POPULAR PHYSIOLOGY;

BEING

A FAMILIAR EXPLANATION OF THE MOST INTERESTING FACTS

CONNECTED WITH THE

STRUCTURE AND FUNCTIONS OF ANIMALS;

AND

PARTICULARLY OF MAN.

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OF THE BOMBAY MEDICAL ESTABLISHMENT.

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PREFACE.

PHYSIOLOGY has been too much studied as a science of opinions, and too little as a science of facts. We have had abundant reasoning from scanty observations, and endless arguments, "long drawn out," from the slenderest foundations. It is hoped this error has been avoided in the present little volume, in which it has been the object of the Author to condense as great a number as possible of well-ascertained facts, connecting them only by as much reasoning as may be necessary to elucidate their mutual relations, and ascertain, by legitimate induction, the general laws which they appear to indicate. The outline of the plan to be pursued will be found delineated at the commencement of the chapter immediately following the Historical Introduction. To this, the Author has nothing to add, except that, in all instances, he has studied to avoid the use of technical terms, or, when obliged to employ them, has taken care to explain them fully, either in words or by references to the plates.

In the course of his work the examination of theories has occasionally been found necessary, and the freedom with which he questions doctrines advanced by men whose talents have gained them universal fame, may appear to some to border on arrogance and presumption. He begs earnestly to disclaim being actuated by any such feelings: he has had no object in view except the discovery of truth; he has never for a moment supposed that his name could be placed in competition with those of the individuals alluded to; but he has merely stated such facts, and adduced such arguments, as appeared to him inconsistent with the doctrines in question; and by the reality of those facts, and the justice of those arguments, he desires to be judged.

It will be observed that his work embraces only those functions, by which animals support their individual life, and maintain their relations with external bodies: all consideration of the functions by which the continuation of the species is insured, has been designedly omitted.

An acknowledgment of all the authorities consulted in preparing the present volume, would have encumbered the pages with foot-notes of reference, and proved abundantly more pedantic than useful. It may, however, be proper to state, that of contemporary writers, the Author is most indebted to Serres, Magendie, De Blainville, Bostock, Bell, Arnott, Flourens, Edwards, Lawrence, Prichard, Desmoulins, and Virey.

ADVERTISEMENT.

A REPRINT of this work being required during the Author's absence on public service in the East, the Editor of the present Edition has carefully examined the latest authorities upon the science, and has marked with brackets such additions as he has found it necessary to make. In justice to the Author, however, it must be said that, of these additions, the most important were anticipated by him in the errata of the First Edition, and the remainder principally consist of later facts and more recent opinions.

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PHYSIOLOGY.

Chapter I.

HISTORICAL INTRODUCTION.

Physiology, or the Science of Life, was at first taught in the schools as a branch of Philosophy. In this way Pythagoras, Alcmæon, Empedocles, and others supplied incidental notices of the human frame in their lectures on mind and matter. From such notices we could derive no instruction; and little entertainment, except from their absurdity. We may, therefore, be excused for passing them over, and commencing our survey of the science with the first man who substituted observation for theory, and fact for imagination.

Born in the noblest days of Grecian literature, Hippocrates proved himself a worthy contemporary of Socrates, Thucydides, and Herodotus. He was of royal descent, his wealth was ample, and pleasures lay smiling in his path; but disdaining the seductive influence of sloth and inglorious ease, he thirsted after that true nobility which arises from superior knowledge, from more extensive power of doing good. His ancestors, expelled from Caria, where they had reigned, settled in the little island of Cos, and established there a medical school, the renown of which has come down to our days. In this school were duly preserved reports of the cases of those who came to be relieved of their maladies; and the collected observations of many generations, on the nature and structure of the human body, furnished abundant materials to stimulate the curiosity and exercise the ingenuity of an inquisitive mind. Here was Hippocrates reared in "all the

B.C. 460.

knowledge and wisdom" of the age. He studied general science—physics, natural history, geometry, and astronomy; and having thus prepared his mind for the grand object at which he aimed, he proceeded to turn all his varied acquirements to the attaining a perfect knowledge of the structure, functions, and disorders of the several organs of the human body. Distrusting the observations, however extensive, made solely in one place, he now determined to travel, and compare the ideas he had acquired at home with the opinions which prevailed in other countries. To this search after knowledge he devoted twelve whole years, and visited Thrace, Thessaly, Macedonia, Delos, Scythia, and many places in Asia Minor. He spent much time at the temple of Diana at Ephesus, where he copied out the accounts of diseases usually inscribed on the votive tablets by persons who imputed their recovery from disease to the interposition of the gods; and having thus filled his mind with useful facts and observations, he returned to employ them for the good of his country and the benefit of mankind. We must not, however, think of following him through the details of a life which added honour to philosophy and dignity to science, but must confine our view to his attainments as a Physiologist.

The question as to whether he ever actually dissected a human body would require too much space to discuss. However, we find scattered through his works observations which, considering the time at which they were made, evince surprising intimacy with anatomical details: his directions for the reduction of dislocations and the treatment of fractures bespeak a knowledge of the skeleton: and though human subjects may not have come under his knife, there seems little reason to doubt that his researches into the structure of other animals were tolerably extensive. The prejudices which then existed may have interrupted his anatomical pursuits, but he showed how highly he valued the knowledge to be thus acquired when he presented to the temple of Apollo at Delphi a brazen skeleton, as the most useful subject of contemplation for the disciples of the God of Healing. It is singular, that as we find in ancient authors obscure intimations of the existence of a western world, the discovery of which lent such lustre to the close of the fifteenth century, so the doctrine of the circulation of the blood, by which our countryman Harvey is immortalized, may actually be inferred at least to a certain extent, from terms made use of by the Father of Medicine.

He was not equally happy in others of his explanations. He supposed that in drinking, a small portion of water insinuated itself into the wind-pipe, which, from the great irritability of its lining membrane, and the accurate closure of its lid, we now know to be impossible. He tells us the auricles of the heart are like bellows filled with air, to cool and refresh the boiling blood with which it is filled; and he occasionally uses his terms with such vagueness that we are at a loss to know his exact meaning. But his failings were those of the period, his excellencies were his own. He was a man who lived before his time. Little has been added by after-ages to his mode of distinguishing diseases*, and none, perhaps, have surpassed him in skill in foretelling their terminations.

B.C. 428.

About thirty years after him, Plato included in his lectures observations upon the economy of the human body, and the principles of which it is composed. As they were, however, rather the vague speculations of philosophic reverie than sober deductions from established facts, a short account of them will suffice. Setting out with two general principles, *God* and *Matter*, he conceived that the first form which matter assumes is triangular. Out of these triangles are composed the four *elements*, fire, air, earth, and water; and from these elements is the human body produced. He considers the spinal marrow to be the part first formed; that this marrow then covers itself with bones, and these bones with

* We should except from this assertion the improvements made by Auenbrugger and Laennec, in the mode of distinguishing chest diseases by means of percussion and the use of the stethoscope; which last we do not hesitate to declare the most valuable addition to medical *diagnosis* that has been made since the times of which we speak.

flesh. The soul he lodges in the brain, which he calls the continuation of the spinal marrow, and the ligaments by which this latter is held in its place, he looks on as the bonds connecting mind with matter. As he supported the doctrine that nature abhors a vacuum, he founded on it an amusing theory of respiration. The air, he says, which issues from the lungs through the mouth in *expiration*, meeting that which surrounds the body externally, pushes it, so as to cause it to insinuate itself into the pores of the skin, and so to penetrate till it has gained the place of that which has been expired; but afterwards returning through the same pores, it obliges the air to rush into the mouth, the only opening now left for it, and in this manner is *inspiration* produced.

Aristotle, who was a pupil of Plato's, imitated him in turning his attention to the structure of the human
B.C. 384. frame. He wrote some books on medicine and anatomy, which have not reached us. Perhaps we should the less regret this from the specimens of physiology which we find scattered through his great work, *The Natural History of Animals*. In no other part of his compositions has he shown so culpable a neglect of examining for himself,—so easy a reliance on the statements of those he employed. His assertions that "all animals have flexible necks, except the wolf and the lion, who have this part composed of a single bone," and that "there is no marrow in the bones of lions," with others of this kind, are sad blots in his general accuracy. That his dissections were confined to the lower animals, and did not extend to man, we may infer both from the nature of his descriptions, and from his own admissions. [Yet let us not forget that Cuvier considered some of Aristotle's descriptions of quadrupeds superior to those of Buffon, and that his details of the lower tribes of animals are said, by Professor Grant, to be sometimes more accurate than those of Cuvier himself.]

The enlightened views of the Ptolemies gave the
B.C. 280. first efficient assistance to this science, which we have seen hitherto struggling through doubts and absur-

dities. With a love of science scarcely to be expected, they ordered that the bodies of criminals should be given for examination to the medical schools. Thus was the foundation laid of a rational physiology, and a termination put to the strained and uncertain analogies by which it was usual to reason on the human body from what had been discovered in the lower animals. The first to avail themselves of this important privilege were Erasistratus and Herophilus, the great masters of the Alexandrian school. With an ardour worthy of the cause in which they were embarked, they applied themselves to cultivating the extensive field of investigation thus opened to them, and they soon produced results worthy of their labours. Anterior to their days, it was usual to derive the nerves from the heart, which was made the centre of the feelings, the reason, and the passions: and so much more powerful is old prejudice than even well-established fact, that up to the present hour this idea prevails in common conversation, and we familiarly speak of a person being sad at *heart*, or of their *heart* being rejoiced within them. Erasistratus was the first who, by accurate examination of the human frame, showed the absurdity of these theories. He traced the nerves carefully, until he found them all springing from the brain and spinal barrow; he first divided them into two sorts, nerves of sensation, and nerves of motion; he first showed that they were the means by which we take cognizance of the impressions made on the organs of sense; and, finally, he raised the brain to its proper dignity, refuted Aristotle's absurd way of considering it as a mere excrescence from the spinal marrow, capable, by its usual coldness and moisture, of allaying the fire at the heart, and showed it to be, what it really is, the true nervous centre to which all sensations are conveyed, and from which all voluntary acts arise.

He had a worthy fellow-labourer in Herophilus, who appears to have lived about the same time, though we do not read of their co-operation. In fact, their own works being lost, we only know them through such parts of their discoveries as are referred to them by subsequent writers. Herophilus seems chiefly to have attached himself to the study of the pulse as an indication of disease; and to such minuteness were his observations carried, that several of his pupils, we are told, gave up in despair the task of following their master's refinements. He has also the credit of having discovered the lacteal vessels, by which the nutritious part of the food is conveyed from the intestines towards the veins; but though he observed the vessels, it does not appear he was fully aware of their use. Such splendid commencements might have been expected soon to brighten into a glorious day, but the clouds of prejudice interposed, popular feeling, always most warm when most misdirected, interfered to prevent the pursuits of science. "Another king arose," unpossessed of the same enlightened liberality; the privilege of dissection was revoked, and surgeons were obliged to practise, in all the awkwardness of ignorance, on the living, that art which they might have learned in safety on the dead. It may be wondered that the custom of embalming bodies which prevailed in Egypt, should not have promoted an acquaintance with their structure; but the people who performed this duty, under the influence of blind superstition, feared to gaze on the wonders before their eyes; and when men were found anxious to inquire into the secrets of nature, they were assailed as sacrilegious and impious, and were said to have carried their investigations to the inhuman length of dissecting malefactors alive, with as much truth as the old fable represents Medea to have thrown men into a boiling caldron, because she first introduced the warm bath as a remedial agent.

From this time centuries passed without a new fact being discovered, or a new observation made. Physicians confined themselves to forming theories, and writing commentaries on the works of Hippocrates and Aristotle; surgeons to the inventing a new form of bandage; and Pharmaceutists to collecting roots and plants of which they knew neither the nature nor the properties. Physiological knowledge was totally at a stand, and the medical world seemed solely occupied with the absurd disputes between the three sects of Dogmatists, Empirics, and Sceptics, into which it was divided.

