy of the limbs? It is of more use to be acquainted with the exterior than the interior parts of the body, as the shoulders, back, breast, the ribs, the belly, and the outward covering of the neck and head; for we are often required to cut into abscesses and sinuses. In the excision of bones it is necessary to cut and dissect; and if we do not know where the artery, vein, or nerve may be, we are more likely to be the cause of death than of health to the patient."

(1137.) Galen is entitled to great praise for having applied himself to the investigation of physiology in connexion with anatomy; so little had hitherto been known on this subject, that we cannot be surprised at the mixture of error which his works exhibit; but although he may often have proceeded on false principles and fallacious hypotheses, yet the reasonings themselves which he employs are always clear and conclusive. His account of the uses of the hand, for example, is remarkably perspicuous and correct. He succeeded in establishing by experiment the fact that arteries contain blood, and thus refuted the doctrines of the Alexandrian school that they are merely filled with air, which they serve to distribute throughout the body. It is interesting also to trace the effect which these subjects of contemplation produced on Galen's mind. After reviewing the structure of the hand and foot, and their adaptation to their respective functions, he breaks out into the following apostrophe, admirably characteristic of a mind imbued with the genuine spirt of piety:

"I esteem myself as composing a solemn hymn to the author of our bodily frame, and in this I think there is more true piety than in sacrificing to him hecatombs of oxen, or burnt-offerings of the most costly perfumes; for I first endeavour to know him myself, and afterwards to shew him to others, to inform them how great is his wisdom, his virtue, his goodness."

(1138.) The great reputation which Galen had acquired, instead of promoting, tended rather to impede the progress of anatomy and physiology during several succeeding centuries. Where no hope was entertained of emulating the fame of one who was regarded as an infallible oracle, all motive to exertion was repressed. But other causes of a political nature also contributed to the decline of anatomy, as well as of other branches of learning, from the time of Galen to the downfall of the Roman empire, and during the ages of intellectual darkness which followed. Learning, however, still continued to be cultivated at Alexandria, until the capture of that city by the Saracens, in the year 640, when its magnificent library was burnt.

(1139.) Anatomy and physiology began slowly to revive among the Arabians ; but no addition seems to have been made by them to the knowledge which the Greeks had possessed on these subjects. The Arabian physicians were satisfied with what Galen had taught them ; and as the rites of the Mahometan religion prohibited all contact with a dead body, an effectual bar was opposed to all improvement in anatomical or physiological knowledge. The work of Avicenna on anatomy is merely a compilation from Galen and other Greek authors ; and whenever he ventures to differ from his authorities he is generally wrong. For more than a thousand years after the time of Galen, anatomical and physiological science may be considered as nearly stationary ; for scarcely any discovery of the least importance was made during the whole of that period.

(1140.) The expeditions of the crusaders were the means of introducing into Europe some knowledge of the literature of the Arabians ; and the light of science, after a long period of darkness and ignorance, began at length to dawn. In the fourteenth century, anatomy was revived by Mundinus, a Milanese, who had become acquainted with the writings of Galen through an Arabian translation, and who published a system of anatomy in 1315.

(1141.) The destruction of the Greek empire by the Turks, in the succeeding century, tended to diffuse throughout the west of Europe, whatever portion had remained of the literature of the east. The learned of every profession fled from Constantinople, which had fallen into the hands of barbarians, and sought an asylum in Italy, where they disseminated the seeds of knowledge. The writings of Galen and of the ancients, could now be read in the original; their superiority to the Arabian authors was soon discovered; and such implicit deference was paid to their opinions, that for many ages no one would venture upon the slightest innovation. The improvement of anatomy was therefore exceedingly slow. It was promoted, however, by the exertions of eminent painters, such as Raphael, Albert Durer, Titian, and above all, Leonardo da Vinci, whose drawings evince considerable knowledge in that study.