In the second century after Christ, under Adrian and several succeeding emperors, lived Galen. He was a man of extensive learning, much ingenuity, great eloquence, and excessive vanity. He aspired to be the leader of the medical opinions of the age, and his success succeeded even his warmest expectations. For more than thirteen centuries he reigned in the medical schools with as undisputed sway as did Aristotle in the metaphysical. To doubt his doctrines was considered heresy, to question his dicta the excess of scepticism. He seems to have been the first who ascertained physiological facts by experiment. In this way he proved that muscles owe their power of feeling and motion to the nerves with which they are supplied, as by cutting these nerves, or applying a ligature tightly round them he paralyzed the muscles: he showed the formation of voice to depend on the muscles supplied by the recurrent nerve, as on cutting this nerve animals became dumb: he refuted the old opinion that arteries were filled with air, and showed that during life they contain blood: he held that the mesenteric veins assisted in conveying the chyle (or nutritious part of the food) from the small intestines; explained the functions of the kidney, and described the duct by which the bile is conducted from the gall-bladder to the duodenum. His medical skill seems to have been very great, and his general knowledge immense. But we are not more attracted towards Galen by admiration of his vast genius, than by observing the depth of feeling with which he speaks of the wisdom and goodness of God, and the generous indignation he expresses against those, who, in the pride of a vain philosophy, attempted to question His existence.

A.D. 140.

"Why," he asks, "should I further dispute with such beings deprived of reason? . . . . The Father of all nature has proved his goodness in wisely providing for the happiness of all his creatures, in giving to each that which might be really useful to them; he has shown his infinite wisdom in choosing the best means to accomplish his beneficial ends; and he has given proofs of his omnipotence in creating everything perfectly conformable to its destination. . . . . True piety consists, not in sacrificing hecatombs, or burning a thousand delicious perfumes to his honour, but in acknowledging and proclaiming aloud his wisdom, his power, his love, and his goodness."

There now followed a long period of total darkness, in which the minds of men, in the gloomiest depths of spiritual prostration, were content to register absurdities and perpetuate mistakes. During this time, rational Physiology was almost extinct, and, in its place, men were content to explain the phenomena of life by astrology and alchemy with Paracelsus; by an '*archæus*,' or intelligent being, placed in the epigastric region with Van Helmont; or by 'animal spirits' with Des Cartes. The person to rouse the world from their A.D. 1543. long sleep, and prosecute science by the true mode of examination and experiment, was Vesalius. Of great talents and an inquiring disposition, he early evinced a decided predilection for Anatomy. So powerful was this taste, that to gratify it, he has stolen bodies from the gibbet, and dissected them in his own bed-room. The results of such investigations were not long doubtful. He soon proved, that Galen's anatomy was in many places faulty, and generally taken from apes and other inferior animals; he hesitated not to make public his discoveries, and at the age of twenty-five, undertook and produced a treatise on Anatomy founded on his own dissections, which for arrangement, copiousness, and accuracy, is admired to this day.

Of course, such a revolution in the medical world would not be tamely submitted to by those who had grown gray in the belief of the infallibility of Galen. A powerful party was formed against our young innovator, his doctrines were denounced as heretical, and having some time after gained permission to open a young Spaniard, who was said to have died of a singular disease, his enemies spread a report that the young man's heart had beat on being exposed, and accused Vesalius before the Inquisition of dissecting men alive. Nothing less than the interposition of the king, (Philip II.,) whose physician he was, could have saved him from an ignominious death; he was, however, ordered to expiate his crime by a pilgrimage to the holy land, in returning from which he was shipwrecked, and died A.D. 1564.

Thus perished Vesalius, a martyr to his love for science: but the spirit of inquiry which he had aroused, perished not with him. The fetters of authority that so long had cramped the minds of men were broken, and they started forward in the new course that was opened to them, with all the vigour of "a giant refreshed from sleep." The following century was signalized by three discoveries equally beautiful and important; discoveries, which lent to physiology a new interest and clearness, and first raised it to that elevated situation, which it now maintains. These discoveries were, the lacteal vessels by Asellius, a Professor at Pavia, in 1622; the general lymphatic system, by Olaus Rudbeck, a Swede, in 1651; and the great discovery of the circulation of the blood, by our own countryman Harvey, which in some measure led to the other two, and which was first announced in the year 1619.

We may be permitted to say a few words on each of these discoveries.

Harvey, after having graduated at Cambridge, proceeded to Padua for the purpose of prosecuting his medical studies. From his anatomical instructor here, the celebrated Fabricius, he learned the lately-discovered fact of the nature and structure of the valves found in the veins; he also possessed himself of the observations of Servetus and Cæsalpinus, respecting the passage of the blood from the right side of the heart to the left through the lungs, and also of the effects of ligatures applied to the veins in living animals, causing them to swell on the side remote from the heart. Carefully reflecting on the knowledge thus acquired, enlarging it by accurate dissection and repeated experiment, he at length arrived at the clear and perfect demonstration of the double circulation of the blood, which he taught in lectures as early as 1619: and of which he published his beautiful and philosophic proofs in the work entitled *Exercitatio Anatomica de Motu Cordis et Sanguinis in Animalibus.* Frankfort, 1628. It was not to have been expected, that the prejudices of centuries would be tamely surrendered to truth ever so fairly propounded. Accordingly Harvey soon found that he had excited against himself a host of opponents, who according to the most approved method in such cases, first denied the truth of his assertions, and when these were proved by incontrovertible experiments, then turned round and declared, that all this was to be found in Hippocrates, Plato, and Aristotle, that they had been long acquainted with it; and in short, that like the Bourgeois gentilhomme, "they had been speaking prose forty years without knowing it."

One of the first to enter the lists against him, was Dr. Primrose, and perhaps, it may be entertaining to adduce from his tract published in 1630, one of those arguments by which Harvey was attempted to be refuted. For Harvey's theory, it was necessary that all the blood in the body should pass through the heart and arteries, and he, by a very ingenious calculation, showed that they were fully competent to the office. He further showed that they were constantly full, by the simple experiment of opening one in the living body. To this Primrose replies, that the arteries did not really contain blood enough to carry on the circulation; that the reason why they appeared to do so might be explained by reference to a well-known fact. "A little milk put down in a large vessel will, by the heat of the fire, entirely fill it or even boil over. In the same manner, a very little blood fills the heart and arteries, *because it boils and swells up!*"

Harvey had the good fortune to outlive the silly opposition to his arguments, and to see his doctrines embraced by all enlightened and liberal persons. His investigations were not confined to the human body, but extended to several of the inferior animals, for which he gained the ridicule of his contemporaries, who considered such subjects as beneath the notice of a philosopher; but they led him to a refutation of the theory of "Equivocal Generation," so favourable to the views of the atheist, and enabled him to establish the important fact, that every living being had its origin from some antecedent living being by means of an ovum or germ, or to give his own brief and comprehensive form of expression, "*Omnia ex ovo.*"

We shall speak more briefly of the other two discoveries, as being less interesting to the general reader. It will be remembered, that we stated Herophilus to have observed the lacteal vessels. As he did not, however, explain their uses, the recollection of their existence soon passed away. Asellius, in opening a living dog for the purpose of noting the movements of the diaphragm, observed several white filaments running on the mesentery. These, at first, he mistook for nerves, but having punctured one of them, he found it to exude a white milky fluid. At this sight, he says, he could scarce restrain his joy, and turning to some noblemen who were present at his demonstration, he called on them to witness his triumph. He did not stop here, but by many experiments and observations, showed their true use to be the taking up the nutritious matter of the food after digestion, and conveying it into the circulation. He failed, however, to trace these vessels to their ultimate termination, a task which was performed almost at the same time by Rudbeck, Bartholin, and Jolyffe. They discovered vessels similar to those of Asellius through all parts of the body, to which they gave the term lymphatics, from the clear nature of the fluid they carried. They also discovered the grand trunk of the whole system, to which Pecquet who had also observed it, gave the name of *thoracic duct*, and they traced it to where, emptying itself into the subclavian vein, it joins the general circulatory system.

This century boasts also of Malpighi, whose researches into the intimate structure of organs, have opened the way to important results; and of Ruysch, who first invented the mode of injecting vessels with a substance (such as wax) which on cooling, should become solid, and thus enable him, after removing the surrounding parts by the knife, or by corrosive applications, to obtain an exact cast of the minutest parts of the vascular system.

Towards the close of this, and commencement of the following century, flourished Herman Boerhaave. His character (such as it is) must depend rather on his medical skill than on anything he did for Physiology. He had more learning than knowledge, more eloquence than judgment: his clerical education (he was originally destined for the church,) inclined him rather to metaphysical inquiries, than to the observation of facts: he was a commentator, not a discoverer, an ingenious reasoner rather than an original thinker. Following in the train of Bellini and Borelli, he may be said to have brought the mechanical school of physiology to its height. In their hands, the body became nothing more than a hydraulic machine, in which all the functions of life were carried on by mechanical movements, subject to the same laws as inert matter, and equally susceptible of mathematical demonstration. Of the certainty which might thus be arrived at, we shall give one example. Borelli and Keill separately calculated the force of the heart's action on the blood, when, after the same show of formulæ and diagrams, the former concluded it to be 180,000 pounds, while the latter, reduced it to the moderate sum of eight ounces!

A.D. 1690—1730.

Of Hoffmann and Stahl, we shall say nothing further than, that having framed theories, they showed sufficient tact in twisting facts so as to support them. They seem to have adopted the poet's idea,

A.D. 1718.

Res adjungere mihi, haud me rebus.

But people were now getting tired of hypotheses that supposed everything and proved nothing; that might have upturned the world, had they a single point whereon to rest. Lord Bacon had some time before shown the true method to be pursued in acquiring knowledge, and the application of his mode to Physiology forms the most important epoch in the history of that science, and quickly conducted to the most beautiful and extensive results.

The man by whom the application was made, was Haller.

A.D. 1708. From his earliest childhood, he had shown marks of decided genius. To the fervid imagination of a poet, he added the solid judgment of a philosopher. From the one he derived an enthusiasm which was neither to be repelled by difficulties, nor cooled by opposition; from the other an accuracy of investigation that penetrated the most skilful sophisms, and a boldness of spirit that feared not to expose error, by whatever authority it was sanctioned.

Well aware of the intricacy and importance of his subject, he spent many years of unremitting labour, in preparing himself to treat it in the manner he felt it deserved. After making himself master of general science, he proceeded to Tubingen, where he studied comparative anatomy under Duvernoy. From that, he removed to Leyden, which at that time (1725,) counted amongst its professors Albinus and Boerhaave.

Having spent two years here, and displayed very accurate anatomical knowledge in a thesis, which he published; he went to England, where he made himself acquainted with the views of Cheselden, Sir Hans Sloane, and Douglas, then our most celebrated professors. He then proceeded to Paris, where he studied anatomy under Le Dran, famous for his surgical skill; and afterwards to Basil, where, under Bernouilli, he completed his mathematical knowledge, keeping up, at the same time, his habits of dissecting.

In 1734, we find him lecturing on anatomy at Berne, his native town; the year following, intrusted with the hospital and public library; and in 1736, George the Second, being anxious to establish a character for his new university at Göttingen, offered Haller the chair of medicine and anatomy, which he accepted, and read his inaugural dissertation in September of the same year. From this his fame daily increased, and with it his endeavours to merit it. Not confining himself to the mere duties of his situation, he extended his laborious researches to every object worthy the attention of the physician or the philosopher. He tells us himself, in the preface to his *Elements of Physiology*, that he had dissected three hundred and fifty human bodies, and a still greater number of inferior animals, many of them alive. He had repeated all the experiments of those who went before him, and instituted many new ones of his own. He had engaged his pupils, several of whom, such as Zinn, Meckel, Zimmerman, &c., afterwards attained the highest celebrity, to undertake each the examination of some difficult anatomical or physiological question which he proposed to them, and the results of which he himself overlooked. He examined the motions of the heart and lungs in living animals, explored the course of the blood in the transparent vessels of cold-blooded animals, described the formation and growth of bone, explained the difference between irritability and sensibility, the former of which he attributed to muscles, the latter to nerves, and made a series of masterly and accurate observations on the chick in ovo, from the time of its appearance as a red pulsating speck, until, complete and finished in all its parts, it breaks the shell and issues forth to "life and light." After twenty years spent in such pursuits he ventured to commence his long-projected work, yet with all the modesty of true genius, he declares his feeling that his preparations were not yet sufficient. The world, however, decided otherwise. Struck with the beauty and order that pervaded every part of the work, with the accuracy of his experiments, the force of his arguments, the candour with which he attributed all due honour to other writers, and the modesty with which he proposed his own opinions, they declared the *Elements of Physiology* to be as proud a monument as was ever erected by genius to science, and conferred on its author the title which he still so justly bears, "The Modern Father of Physiology."