(1142.) The sixteenth century was more auspicious to the progress of anatomy, which was beginning to be cultivated with ardour in Germany and France, as well as in Italy. Berengarius of Carpi, professor at Bononia, acquired such reputation by his skill in dissection, that he was regarded as the restorer of this science. The structure of the ligaments and bones was successfully studied by Charles Stephens; that of the blood-vessels by Fernelius; and that of the muscles by Andernach. Sylvius was also at this time celebrated as a teacher of anatomy.

(1143.) But the extravagant veneration of antiquity, that spell which has for so many ages held the medical world in thraldom, was at length broken by Vesalius, who boldly ventured to call in question the authority of Galen. This extraordinary man was born at Brussels in 1514, of a family which had for a long time cultivated medicine. He united to remarkable talents, a degree of ardour and perseverance which enabled him to overcome every difficulty; and his progress in the study of anatomy, for which he had very early shewn a partiality, was commensurate with these great qualities. He commenced his studies at Louvain, and prosecuted them in Italy. In a short time he made himself master of the Hebrew, Greek, and Arabic languages; so that before he had attained his twentieth year, he had already read the works of Galen and Avicenna in the original. Such was his zeal for anatomy, that it is reported he used to rob the gibbets, and dissect the bodies in his bedchamber. In a few years he excelled his teachers, Fernelius and Sylvius, who were esteemed the first anatomists of their time. He soon detected many errors in Galen, some of whose descriptions of parts had been taken from quadrupeds, and applied to man. These errors he ventured to disclose and to correct in his publications; but his boldness in appealing to nature from the authority of Galen, drew upon him the enmity of all the admirers of that great master. He was assailed from all quarters with the bitterest invectives; and Sylvius himself has not scrupled, in the heat of controversy, to brand him with the epithet of *Vesanus*, or madman, in allusion to his real name. The criticism which Vesalius had passed on Galen, was retorted by his enemies upon himself; and it must be confessed that in the plates which Vesalius published, some errors of the same kind were detected. But still their general accuracy was undeniable. The work of Vesalius was soon acknowledged to be unrivalled, and its author eventually enjoyed a complete triumph over all his opponents.

His fame reached the ears of Charles V., who appointed him his physician; but after being raised to that distinguished station, he was soon doomed to experience the inconstancy of fortune. Having obtained permission to examine the body of a Spanish gentleman, whom he had attended in his last illness, he began to lay open the chest, when the bystanders imagined they perceived a tremulous motion of the heart. This circumstance soon got wind, and probably with much exaggeration, reached the ears of the relations of the deceased, who, seized with horror, denounced Vesalius as a murderer; and coupling this charge with that of impiety, arraigned him at the tribunal of the Inquisition. Where superiority of knowledge was esteemed a crime, Vesalius, however unjustly he might be accused, was certain of condemnation. By the influence, however, of Philip II., who had then succeeded to his father Charles V., Vesalius was permitted to commute his punishment to a pilgrimage to the Holy Land, the merit of which, it was thought, might sufficiently atone for the heinousness of any crime. This journey he was accordingly obliged to perform; and on his return he was invited by the senate of Venice to teach anatomy, but he perished by shipwreck before he reached that city, when he was about fifty years of age.

(1144.) The impulse which had been given by Vesalius to the progress of anatomy, continued to operate; and many were the inquirers who pressed forward in the path in which he had so nobly led the way. The barriers to investigation had been removed; nature was open to inquiry; and men had only to observe and to think for themselves. Every year was now adding some new discovery; and it becomes no longer easy to trace the order of their succession, or to ascribe each to their proper authors. We shall endeavour, however, briefly to enumerate those which are most worthy of being noted.

(1145.) In the year 1561, Fallopius published, in Italy, his *Observationes Anatomicæ*, a work of much merit, and the fruit of great industry. About the same period also, Eustachius arrived at great eminence as an anatomist, and published a set of plates, which he himself engraved; their beauty and accuracy excite astonishment even in the present day.