It is gratifying to know that Haller was as estimable in private, as venerable in public. In his youth, he had been drawn away by the specious plausibilities of the French Encyclopédists to express some doubts of the truth of Christianity: but his was not a mind that could rest satisfied with doubt. He set himself to a deliberate and careful investigation of the arguments on each side, and the result was, as it ever will be, when the examination is made with a candid, simple, and unprejudiced mind, a thorough conviction of the truth of our religion, and of the miseries and evils which, even in a temporal state, would attend on a general profession of infidelity. There can scarcely be a more splendid object of contemplation than the mind of this great and good man, gradually freeing itself from the chilling mists of scepticism, and the clouds of false philosophy, to attain the glorious light of a full and perfect faith. Such a spectacle are we presented with in his *Letters*, his *Brief Demonstration of the Truth of Christianity*, his Preface to Formey's *Examen du Pyrrhonisme*, and in several passages scattered through his numerous works. But both our confined limits and the nature of our undertaking prevent us pursuing this subject further at present.

Before Haller's days Physiology was little more than a collection of isolated facts. He first gave it "a local habitation and a name." He has formed the grand outline of a science which it has been the office of subsequent labourers to embellish and fill in.

Here then we shall terminate our Historical Introduction. To proceed further would be to enumerate names. John Hunter, Bichat, Cuvier, Blumenbach, Majendie, &c., already familiar to every ear, or to give a summary of their discoveries which must be found more at length in the body of the work. [The Chronological Table at the end of the work will supply the smaller links in the history of Physiology.]

Chapter II.

LIFE AND ORGANIZATION.

To investigate the laws of animated nature; to trace the plant from the seed, or the animal from the ovum; to observe them developing the qualities, or performing the duties, to which they have been destined by an all-wise Creator; to inquire into the beautiful structure and arrangement of organs by which they are enabled to "live and have their being;" to notice their rise, progress, and gradual decay, from the time that, radiant with youth and beauty, they spring up to life and the light of day, until, exhausted and worn out, their appointed time being come, they again return to the earth "whence they were taken;"—such are the interesting, the all-absorbing objects of a science that has hitherto been considered too dull and abstract to engage the attention of general readers, too theoretical and inconclusive to extend beyond the schools of medical philosophy.

That in pursuit of physiological knowledge there are many difficulties to be overcome, it is not attempted to deny. "The gods," says the old poet, "have placed labour and toil in the way leading to the Elysian fields." But many of those difficulties arose from the subject being enveloped in technical language and interspersed with technical details interesting only to the profession for whom works on this subject have hitherto been composed. The habit, too, of presupposing a knowledge of anatomy, which general readers cannot be expected to possess, has increased the obstacles that lay in the way of this "proper study of mankind."

In the present little work an attempt will be made to obviate some of these difficulties. The prominent facts of the science will be stated as far as is practicable, in familiar language. Anatomy will be introduced to the extent necessary for understanding the physiological matters under consideration, and wood-cuts will be occasionally resorted to when found to be the most efficient modes of explanation.

When we turn our eyes abroad, and contemplate the ever-varying scenes by which we are surrounded, the endless diversity of bodies, each filling its appropriate part in existence, and each seeming to obey the laws impressed on it by some master-mind; we observe that certain of them are withdrawn, as it were, from the more general laws to which matter is subject, and endowed for a time with a peculiar power, in consequence of which they become furnished with a new and peculiar set of properties. These bodies are living bodies; this power is life. Living bodies are usually divided into the animal and vegetable kingdoms. It may seem at first sufficiently easy to mark the distinction between an animal and a plant, and as long as we confine our views to the higher orders of animated beings there is no room for doubt. But when we descend in the scale to the radiated animals, which present a nervous system but partially developed in some cases, and invisible in others, no organs of sensation, no observable mode of connexion with the external world; it then becomes necessary to inquire more accurately into the peculiar points which should decide us to arrange them under the one class or the other. Perhaps the most certain of these is the presence of a digestive organ. This, in its simplest state of a bag, with but one orifice, into which the food is conveyed, and from which the excrementitious matter is rejected, is invariably found to exist even in the simplest state of animal life. From this bag arise small pores or vessels, through which the nutriment passes for the support of the body, while in plants this office is performed by roots communicating directly with the ground; and, it will be observed, this variety of apparatus is a necessary part of the design which conferred the power of motion on the former, and which denied it to the latter. Cuvier mentions three other marks of distinction which, however, are by no means so general. They are, the presence of nitrogen as one of the chemical components of all animal bodies, the existence of a circulation and respiration. Nitrogen does exist in all animal bodies; but some vegetables, the extensive classes of *fungi* and *cruciformia*, also contain it, and in *cafein*, a principle extracted from coffee, there is actually a greater quantity of it than in most animal substances. Circulation is not found to exist in the lowest class of animals, but some animalcules have simple vessels; insects have the dorsal vessel, and crabs have a distinct one-celled heart; so that, from the presence of the *organs*, we may infer the existence of the *function* of circulation. As for respiration, the leaves of plants so exactly resemble in their action the lungs of animals, in taking from the air those parts that are useful, and returning to it such as are unnecessary or injurious, that they are now familiarly spoken of by vegetable physiologists as respiratory organs.

What life *is*, we know not; what life *does*, we know well. Life *counteracts the laws of gravity*. If the fluids of our bodies followed the natural tendency of fluids, they would descend to our feet when we stood, or to our backs when we lay. The cause why they do not may be referred immediately to the action of the heart and vessels; but it is evident that they derive that power from life.

Life *resists the effects of mechanical powers*. Friction, which will thin and wear away a dead body, actually is the cause of thickening a living. The skin on the labourer's hand is thickened and hardened to save it from the effects of constant contact with rough and hard substances. The feet of the African, who, without any defence, walks over the burning sands, exhibit always a thickened covering; and a layer of fat, a bad conductor of heat, is found deposited between it and the sentient extremities of the nerves. Pressure, which thins inorganic matter, thickens living matter. A tight shoe produces a corn, which is nothing more than thickened cuticle. The same muscle that with ease raised a hundred pounds when alive, is torn through by ten when dead.

Life *prevents chemical agency*. The body, when left to itself, soon begins to putrefy; the several parts of which it is composed, no longer under the influence of a higher controlling power, yield to their chemical affinities; new combinations are formed, ammoniacal, sulphuretted, carburetted, and other gases are given off, and nothing remains but "a little dust and ashes." This never happens during life.

Life *modifies the power of heat.* Beneath a tropical sun, or within the arctic circle, the temperature of the human body is found unaltered when examined by the thermometer. Doctor Fordyce, Sir Charles Blagden, and others, exposed themselves to air heated above the point at which water boils, yet a thermometer inserted under the tongue stood about its usual height of 98° to 100°; and the sailors, who, under Captain Parry, wintered so near the North Pole, when examined in the same way, constantly afforded the same results.

Finally, life *is the cause of the constant changes that are going forward in our bodies.* From the moment that our being commences, none of the materials of which we are composed continue stationary. Foreign matters are taken in from without, and, by the action of what are termed the assimilating functions (to be explained hereafter), become part of our composition; while, on the other hand, the materials of which our frame had been built up, being now old, and unfit any longer for the performance of the necessary duties, are dissolved, as it were, into a liquid or gaseous form, conveyed by the absorbents from the place which the new matter comes to occupy, and finally expelled from the system by the outlets provided for this purpose. In this point of view, then, it is life which gives unity to the several successive combinations of matter that appear under the same general form; and from the constancy of this form results the certainty of our divisions of animals into species. The utility of such an easy mode of recognition must be obvious. Had the arrangement been otherwise, and the general forms been made subject to change, we should have had no means of distinguishing, at a distant view, noxious animals from such as are useful to our comforts or our luxuries: the wolf might have dwelt amongst our flocks, for the eye of the shepherd would then have failed to detect him.

But the very existence of this constant addition of new particles, this constant internal motion in our textures, leads to the ultimate destruction of that life of which it is a present result. In childhood the whole supply is necessary for maintaining our growth and developement. The season, however, for this, is soon past. At birth, the child usually possesses more than one-fourth of the height to which it will attain; one-half is gained when it is two years and a half old; three-fourths between ten and twelve; while its full stature is completed generally at the age of eighteen or twenty. For a time the wild restlessness and unceasing exertions of youth work off the additional quantities of nutritive matter supplied by vigorous powers of digestion. But the youth becomes a man. The serious business of the world commences. His careless recklessness, his wild exuberance of spirits, which evinced themselves in constant exertion, are now sobered down. He becomes more sedate, his actions less violent. The particles which are now added to his frame begin to increase it in bulk. His muscles acquire additional weight, his bones increased solidity, and fat commences to accumulate in the cellular texture. He is, however, still powerful and vigorous, he is, in fact, in the pride of manhood; when the perfect body is governed by a matured intellect, and the consciousness of power is moderated by the calculations of wisdom.

The change still continues. The fibres of the body become more and more rigid; the solid parts increase, while the fluids diminish; there is no longer the easy pliancy of limb, the flexibility, the grace, the facility of motion. If matter continues to be added now, it is laid down in the form of fat, which seems the least animalized and easiest secreted of the principles of our bodies. It collects chiefly on the face, hands, breasts, and in the abdominal cavity. We then have

. . . . The justice
In fair round belly with good capon lined.

But perhaps the digestion begins to fail while absorption still continues its progress. The materials are carried off faster than renewed. The system makes a last struggle against this preponderance; the fat which had been previously deposited is called in to assist in the general nutrition. This supply is quickly exhausted. The density of the textures has now almost reached its utmost. The vessels no longer yield to the fluid which distends them; its course is obstructed, the circulation grows slower, with it the animal heat is diminished. The extremities of the nerves, lacking the moisture necessary to the proper execution of their functions, are no longer affected by objects as heretofore. The ear becomes hard of hearing; the eye is dimmed; the tongue has lost its taste. The flame of life burns more and more feebly, till at length the worn-out frame "Sinks to the grave with unperceived decay," and gently yields its spirit to the God that gave it. Thus the physiologist confirms the poet's maxim,

. . . . omnes una manet nox,
Et calcanda semel via lethi,

and evinces the necessity of what holy writ declares, "It is ordained unto all—once to die."

The simplest form in which we see life displaying itself, requires a structure of solids and liquids; the solids forming meshes or cells in which the liquids are contained, and a mutual action and reaction appearing to exist between them. This is the earliest effort at organization, and is nearly a description of the lowest orders of animals and plants. For instance, the medusæ, those jelly-like masses that are observed floating on the sea, are little more than a double sac, containing in its intervals an immense quantity of watery fluid. Their chief function is nutrition, which is equally performed by the external surface, answering to the skin, and the internal, representing the digestive organs; and a hydra, or fresh-water polypus, when turned inside-out will continue to live as usual, the external surface then appearing to become the stomach, and the internal the skin. Yet even this structure, simple as it is, cannot be framed or imitated by the most ingenious earthly mechanic. His power is confined to inorganic matter. The chemist can resolve green vitriol into its component parts, sulphuric acid and oxide of iron; he can put those parts together again, and make the vitriol as perfect as before, but an organic body is beyond his power. He can resolve it, indeed, into its solid and fluid constituents; he can still further show these to be made up of what he calls elementary principles, such as oxygen, hydrogen, nitrogen, and carbon; but no exertion of human intellect has yet been able to put them together again, and make from them an organized body. "We never," says Cuvier, "see matter either organizing itself, or organized by any external cause." Chevreul, indeed, made what he calls a sort of oil, by the action of sulphuric acid on cast-iron; and Bérard made something analogous to fat by passing a mixture of carbonic acid, pure hydrogen, and carburetted hydrogen, in the proportion of one measure of the first, twenty of the second, and ten of the third, through a red-hot tube; but no person will consider such very loose analogies as any reply to the general principles we have advanced.

[Wöhler and Liebeg have produced urea in the laboratory; alantoin, another animal principle, has also been formed by artificial means; a fluid analogous to the gastric juice was obtained by Eberle, in 1834, and there are a few more similar facts on record. There are some who recognise in these results the first facts of a science that will teach men to produce at will, from inorganic elements, the organic products of animal as well as of vegetable life; and who not only identify these artificial products with analogous principles elaborated in living beings, *but generalize the operations whereby both are produced:* but the greatest philosophers are less sanguine of the first, and more humble in the last; they cannot regard the same otherwise than as isolated, though successful, imitations of the most simple of the physical products of life; they are anxious to disclaim the presumption that the powers of the chemist are in any way allied to vital agencies.]

Life is constantly found combined with organization. Hence an attempt has been made to deduce the conclusion that it is the result of organization. Now, as far as the fact of co-existence goes, it would equally prove that organization was the result of life; but an experiment, first carefully made by Réaumur, and since often repeated with uniform success, will teach us which conclusion to adopt. Take one of the crustacea, for instance, a fresh-water crab. Break off one of its claws at the joint, and preserve the animal where you may observe the process of reparation that ensues. An exudation of a shapeless mass of matter first takes place from the end of the stump: by degrees it becomes hard on the surface, and something like a nail appears at its extremity. At each period of moulting, this limb grows in a greater degree than any of the rest, becoming at the same time more of a natural shape and structure, until, after a given number of moultings, it becomes a perfect claw: perfect in organization and functions, with shell for protection, nerves and muscles for motion, and vessels for nutrition. The same process we see going forward, in a lesser degree, in our own bodies, whenever it is necessary to repair a wound, or fill up a breach in the continuity of surface; and it is well known to surgeons, what a beautiful provision is made for the carrying away diseased bone, and reproducing healthy, in the affection called Necrosis. Now, as the cause must exist before the effect, and as in all these cases we see that the life existed previously to the new structure which is springing up before our eyes, it follows that life is the formative principle, and organization the result.

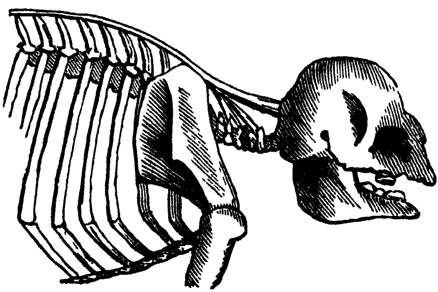
To follow up this argument a little further. Life, as we have shown, is the cause of organization. But the most accurate observations of Natural Philosophers have never been able to show life originating spontaneously; nor can it be the result of chemical or mechanical causes, for it exerts influences directly opposed to their laws: we all have received our life from living beings of whose bodies we once formed part, in the shape of ova, germs, &c.; our forefathers, in like manner, received it from the generation before them: coupling, then, these facts with the well-known increase of the population of the world, evinced by all accurate statistic accounts, and its consequent decrease, as we trace it backwards, we are led directly to the doctrine of a common ancestor, who must have derived his life from the Creator.

We have observed above, that organization, even in its rudest form requires a structure composed of solids and liquids. In the instance there given, they are both extremely simple; the solid part appearing nothing more than a loose cellular structure, and the liquid water holding in solution albumen and a few salts. This albumen is invariably found in the nutritive fluid of animals of all orders. It is therefore looked on as the nutritive principle, that of which the several parts of the body are formed. It exists in the body in two states; first, liquid, in which state it is one of the constituents of the blood; and secondly, solid, as found in cellular membrane, skin, glands, &c. Liquid albumen is best procured from the white of eggs, which consists almost wholly of this principle dissolved in water with a little soda and salts; in fact, exactly resembling the fluid found in the medusa, and serving to the same purpose, the growth of the animal to which it belongs, and which, in this case, is the chick contained in the egg. Liquid albumen is coagulated or rendered solid by various causes. In the egg, exposure to heat produces this effect; and it then appears a white, solid, opaque body. On this property is founded the method of clarifying by means of albuminous solutions. For instance, when you add the white of an egg to boiling coffee, the albumen, being coagulated by the heat, entangles in its substance all the particles which are floating about undissolved, and carries them with it to the surface of the liquid.

Mineral acids affect albumen in the same way as heat, but when once coagulated by these means, it is no longer capable of resuming the liquid form. If, however, you expose it in thin layers to a current of air, it dries, and becomes a solid and transparent substance, which retains its solubility in water; in short, in external characters it closely resembles that simplest of animal solids, which we have already named cellular membrane, and of which chemistry shows it to be the principal component part. We may thus observe, at the commencement, as it were, of animated nature, the close and necessary connexion between the solids and the fluids from which they are formed. On this simple basis are all the orders of animals built, the blood still increasing in complexity of composition as new organs are added, or systems multiplied.

Cellular membrane then is the most important, as it is the most universally met with, of the solid parts of animals. It presents itself in the higher classes as a thin, white, sometimes semi-transparent, membranous substance, continuous throughout the whole body, exhibiting nowhere either commencement or termination; it is composed of filaments and laminæ meeting together in all directions, so as to enclose cells of a great variety of shapes, which cells communicate freely with each other, so that air or liquids will readily pass from one to the other. Of this circumstance, a dishonest advantage is taken sometimes by butchers, who, making a hole in one of the cells, which are to be found everywhere, and introducing a pipe, can from it inflate all the cellular membrane of the body, so as for a time to make it look fuller and plumper than it really is. In dropsy also, the infiltration of fluid, when once it has begun, soon spreads generally through this structure, which usually is found placed immediately beneath the skin. It is in such cases, that the surface pits on pressure; the finger squeezing the water out of the cells immediately under it, and as it only returns slowly, the impression remains evident for some time. This communication also shows why dropsical people usually find their feet and ankles most swollen towards night, the water having gravitated during the day, in consequence of their erect position; and why, on the contrary, when they attempt to lie down at night, they are so often seized with difficulty of breathing, and obliged to start up suddenly, or have themselves supported in the bed with pillows, as the water is then pouring back on their chest, and impeding the actions of the lungs and heart.

The cellular membrane is to be met with everywhere. It envelopes every organ, and enters into its substance; it gives sheaths to the vessels, to each muscle, and to every particular fibre of each muscle; it encloses the nervous matter; forms the frame-work, which, hardened by the deposition of earthy matter, constitutes the bones; and fills up all spaces in the body not occupied by more useful parts. Its properties are very simple; cohesion, flexibility, extensibility, and elasticity. This last is the property of most importance, and is that by means of which we must suppose it capable of causing a motion in the fluids of the bodies of the lower animals, where it is the only solid. This quality is carefully to be distinguished from that power of muscles termed contractility, as it is produced by wholly different stimuli and maintained in a wholly different manner. It is on this power, as we shall have occasion to show hereafter, that the action of the vessels depends, and of the yellow ligamentous matter, which, in quadrupeds with heavy heads, as the cow, the horse, or the elephant, is so advantageously stretched from the spine to the back of the head, to support the immense weight which would otherwise require a constant and most fatiguing muscular exertion.



Head and neck of Elephant; showing situation of this ligament, which is termed the *ligamentum nuchæ*, and, by Paley, the *pax-wax*.

Nervous influence and electricity, which at once produce contraction of the muscles, are totally unable to excite this power to action. The membrane in the living body may be cut, or torn, or pricked, without producing any pain, but its elasticity may be excited by the contact of some irritating substances, but more particularly by the action of cold, insomuch that persons in whom this structure abounds, find themselves perceptibly shrunk in cold weather, and their clothes hanging loosely about them. This tendency is also shared by the skin; and, in consequence, a bleeding from the surface, or from the lining membrane of the nose, which we shall afterwards show to be nothing more than an internal skin, is commonly stopped by the application of cold, either by means of a large iron key put down along the spine, or, what is better, a handful of salt slowly stirred round in water until dissolved, as by this means, a marked reduction of temperature is produced. Another advantage of the elastic qualities of this substance is taken in the construction of the elephant's foot.

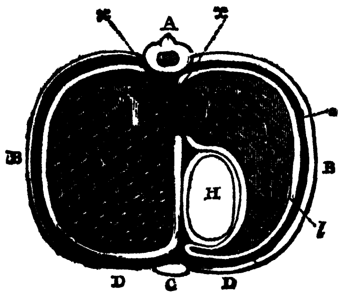
The elephant walks on the points of its toes, and to prevent them from bending under its enormous weight, a cushion of this cellular membrane, fine, close and elastic, containing in its interstices a solid granular fat, occupies all the hollow part of the foot, and forms in a great measure the support on which it rests. Any person will readily comprehend this mechanism, who just half bends his fingers, and places them with their points against a table, and observes how useful an elastic cushion under the palm would be, in enabling him to support a weight placed on the back of the hand. A similar contrivance is found in the foot of the tiger and the common cat, placed both in the centre and under each individual toe; but its use here is to break the fall in the immense bounds they make when attempting to seize their prey. How little a cat suffers in leaping from a great height, is well known.

This tissue is found in considerable abundance beneath the skin, and as it is in its cells that fat is deposited, this accounts for the fat being so much on the surface, in animals fed for the market, and the collections of suet about the kidneys are the result of an exactly similar disposition, the cellular membrane appearing in this situation to be used as a sort of sheath for those delicate organs.

As this is the first of the animal solids mentioned, it may be interesting to consider how its developement is affected by variety of situation, inasmuch as this bears directly on the great question, how far the varieties of the human kind may be attributed to climate and locality. Now a property of this membrane, not before mentioned, is, that it is eminently hygrometrical; that is, it readily absorbs, and is swelled up by moisture. From this it necessarily results, that the inhabitants of low moist countries will be of a fuller softer appearance than those whose atmosphere is dry, hot, and parching. Compare an Englishman with an Arab of the Desert, or a Dutchman with one of the Neapolitan lazzaroni. Observe how, in the former, the whole outline may be described by circles or curves gradually fading into one another; how the interstices between the muscles are filled in, and the whole figure is round and plump: while in the latter, everything is hard, dry, and angular; the muscles start forth abruptly from the skin, and, on the least exertion, display themselves as if cleared off by the knife of the anatomist; the cellular membrane being here so withered and dried up, as to afford but an extremely slender covering. This contrast is beautifully marked by Sir Walter Scott, in his description of the trial of strength and sleight of hand between Richard and Saladin, in the *Tales of the Crusaders*. That the same point holds good in other animals will appear from comparing the light shapely limbs of an Arab steed with the heavy unsightly bulk of a Flanders or Kentish dray-horse; and it is remarkable that the slender bone of the former is so much closer in grain, and denser in material, that it actually outweighs the large open porous bone of the latter. In some animals, the cellular texture immediately beneath the skin is extremely lax, thus allowing great freedom of motion to the skin. This is peculiarly observable in the Batrachian reptiles, such as the frog, toad, &c.; and in consequence of this, and the peculiar mode in which they breathe, by swallowing the air, they are enabled by filling their large vesicular lungs, to inflate their bodies to a very great size. The fact has been long since observed, and made the groundwork of the well-known fable of the Frog and the Ox. The skin is nothing more than a modification of this cellular structure, but we shall reserve the consideration of this until we come to the sense of touch. Other modifications of it present us with the coats of vessels, ligaments, tendons, cartilage, and bone; which last differs from the one preceding, only by containing a quantity of earthy matter, consisting chiefly of the phosphate and carbonate of lime.

A more curious modification, and the last we shall notice, is that by which it is converted into serous membrane. In this form it appears exceedingly fine, transparent, deprived as it were of its cells, and lubricated on its internal surface by a fluid, which is constantly exhaled, and as constantly during health absorbed. Serous membrane is invariably found in the form of a shut sac, that is, a bag closed at both its extremities. [There is an exception to this in the serous membrane that envelopes the intestines of the female, which is perforated at the free extremity of the tube through which the ovule passes to the womb. This is the only place in the whole body where a serous membrane communicates with its exterior.] It is used in the system to cover neighbouring organs which require some freedom of motion among themselves; and to facilitate this, it is always its external surface that is applied to the organ, while its internal, being free, moves easily on the opposite surface, also internal, with which it is in apposition. Thus, while it covers an organ, the organ is actually outside it, and it is possible to conceive the organ freed from it without making an opening in it, or destroying its continuity as a closed double membrane. This probably requires a little further explanation. The most important of these membranes in the body, are the arachnoid, which envelopes the brain; the pleura, the lungs; the pericardium, the heart; the peritoneum, the intestines; and the tunica vaginalis, which, in fœtal life, is continuous with the peritoneum, but afterwards becomes a separate sac, and covers its own organ. Now, perhaps, of these, the disposition of the pleura will most easily explain how an organ may be covered by a membrane, and yet be without it.

This diagram will give an idea of the mode in which the serous sacs would appear in a horizontal section of the chest made about its centre.