(1146.) *Fabricius ab Aquapendente*, a professor of anatomy at Padua, was also one of the most distinguished anatomists and physiologists of that period. He published a splendid volume on the formation of the fœtus, and bestowed much pains in investigating the mechanism of the motions of animals. He was the first who delineated and drew the attention of the public to the valves of the veins, which had, indeed, been imperfectly seen by Stephens, Sylvius, and Vesalius, and the existence of which had been denied by Fallopius and Eustachius. It was this discovery, perhaps, more than any other, which paved the way for that of the real course of the blood in its circulation; a discovery which was reserved for the illustrious *Harvey;* and which has justly rendered his name immortal. As it may be interesting to review the steps which led to this important physiological discovery, we shall retrace its history to a period somewhat more remote.

(1147.) It is perfectly well ascertained, from an examination of the works of Galen, and of others who have copied from him, that the ancients had not the most distant notion of the real nature of the circulation. The blood was believed by them to have its origin in the liver, and to be undulated alternately in opposite directions in the veins; they imagined that the finer part of it transuded through the septum, or partition separating the cavities of the heart, from the right to the left side, where it mingled with the air received into the lungs, and forming a vital spirit, was moved by a sort of flux and reflux along the arteries.

(1148.) On the revival of anatomy in Europe some vague notions of the pulmonary circulation appear to have suggested themselves to many eminent men. Vesalius demonstrated that the blood could not possibly pass from the right to the left ventricle through the septum of the heart. Realdus Columbus, who was professor of anatomy at Padua, and had been a pupil of Vesalius, distinctly traced the passage of the blood through the vessels of the lungs. The same fact had, however, been already discovered by Michael Servetus, who was born in Aragon in 1509, and who is more celebrated as a theologian than as a physiologist. Further progress was made by Andrew Cœsalpinus, an Italian physician, who speaks of a communication existing between the veins and arteries at their remote extremities, and notices the effect of the valves of the arteries and of the auricles as calculated to prevent a reflux of the blood; but he is quite at a loss to reconcile this observation with the common notions, which he had imbibed, and to which he still adhered, of the functions of these vessels. But notwithstanding these apparent approximations to the truth, it is probable that many ages would have elapsed before the complete discovery of the circulation, if some bold and penetrating genius, such as that of Harvey, had not arisen.

(1149.) This illustrious man was born in the year 1578; and the circumstances of his family gave him the advantage of a liberal education. After six years spent at Cambridge, where he was instructed in all the philosophy of the times; finding that the university furnished but very imperfect means of studying either anatomy or medicine, he repaired, at the age of twenty-one, to Padua. Here he became the pupil of Fabricius, who was at the time demonstrating to his students, with all the enthusiasm of a discoverer, the newly observed valvular structure of the veins. The attention of Harvey being thus directed to this remarkable conformation, he became anxious, on his return to England, to prosecute the inquiry into the purposes which were accomplished by it. He was obliged, for this purpose, to make many experiments on living animals; and these revealed to him the real course of the blood in its circulation; a discovery which ranks unquestionably as the noblest and most important ever made in Physiology. Harvey taught this new doctrine in his lectures about the year 1616; but did not publish any account of it till the year 1628. On its being made known to the world, it met with the most violent opposition; and so inveterate were the prejudices of the public, that the practice of Harvey was considerably diminished in consequence of his discovery. It was remarked that no physician who had passed the age of forty would admit the truth of a doctrine so much at variance with all the systems in which he had been educated. Envious of his growing reputation, many of his cotemporaries had recourse to all kinds of sophistry with the view of detracting from his merit. They at first vehemently contested the truth of the doctrine; but afterwards, when forced to admit it by the decisive evidence adduced in its support, they changed their ground of attack, and alleged that the merit of the discovery did not belong to Harvey, the circulation having been known even to the ancients. But vain were all the efforts of envy and detraction to lessen that fame, which will command the admiration of all future ages. The physiological researches of Harvey were not confined to the function of circulation; but extended also to that of generation, and to the evolution of the ovum, on which he made a series of very valuable observations.

(1150.) The beginning of the seventeenth century was an important era in anatomy, for it was also marked by another brilliant discovery, namely, that of the lacteals by Asselli in 1622. It appears, from the testimony of Galen, that Erasistratus had noticed white vessels on the mesentery of kids ; but the observation was not followed up, and these vessels were supposed to have been merely veins. Asselli was born at Cremona, and was professor of medicine at Pavia. He observed on the mesentery of a dog numerous vessels, filled with a white fluid ; he was immediately convinced that he had made an important discovery, and uttered in the fullness of his feelings, the exclamation "Ευρηκα." Perceiving similar vessels upon the surface of the liver, and entertaining some theoretical views concerning the functions of that organ, he too hastily concluded that the lacteals terminated in the liver. Asselli published an account of his discovery with coloured prints in 1627.

(1151.) It was not till about thirty years after this discovery of Asselli, that the lacteals were traced by *Pecquet*, a French anatomist, into the receptaculum chyli, and thence into the thoracic duct, which he also followed to its termination in the great veins near the heart. These observations were published in the year 1651. All these discoveries were made in brutes ; and it remained to be shewn, that similar structures existed in man. This was accomplished by Veslingius, who had already demonstrated the human lacteal vessels, in the year 1634; and the human thoracic duct in 1649. These parts were afterwards more fully investigated by Peirish and Vanhorne. Shortly afterwards, the general absorbents of the body were discovered by Olaus Rudbeck, a Swede, who was born at Avosa, in the year 1630. This discovery was also claimed by Thomas Bartholin, who was born at Copenhagen in the year 1616; but by his own account he had not seen these lymphatic vessels till December 1651, whilst Rudbeck had not only observed them, but had distinguished their peculiarities the year before; Rudbeck had also traced them to the thoracic duct, which Bartholin had failed to do. Dr. Joliffe, an English physician, has also contended for the honour of this discovery; but from a comparison of dates, the priority is clearly in favour of the Swedish anatomist. When we consider the minuteness of these vessels and the transparency of their coats, we are able to appreciate the difficulty of detecting their existence, and our surprise must cease at their having remained unknown for so many ages.

(1152.) No discovery of equal importance to those we have mentioned has been made in anatomy since that period. Many parts of the body, which were unknown in Harvey's time, have indeed been brought to light; but the principal improvement has consisted in a more accurate knowledge of the composition and minute structure of the several organs. For this we are chiefly indebted to the invention of new anatomical processes both of investigation and of demonstration. Two principal means were employed in these researches; the one was the microscope, the other the practice of injections.

(1153.) The microscope was first applied to the purposes of anatomical inquiry about the year 1661, by Malpighi, who was born near Bologna, in the year 1638. He examined, by the aid of this instrument, the minute organization of all the vital parts; and more particularly the glands. These researches into the intimate texture of the various parts of animals were prosecuted with great ardour by Leeuwenhoek, a Dutch anatomist, about the year 1680. In exploring this new field of inquiry, which opened views so remote from common apprehension, his enthusiasm has often carried him beyond what was real, both in the power of the instrument, and in the results it afforded. But still much has been effected, and the boundaries of the science have been greatly enlarged by the skilful employment of the microscope.

(1154.) The arts of preserving the parts of animals when dissected, by drying and varnishing them, and by other modes of preparation, had long been practised ; and in these Vanhorne is said to have attained superior excellence. But the most valuable invention of this kind was that of injecting into the vessels certain fluids which would, after a time, become solid, and admit of the course of these vessels being easily traced. The injecting syringe used for this purpose was invented by De Graaf, a Dutch anatomist, about the middle of the seventeenth century; and soon after, the proper materials for injection were discovered by Swammerdam. The art of injection was carried to a very high degree of perfection by Ruysch ; but with a degree of selfish illiberality which cannot be too strongly condemned, he kept secret the methods he employed.