A The back-bone.
B B The rib on each side joined by
D D Their cartilages to
C The breast-bone.
F Space occupied by right lung.
G Ditto by left.
H Ditto by heart.
a l The serous sac, which at the same time invests the left lung and the opposite ribs: *a* ought to be closely laid against the rib B; for the sake of distinctness it is a little removed from it. It is evidently the outside of the sac, which is laid against the lung and the rib. The inside, between *a* and *l*, is free, and here one of the surfaces glides easily over the other, allowing the necessary motions of the lungs in expiration and inspiration.

The serous membrane, it is evident, does not entirely cover the lung. A space is left, *x x*, termed the root of the lung, by which blood-vessels enter, also the first divisions of the wind-pipe, which are here represented subdividing themselves into three principal tubes for the right lung, and two for the left, answering to the number of their lobes.

The fact that a man's head, though covered by a double night-cap, is yet outside it, may be added as a familiar illustration. It is clear, that to get inside it, he should rip it up.

This cut will also explain a second form of dropsy; for as the exhalation takes place constantly on the inner surface, and therefore into a close sac, if the absorption should, at any time, from debility or other causes, become insufficient to remove it, a collection of fluid must consequently occur, and as the ribs will not yield, the pressure is thrown entirely on the lungs. This form of dropsy, which is commonly termed water on the chest, is so much more dangerous than the former, which was mere infiltration of the subcutaneous cellular structure, inasmuch as a direct obstruction is here offered to the play of the most important vital organs. The danger is indeed so imminent, that not unfrequently an incision has been made between the ribs into the sac, and the fluid thus drawn off.

Small serous membranes, with a rather more viscid fluid, are also placed at all the joints, their outer surfaces being still those which are applied to the extremities of the bones, while the inner, resting against each other, afford beautifully smooth and lubricated surfaces for every kind of motion. It is clear, the thin aqueous exhalation that sufficed, while the motion was between two soft organs, would no longer answer here. It is, therefore, changed in its qualities, rendered thicker, of a consistency more approaching that of oil, or much resembling the white of an egg. Anatomists call it synovia; from its evident use, Paley gave it the appropriate name of joint-oil. Similar structures are found developed beneath tendons, in false joints the result of accident, and in short, wherever free motion is necessary. But that no doubt should remain as to their use, when motion is prevented, these structures disappear; thus, when a surgeon is treating a fractured limb, as soon as the union of the bones has acquired some consistency, he becomes most anxious that the neighbouring joints should every day have a gentle degree of motion. He knows that, if he neglected this, the synovial membrane of the joint would be absorbed, as if the constitution perceived that its offices were no longer required; adhesion would take place between the opposite surfaces, and the patient would rise with a stiff joint.

Comparative anatomy furnishes a still more interesting proof. The lungs of birds are immoveable, as we shall have occasion to explain more fully in our chapter on Respiration; consequently it would be of no use to envelope them in a double serous sac, as is done with our lungs. Before, however, this was argued out by man's reason, it was known to the Power that secretly made and fashioned them. The membrane is omitted, and the lungs adhere closely against the back-bone.

Enough has now been said (in proportion to our limits) of this structure, which, from its being so universally diffused, and from its appearing to be the origin of the other structures, has received from De Blainville the name of "the generative element." [The flowers of all wild roses consist of four distinct parts placed in circles, one within the other. 1. A circle of five green leaflets upon the outside. 2. Another of five larger, and generally pink leaflets, called petals. 3. Another ring of more than twenty thin thread-like stamens; and, lastly, several thicker thread-like styles in the centre of all. No two of these parts differ more one from the other than the large pink petals do from the delicate thread-like stamens; yet all are composed of the same cellular tissue, and the latter may be changed into the former by cultivation. In the cabbage-rose these threads may be seen in all stages of transformation expanding into broad petals; and, like the metamorphoses of insects, should familiarize our minds with the unity of the internal structure of the whole, notwithstanding the apparent dissimilarity of the parts.

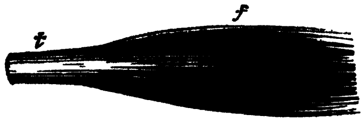
The most simple plant when fully grown, and the embryo of the most complex, consist of the same material moulded in the same form—a film of cellular tissue, like a soap bubble, which has arrived at its maturity in the first case, while in the last, it has to be condensed into cells, and vessels, and epiderm, before the tree can be developed. The adults of the most simple animalcule, and the embryo of a mammal, are also alike in form and substance; but the one has perfected its being, while the other, in words of anatomical authority, "becomes condensed on the surface to form the skin; the skin folding inwards, forms a stomach, or by passing through the body forms an intestinal canal, which, by lateral prolongations, form glands and vessels:" *and the individual organs thus developed, successively assume the same series of changes of form and function,* *whether we trace them through every species of animal, from the lowest to the highest, or follow the same organs through the developement of the individual man from his conception to his birth and maturity.* We cannot too strongly impress these large but simple truths upon the student's mind. The metamorphoses of this first tissue of life into parts that appeal to our senses as dissimilar, in size, and form, and colour, are innumerable; but the material is the same in all, infinitely plastic and obedient to that Word which, in the beginning, said, "Let there be life."] It has been shown to be the earliest deposited of the animal solids, to be found in the simplest state of animal life, and to co-exist with a fluid which supplies the materials for its formation, the most important of which is albumen. The two other textures which are found in the more perfect animals, and which we have next to consider, are the muscular or contractile, and the nervous or sensitive.

That part of an animal which is usually termed the flesh, or the lean, as contradistinguished from the fat, is muscle. It is always of a fibrous appearance, and in the higher animals is usually of a deep red colour, which is owing to the quantity of blood it contains. The colour, however, is by no means invariable, but seems rather proportioned to the perfection of the muscle and the quantity of exercise it undergoes. Thus, in the carnivorous animals, the lion, the tiger, the cat, it is a deep and well-marked red. The same is the case in the stronger graminivorous animals, as the horse, the cow; and it will be observed that in this latter the muscles do not acquire their appropriate colour until in some measure advanced towards maturity, the flesh of the calf being well known to be white. In other animals, such as the rabbit, which, weak and timid, generally keeps itself squatted in its hole, or ranges but a very short distance from it for food, and consequently has no necessity for much vigorous muscular exertion, the muscles are white and soft; while in the hare, which has no hole for shelter, but depends chiefly on its speed for protection against the attacks of its enemies, the muscular fibre is much more perfect, distinct, and of a very deep colour. As these last two animals also feed in exactly the same way, it cannot be true, as some have pretended, that this difference of colour can depend on difference of food. The nearer approach to maturity, or the greater habit or power of exertion, are the true causes to which it should be referred.

The nature of the place inhabited is also to be taken into account, and we shall find those mammalia that inhabit the sea, such as whales, dolphins, porpoises, exhibit a remarkably deep colour in their muscles, which may be fairly attributed to the great quantity of dark venous blood circulating in those animals. Of birds, such as are of high flight and powerful wing, principally birds of prey, show this and other qualities of muscle in the greatest perfection. Birds, on the contrary, that fly to no great distance, do not nest in trees, but usually remain on the ground, have their muscles soft and white. Such are the common barn-door hen, the turkey, the partridge. Age also shows its influence here. In many places pies are made of young rooks, caught before they are able to fly, as at that period their flesh is white and tender: in the full-grown bird it is rank and almost black. The influence of situation, too, is observable. Aquatic birds, such as ducks and geese, have their flesh invariably dark-coloured; but though it imitates in tint, it never approaches in density, to the muscle of birds of high flight. In white-blooded animals the muscles, as far as we know, are always white. The crab is an example.

It is to be observed that a muscle, such as it appears to us, is a compound organ, consisting of the peculiar muscular, or as De Blainville calls it, fleshy matter, deposited in little sheaths, formed by the cellular tissue, and supported with arteries, veins, lymphatics, and nerves. These cellular sheaths, which enclose the fleshy matter, meeting together at the ends, and becoming condensed, form the tendon in which we so generally find a muscle to terminate.

The central part *f* in which the fleshy matter is most collected, is termed the belly of the muscle. The tendon *t* is shown to be formed by the cellular partitions meeting at the extremity. Sometimes this order of parts is reversed, the

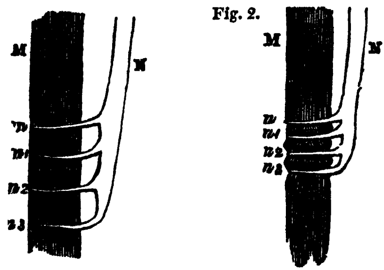


Cut of Muscle; showing fleshy belly and tendon.

tendon being in the centre, and a fleshy belly placed at each end, as is found to occur in the muscle of the throat which, for this reason, is termed digastric or double-bellied. The reason of this deviation we shall speak of when describing the act of swallowing. But whatever may be the arrangement, it is in the fleshy part that the peculiar quality of the muscle, which Haller terms irritability, is found to exist.

This quality, which is now more usually termed contractility, is that by which a muscle, when stimulated, diminishes its length, and thus causes its extremities and the bones to which they may be attached to approach one another. It is evident that if one of these extremities be fixed, the other only will be acted on, and this is the principle of all the motions performed in our bodies. To investigate the nature of this power was long a favourite object with physiologists, and the results of their inquiries afford melancholy instances of learned trifling and misdirected ingenuity. Of the immediate means by which the contraction is performed we may have an idea from the microscopical observations of MM. Prevost and Dumas, who inform us that the muscular fibres, which during relaxation are straight and smooth, become wrinkled up in a zig-zag direction during action, and thus shorten the distance between their extremities. Perhaps the theory of the mode in which this is produced may be cited as one of the most ingenious framed on this subject, though it is by no means satisfactorily proved. The action of the nerves is allowed by all to be the appropriate stimulus to a large class of muscles, namely, those of voluntary motion. The smallest muscular fibre seems supplied with its nervous fibril by which this stimulus is conveyed: and this stimulus is supposed (on what grounds we shall state hereafter,) to be identical with the galvanic or electric fluid. The most accurate dissections, assisted by glasses, seem to show that the ultimate course of the nervous fibrils crosses the direction of the muscle nearly at right angles, or as represented here.

Fig. 1. Fig. 2.



Cut explaining Theory of Muscular Contraction.

Let M (fig. 1) represent the muscle; N the nerve approaching it; n n^1 n^2 the fibrils of the nerve dividing to supply the muscle, and crossing its fibres almost at right angles. When, therefore, by the act of volition the nervous influence passes along n n^1 n^2 these become electrically attracted towards each other, the intervening parts of the muscle are wrinkled up to admit of their approach, and thus contraction is produced. This is represented in fig. 2, and MM. Prevost and Dumas assure us that the nervous fibrils are then found to occupy exactly the angles formed by the wrinkling of the muscle.

To enumerate the other theories framed on this subject, the chemical, the mechanical, &c., would require a long chapter, and would be beside our object, which is rather to convey facts than to record opinions. Theories have often done for physiology what commentaries have done for original works, they have rendered that which was clear doubtful, and that which was doubtful unintelligible.

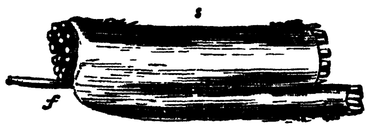
Another quality of the fleshy matter is, that an increased demand for it always produces an increased supply. The more a muscle is exercised, the more it grows in bulk and density. Every one has observed the size of the muscles in the calf of a dancer, and the great developement they acquire on the arms and chest of a smith. Rest affects them in a directly contrary manner. The fleshy fibre seems to be by degrees carried away, and its place supplied by fatty matter. This degeneration has been observed in those muscles which have had their action prevented by paralysis consequent on certain poisons of lead. The muscles, too, which are provided for the motion and support of that naturally flexible column, the human spine, finding that support is given by tight stays, and all motion prevented by the use of stiff whalebone or steel plates, yield up their office. Nothing useless is suffered to continue in the frame, consequently they become absorbed; and, in place of the full, plump, muscular cushion which should run along each side of the spine so as to leave it actually sunk between them, the anatomist finds nothing but cellular structure with a few pale emaciated fibres; the processes of the back-bone project like so many unprotected points, while the poor victim of an absurd fashion having marred Nature in her fair proportions, is compelled to continue those external supports, the necessity for which she has entailed on herself.

Of the chemical composition of muscular matter it is not necessary to say much. The analyses made of it have generally been imperfect, inasmuch as the whole muscle has generally been operated upon at once. But it is shown above that a muscle is a very compound organ, containing, in addition to the proper muscular matter, cellular membrane, blood-vessels, nerves, and lymphatics. This is an evident source of inaccuracy that has not been sufficiently guarded against. The proper matter, however, is termed fibrine, and it is found to contain nitrogen in very great abundance. As this is the element which prevails in animal bodies, and in most cases distinguishes their chemical composition from that of vegetables, it is usually termed the animalising principle; and fibrine, as containing it in a higher degree than other parts of the animal body, is said to be most highly animalised. This fibrine is procured by pouring successive quantities of cold water over a muscle, say, for instance, the lean part of beef, until you have washed away most of the colour, which depends on the blood and some loose fat, albumen and jelly that may have adhered to it. Then use boiling water, which will extract whatever may remain of those principles, together with a new principle termed osmazôme, the principle to which soup owes its peculiar flavour and odour. You will have then remaining nothing but a white fibrous texture, insipid and inodorous: this is fibrine, the essential part of the muscle. As an animal verges towards old age, you will find less of the fleshy matter, and more cellular sheath. It is on this account that old meat is tough.

In making some improvements in Paris, it was found necessary to intrude on ground which had for many years been used as a burying-place. In removing the bodies for this purpose, it was found that the muscles and other soft parts had been converted into a gray fatty-looking matter, of a peculiar, but not very disagreeable smell. This alteration was most complete in the bodies which had been interred about three years, and occupied the centre of the pits in which they were piled. This singular appearance attracted the notice of the Parisian chemists, and an accurate examination showed it to be a sort of soap, formed by the combination of ammonia, which all animal bodies give off in putrefying, with a peculiar fat termed adipocire, into which it was found muscle could be converted by the action of nitric acid, or of moisture continued for some time. Pursuing up this discovery, they found that this change was operated much more quickly by immersion in cold water, especially in a slow running stream; and the idea thence occurred that by this means the carcasses of animals not fit for food such as dogs, cats, horses, &c., might be, as it were, manufactured into fat, and used for purposes of domestic economy. Attempts were made both in this country and in France, but failed, because no means could be found of removing a certain unpleasant smell that accompanied the fat produced in this way.

We now come to the nervous matter, by means of which the directions of the will are communicated to the muscles, and our connexion with the external world altogether supported. Its functions are so important as to require separate consideration, so that we shall here merely view it as one of the constituent parts of the animal body, and consider it with respect to its characters and mode of distribution. If a nerve be examined, it is found, like a muscle, to have always a cellular sheath, and in this is deposited the proper matter of the nerve, which is termed *neurine.* This neurine is a soft, almost semi-fluid substance, varying in colour from a clear white to a gray, yellowish, or even dark colour. Examined chemically, it is found to contain a large quantity of water and albumen, with a peculiar fatty matter, osmazôme, phosphorus, sulphur, and some salts. It is thus a very compound substance, indeed the most so of the constituent solids of the body. It is to be found in greater abundance in the brain, which De Blainville describes as a very loose cellular web with large meshes, into which this neurine is secreted or deposited by the numerous blood-vessels with which it is supplied. On the external part of the brain it is of a gray colour, and is termed cineritious, or cortical, while internally it is of a pure white. In the spinal marrow this order is reversed, the gray being in the centre, so that the term cortical becomes here improper, and the white towards the surface. In the nerves, the white matter only appears, while the ganglia seem altogether gray, to which a reddish tint is given by the blood which they contain. It is usual then to divide the nervous system into four parts; the brain, the spinal marrow, the nerves, and the ganglia.

The brain is the great centre in which all impressions are perceived, and from which the stimulus to motion emanates. It gives origin directly to all the nerves of the senses, and even to the nerves which produce motion in the muscles of the eye, the general muscles of the face, the tongue, the upper part of the throat and windpipe, in short, those which we might consider it advantageous to have more immediately under the command of the will. If the nerve be divided between the brain and any of those organs, the organ is rendered useless. Thus, if you cut the optic nerve, though the eye may remain as perfect as before, though the light may fall as fully on it, there is no perception of it, because the medium by which the impression should be communicated to the brain is cut off. From this we conclude that one office of the brain is to perceive, of the nerves to convey, impressions. The nerves always arise in pairs, one for each side; and nine of these pairs have their origin from the brain. The spinal marrow is, as it were, a continuation of the brain along the canal of the back-bone, for the more convenient supply of nerves to the muscles and integuments of the body. It serves its purpose, however, only as long as it is in connexion with the brain; for, if divided anywhere, all the parts supplied with nerves whose origin is below the division become paralyzed and insensible. It appears to consist of four columns or rods, of which the two front give origin to the nerves of motion, and the two posterior to the nerves of sensation. The nerves themselves are small white cords, appearing, when examined with the misroscope, to be made up of numerous filaments, each having its own peculiar sheath, and all enclosed in a general sheath.



Magnified view of a Nerve, exhibiting *s* common sheath of nerve; *f* one filament dissected out.

The ganglia are always found deep in the frame, as in the inmost parts of the chest, abdomen, &c. The nerves which issue from them go to supply the most important organs, as the heart, liver, and stomach. They are for this reason termed the nerves of organic life; and from their innumerable junctions and intertwinings with each other seems to arise the sympathy between the several parts which unites all the organs in community of feeling, relation, and action. Every ganglion is directly united with the one which precedes and follows it; and the nerve by means of which this connexion is continued through the whole chain, is termed the great sympathetic.

We have thus got an idea of what are termed the primary solids; the cellular texture which gives form to the frame, and envelopes and binds together all our organs; the muscular texture, which is the immediate agent in all motion; and the nervous texture, on which depends our sensation. The next thing to be considered is, in what manner these are put together so as to form a living body.

A medusa, it was stated before, might be considered as a sort of double sac, possessing two surfaces; an external, performing the office of the skin; and an internal, performing those of a digestive canal. The same general view may be taken of every animal. We now propose applying it to the highest, man. The human frame, then, has its two surfaces; the external, the skin; the internal, the lining membrane of the alimentary canal; and these are accurately continuous. Let a person observe carefully any of the orifices of the body, say, the mouth or nostrils; he will readily perceive that there is no point at which he can say the skin ends and a new membrane commences; but he will observe the skin folded in over the edges of the lips or nostrils, to acquire new properties in its new situation, and to become more vascular, as shown by its greater redness, softer, and constantly moistened by the secretion from a number of little glands placed immediately beneath it, and which are termed mucous. In short, the skin has been converted into what is termed a mucous membrane, and in this form lines the mouth, throat, stomach, and all the intestines, resuming again at their termination, its original characters and appearance. Man is thus a double sac, having in his external surface all the organs of the senses, the means by which he communicates with the external world; and in or close to his internal surface, all those glands, such as the liver, pancreas, &c., whose secretions are necessary or useful for digestion. In the intervening texture will be found the skeleton, the framework on which the whole is supported, and the muscles by which the whole is moved. Here also are found all those organs charged with elaborating, either the impressions transmitted from the external surface which should give perception, sensation, volition, &c., or the nutritive materials furnished by the internal surface; such are the organs of circulation and respiration. This is a general outline of the human frame, which we proceed to fill in more in detail.

The function by which all the parts are furnished with the materials necessary for their growth, should clearly be the first examined. This function is DIGESTION.

CHAPTER III.

DIGESTION.

PART I. *Of the Mouth, Teeth, and Gullet. Chewing and Swallowing.*

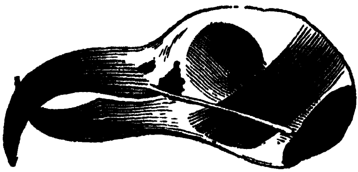
THE function of Digestion, by which foreign substances taken in are applied to repair the waste of the body, while such parts of them as are useless are rejected, exists through the whole scale of animal life. The organs for the performance of this function are, in the lower animals, extremely simple, consisting of little more than an orifice through which food is admitted, and a sac in which it undergoes the necessary changes. But, as we rise in the chain, new parts are continually added, and we recognise at last, means of seizing the food; of cutting and bruising it; of subjecting it to a sort of preparatory maceration by means of salivary glands; of swallowing it through a passage rendered constantly moist and slippery to facilitate its progress; of performing the peculiar offices of the stomach, to which properly the name of digestion belongs; of ensuring the mixture of the chyme, or matter thus prepared, with certain secretions, the bile, the pancreatic juice, &c., which produce further changes on it, separating the chyle or nutritious part from the rest; of absorbing this nutritious part so that entering the circulation it may be conveyed to all regions of the body; and finally of passing on the useless or excrementitious part until it is expelled from the system.

In considering such a variety of operations, it will be necessary to follow some order, to ensure a due share of attention to each. We shall first then examine the mouth and its appendages, as placed at the summit of the alimentary canal; next, the œsophagus, or gullet, through which the food is conveyed; thirdly, the stomach and small intestines, including organs, such as the liver and pancreas, which unite their offices with these; fourthly, the means by which the nutritive matter is retained; and fifthly, those by which the residue is expelled.

The mouth shows itself at first as a mere sucking orifice, unfurnished with teeth, tongue, or jaw-bones. The earliest rudiments of these may, perhaps, be observed in certain mollusca, such as the snail, in which also, it is well known, the salivary glands are well developed. In worms, as, for example, the leech, its powers of suction are familiar to every person; but here it is also supplied with a double row of fine teeth, by means of which it penetrates the skin, while the suction producing a tendency to a vacuum, the blood rushes towards the place, and continues to be drawn until the animal is quite filled. The mouth is here also an organ of locomotion, as by this suction-power the animals fix their anterior extremity, and then draw the posterior towards it. In insects true jaws exist, with this peculiarity, that they are always lateral, that is, act from side to side, not from above downwards, as is the case in all the mammalia, of which we may take ourselves as an example. In some animals of this class, as bees, the jaws are lengthened out, rounded, and united together, so as to form a beautiful little tube, through which they suck up the fine juices from the nectaries of flowers. In fishes we seem to find a connecting link between such animals as have teeth and such as have them not, the sturgeon being an example of the latter kind, while the pike adequately represents the former, showing teeth, not only in their usual place, but on the tongue, the palate, and even in the throat. In reptiles, too, the same varieties occur, from the tortoise, which has merely hard horny gums, meeting like the blades of scissors, and cutting its food, up to the fangs of the rattlesnake, or the formidable rows in the jaws of the crocodile.

In birds, the teeth again vanish, and the jaws become prolonged and hardened, assuming the form of a beak or bill, which can no longer be used as an organ of mastication, but merely serves to pick up their food, as in the common fowl; to assault and destroy their prey, when it is always combined with strong wings and powerful talons, as in the eagle, hawk, &c.; or as a means of climbing, when it assumes the peculiar hooked appearance which we observe in the parrot tribe. In some long-billed birds, such as the snipe, duck, woodcock, the beak is covered by a soft membrane, abundantly supplied with branches of nerves, by means of which they are enabled to use it as an organ of touch. This is absolutely necessary in their case, inasmuch as these animals, constantly seeking their food by their long bills, in places out of view, must be endowed with a power of discrimination in that part to enable them to reject such things as would be useless or prejudicial to them. The bill of the woodpecker is long, pointed, and wedge-like, to enable it to penetrate into the decayed trunks of trees, in which the insects that form its food are found; and it is still further assisted in this by its tongue, which is furnished with sharp horny points at its extremity, and being very narrow, and capable of protrusion to a great extent, serves for searching into the smallest crevices. But in no bird is an apparent defect more really a beautiful instance of the adaptation of organization to the supply of natural want than in the cross-bills.

These little birds derive their name from the upper mandible* of the bill not lying exactly over the lower at its extremity, but curving downwards, generally to the left side, while the lower curves upward, and to the right.



Skull, with Mandibles, of a Cross-bill. In this specimen, the overlapping does not appear to have been made in what we consider the most ordinary direction.

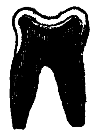
From the appearance of this bill at first, we should be inclined to pronounce it totally useless; for how, we would say, can these points, which cross each other, serve to pick up seeds, or how can the mouth be opened sufficiently wide to catch insects? Neither are they suited to a bird of prey; as how could it attack any animal with such an ungainly weapon? But these are not the objects for which it was formed. This bird was to nourish itself by the seeds picked out of the cones of the pine and different firs, and it has got the instrument most exactly suited to this purpose. It has the power of bringing the points of its mandibles together, and inserting its beak in this state under the scale of the cone, it then opens it by drawing its lower mandible sideways, in which direction it is evident the scale is much less capable of offering resistance, than if attempted to be forced directly upwards. The seed is thus uncovered, but the bird has not yet attained it. For this purpose it is furnished with a long scoop-like tongue, sharp on the edges and towards the point. While, therefore, the scale is separated from the body of the cone by the beak, the tongue is enabled to direct its cutting scoop underneath the seed, which

* Mandible, the term applied to the upper and lower parts of the beak in birds; what in other animals we would term the upper and lower jaw.

is at the root of the scale, and the food thus dislodged is transferred to the mouth.