(1155.) The advancement of Physiology was greatly promoted both by the practice of this art, and by the dexterous employment of the microscope ; and discoveries in this science have succeeded one another so rapidly from the period of their invention, that in giving an account of them, it is scarcely possible to preserve an unbroken narration ; and it would be impossible, in this sketch, to recount the numerous minor improvements which have been made in our knowledge of this department of science from the epoch down to which we have now brought its history. Much error was still mingled with the acquisition of real knowledge on these subjects; and it has required the exertion of the more severe and scrutinizing spirit of inquiry which characterizes the philosophers of a later period, to winnow the grain from the chaff, and refine the pure metal from the superfluous ore which had been dug up along with it from the mine. Physiologists were slow in recognising the peculiarities which appertain to the vital powers, and those of the beginning of the eighteenth century long persisted in ascribing the phenomena of life to the operation of the same laws which regulate those of inanimate nature. Hence the history of physiology is occupied at that period, chiefly by the contentions which arose between the rival sects of chemists and mathematicians; each striving to apply to physiology the principles and methods of investigation which prevailed in their respective sciences. Much ingenuity was wasted in these unprofitable researches; for although some important fact was occasionally brought to light by the prosecution of elaborate inquiries, prompted by endeavours to support each favourite speculation, yet not one of these hypotheses could long maintain its ground, nor could it be said that a single general principle had been established.

(1156.) A new light was now thrown on the subject of physiology, which tended to dissipate the clouds of error in which it had been obscured by the dogmatical tenets of both the chemical and the mechanical sects; and to effect a complete renovation in the science. The new doctrine which thus superseded the former, originated in Stahl; who, although educated in the school of the chemists, soon shook off the trammels of his instructors, and with the vigour of native genius began to reflect for himself. He perceived the futility of their doctrines, and strongly impressed with the wide differences observable between the phenomena presented by organized beings, and those which the same bodies exhibit when devoid of vitality, conceived that they were governed by some agency opposed to the ordinary physical powers of matter ; and to this agent he gave the name of *anima*, (see §. 101), ascribing to it endowments allied to intelligence, which controlled all the changes in the system, and of which the operations were always directed to salutary ends. This hypothesis, gratuitous and unphilosophical as it was, had the beneficial effect of directing the attention of physiologists to the phenomena which peculiarly characterise the living state, and prepared them for the study of the laws of these vital phenomena. Much praise is also due to Hoffmann, who, although too hasty in his conclusions to inspire confidence in their correctness, appears to have been amongst the earliest of the followers of Stahl, who entertained proper views of the principles and objects of physiology. Boerhaave was celebrated at this time for the extent of his information, the soundness of his judgment, and his talent in the art of instruction. His doctrines had extensive influence in the schools of medicine ; but being destitute of the solid support of facts, they did not long survive their propounder.

(1157.) But the great founder of modern physiology is unquestionably Haller, whose labours in this field of inquiry are so prodigious in extent, and so fruitful in results, that the publication of his Elements, to which it may be perceived we have had occasion in the course of this treatise perpetually to refer, must be considered as forming an important era in the history of the science.

(1158.) The attention of physiologists was beginning to be more particularly directed to the functions of the nervous system ; and the labours of Whytt at this period had tended much to give it this impulse. Amongst the host of names which claim our notice as having contributed their share in the rapid progress of discovery, since this time, we can point out only a few of the most illustrious. William Hunter, the Monros, and Cullen, are amongst those most eminent for the services which they have rendered to physiology ; but perhaps the largest contributor to the mass of facts collected in modern times was John Hunter. The merits of Bichat were also of the first order ; and considering how early his career was cut short by the hand of death, the additions which he has made to the stock of facts, and the influence which his opinions have had on the progress of the science, must excite astonishment. Germany and Italy, as well as France, have been prolific in ardent devotees and successful cultivators of physiology ; and although it might be invidious to point out particular names, we should be sorry to omit those of Spallanzani, Blumenbach, Soemmerring, Meckel, Gmelin, and Müller; nor should the justly earned fame of Cuvier be passed over in silence, even in this brief and imperfect retrospect of the benefactors of our race, for such we must esteem all those who enlarge the sphere of human knowledge, and thereby confer the most solid accession to the power and happiness of man.

INDEX.

THE NUMBERS REFER TO THE PARAGRAPHS.

THE END.