But we now come to the last and highest class of animals, the mammalia, to which also we ourselves belong; and in every order of these, except one, we find the mouth furnished with teeth. This order is, from the peculiarity of the circumstance, termed *edentata*, or toothless; and includes very few animals, chiefly of the sloth and ant-eater kind. In fact, the name is only applicable with propriety to these latter, and as their food consists of insects, already sufficiently small, and perhaps occasionally of honey, it is evident that organs for chewing or grinding the food would here be useless. In place of them, they are provided with long and powerful claws, by means of which they root up ant-hills, and a thread-shaped tongue, covered with a thick slime, which licks up these insects in great numbers. With this exception all mammalia have teeth, and the variety of their nature, uses, and distribution, have furnished naturalists with some of the most useful characters for classification and distribution. As these varieties of the teeth are always connected with varieties in the structure and functions of other parts, or rather of the entire frame, it will be necessary to consider some of the most prominent of them. The mode in which teeth originate and grow is, perhaps, one of those questions on which physiological inquiry has led to the most satisfactory results. Every tooth presents us with two parts, the ivory or body of the tooth, and the enamel. The existence of this last, indeed, has been denied in the tusks of the elephant, in those of the walrus, the narwal, and in the incisor teeth of the African hog; yet in all these we find an external thin covering of a different substance from the body of the tooth.

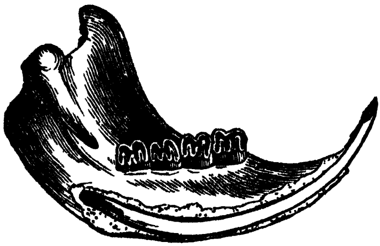
If at a very early period, say during fœtal life, we examine the jaws, we shall find, between the bony plates termed alveolar processes, a soft round pulp deposited, by which the body of the future tooth is to be formed. It is in great part surrounded by a sac, the office of which is to deposit on it the enamel. This enamel in us covers the crown and body of the tooth, and reaches as far as the neck, or the point where it is implanted in the gums. For instance, let this represent a section of a jaw-tooth: the fangs and body of the tooth, which are made of ivory, are represented shaded; the enamel, reaching as far as the neck of the tooth, is represented white; and the darkened figure in the centre, represents the cavity in the body of the tooth, containing the remains of the pulp, to which canals are seen leading along each fang, through which run vessels and nerves. But to return to our pulp. If we examine it a little later, we shall perceive a fine scale of bone or ivory deposited on its upper surface, supposing it to be in the lower jaw. This scale we can detach with our nail, and it will present exactly the figure of the future tooth. It may be discerned in the figure as the bounding line between the body of the tooth and the enamel. Successive scales continue to be deposited within this, gradually diminishing the size of the pulp, until, at length, nothing remains but the small portion shown above. The body of the tooth is now formed, and the sac, which envelopes it as far as its neck, commences to deposit upon it the enamel, always in a direction perpendicular to the surface. The growth continuing at the same time at the roots, the crown of the tooth, thus covered, is pushed up, and gradually cuts the gum; in its progress, also, necessarily tearing the sac which had deposited the enamel. From this it is clear, that if the enamel be in any way injured or destroyed, there are no means for its reparation; and as we know it to consist chemically of certain salts of lime, which are soluble in acids, we see the danger of using such applications as contain them, and which are too often sold under the name of detersive mixtures, dentrifices, &c. They certainly remove dirt or tartar from the surface, but they as certainly remove with it part of the enamel, so that if their use be continued, the enamel is by degrees totally destroyed, and the soft ivory left bare and exposed.



The enamel is the hardest production of the animal body, so hard that it will strike with steel. Its use is, therefore, evident, where the parts are subject to so much attrition and friction.

It is usual to divide the teeth into three kinds, which, from their situation, are termed by Blumenbach front teeth, corner teeth, and back teeth. Thus, if we examine our own mouths, we shall find that each jaw contains four of the first kind, two of the second, and ten of the third, making in all thirty-two, which is the full number in the adult human head.

The front teeth we shall first examine. They were called by Linnæus *incisors*, from their use in cutting the food. In man, it will be observed that the incisors of the upper jaw generally pass outside those of the lower jaw, so that they act like the blades of scissors. When the reverse is the case, the person is said to be *underhung*, and painters look on this as a defect. In the horse, these teeth, which are termed nippers, do not cross, but meet; consequently, in the grinding of the food by the back teeth, these teeth are rubbing against one another, and are thus subject to very great wear. To enable them to resist this, they have an additional plate of enamel running down the centre, and when the prolongation of the sac, which was sent in to secrete this enamel, is taken away, a hole is necessarily left in the tooth, which, being filled with particles of the animal's food and other foreign matter, is usually of a dark colour. This is termed by jockeys the mark, and they judge of a horse's age by it, as, of course, when the tooth is ground down the mark disappears. In the rodentia, or gnawing animals, such as the beaver, squirrel, or rat, these teeth, being required for cutting through very hard substances, are shaped like a chisel, and by a beautiful arrangement, the enamel being placed in front, and the bone behind, the latter, which is soft, wears away faster than the first, so as to leave the tooth always with a sharp edge. In these animals, also the pulp is not destroyed, but remaining at the bottom, is constantly adding fresh matter, and pushing up fresh tooth to supply the waste above. The great size of these teeth is remarkable, although a small portion only of this length appears through the gum. They represent the segment of a circle;



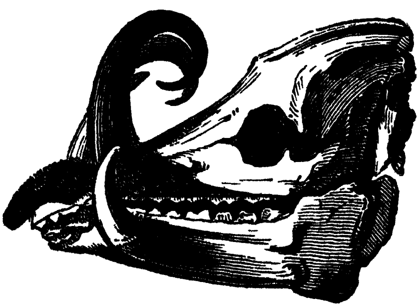
Lower Jaw of a Squirrel, with a section made to exhibit course of Incisor Teeth.

and are contained in a canal of bone which, in the under jaw, runs beneath the roots of the back teeth almost to the very extremity of the jaw, so that, although their anterior cutting edge is in the front of the mouth, their posterior extremity is behind all the teeth.

These teeth in man are always perpendicular in the lower jaw, while in other mammalia they are more or less oblique. This distinction does not hold in the upper jaw, as may be seen in negroes.

In horned animals that chew the cud, such as the cow, there are no incisors in the upper jaw. The grass is gathered in by their tongue, and cut by eight sharp incisors placed in the lower jaw, and acting like a sickle.

The corner teeth, called also canine, and eye teeth, are more particularly confined to carnivorous animals, and in them are used for the purpose of seizing and tearing their prey. The fangs of the lion and tiger are good examples; also the *holders* of the dog. These teeth are, of all others, most liable to varieties, particularly when they occur in graminivorous animals, where they are not required for the above, which seems their more appropriate, use. Thus, in the elephant they assume the form of tusks, which are nothing more than canine teeth enormously developed, and changed in their use to organs of defence. We see the same in the wild boar, where they also serve for rooting up the ground. In the walrus, these tusks are of a very singular appearance, and Sir Charles Bell conjectures they may serve as organs of locomotion, enabling the animal to drag up its unwieldy bulk on an iceberg. The long spear-like tusk of the narwhal belongs also to this division, though, for anatomical reasons, both it and the tusks of the elephant have been by some referred to the incisors. In the *Sus babyroussa*, or stag hog, the variety is still more remarkable; for the upper canine teeth here, in place of growing down, grow upwards, penetrate the upper jaw-bone, and bending back towards the eyes, form almost a complete circle. The reason for this seems not yet well ascertained. Paley thought that the animal slept standing, and, in order to support its head, hooked these tusks on the branches of trees. This is really so ingenious, that we almost regret not to find it confirmed by facts. Sir Everard Home supposes them to act as a defence of the eyes when the animal rushes through underwood; but as other animals rush through underwood without having this defence, we can hardly consider the point as yet decided.

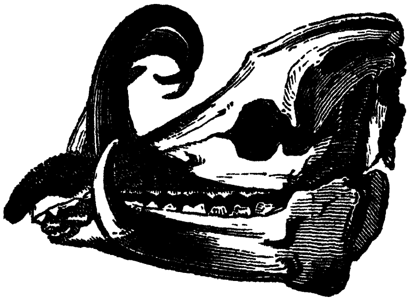


Head of *Sus babyroussa*, showing upper canine teeth growing through the upper jaw, and curved backwards: lower canine teeth project also, and constitute the tusks.

Neither is man totally exempt from the law of variety impressed on this description of teeth, as we know from the example of William de la Marck, who, from the prominence of his under jaw, and the undue developement of its canine teeth, received the well-known soubriquet of "the Boar of Ardennes."

The teeth of fishes are not, in general, fitted for mastication, but rather for seizing and detaining their prey. They, therefore, belong rather to this class. They have the peculiarity of not being formed like other teeth within bony processes termed alveoli, but externally, and rather in the manner of horn. In serpents, the under jaw is always provided with a row of teeth sharp and hooked. The upper jaw serves to distinguish between the poisonous and non-poisonous species. In the former we find a moveable bone attached to it, from which depend the fangs. These are usually in a *recumbent* position towards the back of the mouth, but when the animal is excited they are brought into a state of erection by the action of a muscle, which, at the same time, compressing the poison-gland situated beneath it, forces its contents through the canal that communicates with the fangs. These fangs are themselves hollow and perforated, so that they afford the poison a ready passage into the wound which they inflict. The non-poisonous serpents are never possessed of these fangs, but in their place have a double row of teeth in their upper jaw. It is fair, however, to state that Cuvier doubts whether some serpents without fangs may not be poisonous. But he adduces no direct example, and seems to speak of it rather as a matter requiring further observation.

The back teeth, termed also molars or grinders, are the most important, as it is by their action that the food, seized or divided by the front or corner teeth, is more immediately prepared for digestion. They are, consequently, the most universally present, and are found when the others are totally wanting, as in the armadillo. The only exception to this is the narwhal or sea-unicorn, which has no tooth of any kind teeth enormously developed, and changed in their use to organs of defence. We see the same in the wild boar, where they also serve for rooting up the ground. In the walrus, these tusks are of a very singular appearance, and Sir Charles Bell conjectures they may serve as organs of locomotion, enabling the animal to drag up its unwieldy bulk on an iceberg. The long spear-like tusk of the narwhal belongs also to this division, though, for anatomical reasons, both it and the tusks of the elephant have been by some referred to the incisors. In the *Sus babyroussa*, or stag hog, the variety is still more remarkable; for the upper canine teeth here, in place of growing down, grow upwards, penetrate the upper jaw-bone, and bending back towards the eyes, form almost a complete circle. The reason for this seems not yet well ascertained. Paley thought that the animal slept standing, and, in order to support its head, hooked these tusks on the branches of trees. This is really so ingenious, that we almost regret not to find it confirmed by facts. Sir Everard Home supposes them to act as a defence of the eyes when the animal rushes through underwood; but as other animals rush through underwood without having this defence, we can hardly consider the point as yet decided.



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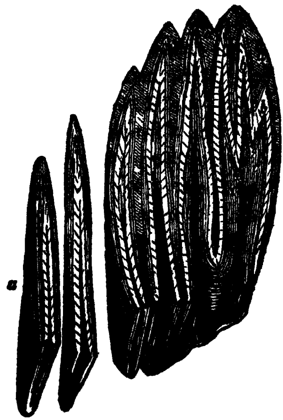
A lion or a tiger has killed its prey in the woods, and having sucked the blood, and devoured some of the richest muscular parts, it perhaps retires, leaving the remainder to be fed on by the chacal, the wild dog, or the wolf. These lie gorged around it, and the vulture and the carrion crow have picked from the bones the last shreds of flesh that adhered to them, while myriads of flies hovering about deposit their eggs where they know the young maggot, as soon as hatched, will find its appropriate nutriment. The heat of the sun soon brings them forth, and they penetrate even into the remotest cavities of the brain and spine. One part of the animal, however, yet remains: the rich marrow in the long bones of the legs. This is reserved for the hyæna, who, to enable it to get at this, is furnished with molar or jaw-teeth of immense strength, wide at the base and conical. By means of these it breaks with ease even the largest bones of the ox, the rhinoceros, or the elephants and then, with its long taper tongue, licks out their contents.

This brings us so directly to Professor Buckland's interesting dissertation on the bones found in the Kirkdale Cave, Yorkshire, that a view of his course of argument becomes necessary. This cavern was discovered in the summer of 1821, by cutting back a quarry, and was visited by Professor Buckland in the December of the same year. He first observed the means by which the mouth of the cavern had been closed, and found it to consist of beds of loam and clayey sand, mixed with rolled pebbles; in short, that description of matter which is termed *diluvial*, from the general, and, indeed, almost unavoidable, conclusion, that at the time of the Deluge this stratum, in the form of a thick mud, spread over the plains, covered the floors of the caverns, and choked up the fissures of the rocks. A similar layer was at the bottom of the cavern, and in it the bones of the elephant, rhinoceros, horse, ox, deer, hyæna, tiger, and other beasts of prey; hares, rats, and mice, and even of some birds. Such animals could not all have dwelt together in this cave; the question then is how their remains became collected. There were no rolled pebbles at the bottom of the cave, which would have been the case had the bones been brought together by the action of water. The bones were smooth, or rather flat, on one side, as it was found on laying them down that they only rested easily in one way. This Professor Buckland referred to their being rubbed by the constant passage of animals over them. They were all broken, and the fracture was sharp and splintery. Some ox-bones were given to a hyæna which happened to be then exhibiting; they were readily broken by the animal, and on comparing them with the fragments found in the cavern, a striking similarity in the form of fracture was observed. Of the teeth of the hyæna great numbers were found, so that one man alone gathered more than three hundred of them. Some of these fitted exactly into some of the notches formed in the bones by gnawing.

Some round balls were found, which, chemically examined, yielded phosphate of lime. They were, therefore, animal matter. The keeper of a menagerie, on being shown them, without hesitation declared them to be the droppings of the striped hyæna. Finally, Professor Buckland compared the circumstances of this cave with the dens of living hyænas, and with similar caverns discovered in Germany, and found a most exact correspondence. The conclusion then was, that this had been, for a long series of years, the den of successive generations of hyænas, and that by their means had been collected the prodigious quantity of bones belonging to such very dissimilar animals. As hyænas are well known to plunder grave-yards, and prey on the remains of the human subject, it is probable, from no human bones having been found in this, or indeed in any similar cavern, that these countries were not peopled at the remote period to which the revolution that closed up these caves must be referred. It is also probable that the climate was widely different from what we enjoy at present, to admit of the growth and residence of some of the animals we have mentioned.

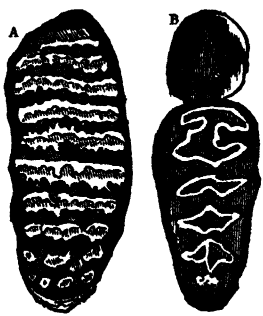
The grinding tooth of the elephant possesses, in addition to ivory and enamel, a third matter, termed *crusta petrosa*, which is placed outside and around the enamel, and seems to assist in maintaining an irregularity of the surface. In fact we might almost consider this tooth as made up of a number of smaller teeth united together by their sides; and a vertical section will show us the bone of each of these springing up, as it were, from a common base, surrounded by its own enamel, and then, outside all, the *crusta petrosa*, resembling a cement, holding all these individual teeth together, and binding them into one.

In the cut we may distinguish *d*, the hollow in which the pulp was lodged, sending up its various prolongations which served to secrete *c c c*, the ivory or bony parts of the tooth, outside which we see *b b*, the enamel, deposited in crystals perpendicular to the surface of the bone, and outside all *a a a*, the *crusta petrosa*, holding all together, and filling up the inter-



Vertical Section of Elephant's Tooth.

spaces. Blake described two parts external to the enamel, the internal of which, marked in our figure by long lines coursing round the surface of the enamel, he seemed to consider as the true *crusta petrosa*, while the external, or that which we have marked *a*, he denominated "adventitious matter." When these two are worn away by grinding the food, it is evident the enamel on the tops of the several denticuli, or lesser divisions of the tooth, will appear; and the difference of figure which it presents in the tooth of the Asiatic and African elephant, has furnished the grounds for deciding them to belong to different species. In the former, the figure is always oval, in the latter something of a lozenge-shape, as may be seen in this cut, in which A represents the grinding surface of the tooth of an Asiatic, B, of an African



elephant; the white lines are the enamel, and the dark, the adventitious matter, or *crusta petrosa.*

The true whales have no teeth. Instead of them they are provided with certain plates called whalebone, solid at the top, but opening out like a brush at the bottom. A number of these are placed across the palate in parallel rows, from the lips to the top of the throat. However singular it may appear, it is no less true, that whales feed on extremely minute animals, chiefly of the molluscous kind. These are known to exist in the greatest numbers in the northern seas, insomuch that Captain Franklin says the slightest thaw on an iceberg produced a number of little pools that seemed absolutely alive, so great were the swarms of animalcules. When the whale, then, wishes to feed, he opens his mouth, which is of enormous size, though we may not actually go so far as to believe Sibbald's report that a sloop in full sail, with all its equipage and complement of men, was seen to enter the open throat of one that had been cast away on the shores of the great ocean. The next thing to be done, then, is to swallow the food; but the immense quantity of water by which it is surrounded, would be of no use, or rather would be a great inconvenience in the stomach. To get rid of this, then, he makes the motion of swallowing, at the same time stopping the true passage to the stomach. The water is thus passed through all these plates of whalebone, by which it is completely strained of its animalcules, and arrives at the back of the throat pure. But here the passage downwards is closed against it, so that it is forced upwards into two large membranous pouches, situated beneath the skin. Strong muscular fibres meet above these pouches, by the contraction of which they are pressed on, and the water thus finally expelled through the spiracles or blowing-holes with great force, rising at times to a height of thirty feet or upwards. Another use of these spiracles is, that being situated on the top of the animal's head, and communicating directly with the windpipe, they enable it to breathe by just rising to the surface, without the necessity of putting its mouth up out · water.

The teeth are placed beyond the reach of the circulation. No blood-vessels enter them; therefore, when once formed, they can never increase in size. From this arises the necessity, in man, for the second set of teeth, which are both larger and more numerous than the first, to suit themselves to the increased size of the jaw-bone. If the fœtus be examined, in the second month of conception, we shall find the jaw-bone just commencing to be formed. In the fourth month the rudiments of twelve teeth, that is, the pulps from which they are to be formed, appear, supplied with blood-vessels and nerves. At birth the mouth shows no marks of teeth, but, like the mouths of the lower orders of animals, is nothing more than a sucking orifice. The rudiments, however, of two sets of teeth are at that moment contained in the jaws; for after the pulps of which we have spoken have nearly formed the first set, they each send off a little pulp like a bud, which seems to spring from their sides, and is destined for the formation of the second set. The first set are termed the deciduous or milk-teeth. They are twenty in number, and appear at very irregular intervals. The first to come up are the centre incisors of the lower-jaw, then in a short time after, perhaps, those which oppose them in the upper. These may be usually looked for about the fifth or sixth month, but sometimes appear as early as the third. The other incisors then cut the jaw, then the most anterior of the jaw-teeth, and last of all the hinder jaw-teeth, which do not rise till the beginning of the third year. To these, in the adult set, are added three more jaw-teeth, for which, in fact, there is no room at present, as will be seen in this cut.

a Deciduous or Milk Teeth up; *b* Permanent Teeth in preparation.

In the sixth and seventh years the jaws have grown so much that they are too large for the teeth. Spaces are left between them, they get loose and begin to fall out. The permanent teeth spring up in their place, but it is not until eighteen or twenty, that, the jaw having acquired its full size, the hindermost jaw-tooth, commonly called the *wisdom-tooth*, has room to rise, and then the process of dentition is complete. As the teeth are destined to undergo a constant and considerable degree of pressure, they are provided with a sort of springiness or elasticity at the bottom, which gives them a constant tendency to rise. The result of this is very evident when a tooth is lost; for then the one opposite it being no longer pressed on, except indirectly, is very apt to rise in the jaw, and so become loose and drop out in its turn.

In animals, such as the beaver, in whom the tooth constantly grows from the bottom, it becomes so long as to be a positive inconvenience, if the animal be restrained from gnawing hard substances. In the elephant, the mode in which the tooth cuts the gum is from behind forward; and as the front layers are worn down, fresh layers are added behind, and fresh teeth formed. If this animal be confined wholly to soft food, the tooth in front is no longer worn down fast enough; and matter continuing to be added behind, the layers become crusted together in a most extraordinary manner, as may be seen in a tooth preserved in the Museum of the College of Surgeons.

The jaws are joined together in such a manner as to allow motion suited to the teeth. Thus in carnivorous animals we have said the teeth were chiefly used in cutting their food, and closed the one within the other, like the blades of scissors. The only motion necessary here, then, is a direct up-and-down motion, such as would be given by a hinge, and this consequently is all that they are allowed; the lower jaw being closely locked into a deep cavity of the upper. In graminivorous animals, where the molar teeth have broad flat surfaces for grinding, this motion would no longer be sufficient. In them, therefore, the jaws are united by surfaces playing freely over each other, and allowing an extensive motion from side to side. They have also the former, or hinge-like motion, which is necessary to enable them to crop their food. But there is still a third kind of motion by which the lower jaw is thrust from behind forward. It is observed in the *rodentia*, or gnawing animals, is necessary for the advantageous employment of their chisel-shaped front-teeth, and in fact is that motion by which the rat or the beaver so quickly gnaws through a piece of timber. The instinct that teaches animals to avail themselves of the peculiarities of their organization is well displayed in a passage from that most interesting little work, White's *Natural History of Selborne.*

"There are three creatures, the squirrel, the field-mouse, and the bird called the nut-hatch, which live much on hazel-nuts, and yet they open them each in a different way. The first, after rasping off the small end, splits the shell into two with his long fore-teeth, as a man does with his knife; the second nibbles a hole with his teeth as regular as if drilled with a wimble, and yet so small that one would wonder how the kernel can be extracted through it; while the last picks an irregular ragged hole with its bill. But as this artist has no paws to hold the nut firm while he pierces it, like an adroit workman, he fixes it as it were in a vice in some cleft of a tree, or in some crevice, when, standing over it, he perforates the stubborn shell. We have often placed nuts in the chink of a gate-post, where nut-hatches have been known to haunt, and have always found that these birds have readily penetrated them. While at work they make a rapping noise that may be heard at a considerable distance."

All the kinds of motion we have mentioned exist in the jaws of man. The hinge-like motion is used in biting our food; the lateral in chewing it. For the motion from behind forwards there does not appear any particular necessity, but, that we have it, any one can convince himself, by moving his under jaw beyond his upper. The different direction of the teeth prevents its being at all applicable to the same use as in the *rodentia*. From this variety of motion, from the form of our teeth, and structure of our digestive canal, physiologists have determined that man is not, like other animals, confined either to flesh or grass, but is omnivorous, that is, capable of living on all kinds of food*. Were he otherwise, his faculty of supporting all varieties of temperature would be of no use. In the snowy regions of Tierra del Fuego, or the ice-bound coasts of the Northern Sea, no vegetables are to be had for many months of the year. During this time, therefore, the inhabitants use a wholly animal diet, and they appear as vigorous and healthy on it as those of the temperate zone do on a mixed diet. In the torrid zone, on the contrary, where flocks and herds would languish beneath the heat of the tropical sun, where scarcely sufficient grass could often be found for their subsistence, and where their numbers would be constantly diminished by the attacks of beasts of prey, mankind no longer depend upon animal food, but find its place amply supplied by numerous and valuable vegetable productions. It is here the cocoa-nut and plantain flourish; the yam, cassava, and other roots; the rice and millet, while a thousand cooling and refreshing fruits invite by their flavour to that description of diet which is most suitable to these countries.

During mastication, the food is constantly mixed with the saliva, which is supplied by three glands on each side, called salivary. The first of these is placed before the ear, or rather in the narrow space between the lower part of the ear and the ascending branch of the lower jaw-bone, which can be felt in this place. From this situation, it is termed *parotid*†. A canal running from it opens into the mouth, nearly opposite the second jaw-tooth. The second of these glands is the *submaxillary*, placed, as its name indicates, beneath the lower jaw.

[* The stomach is not only capable of adapting itself to variety of food, but that very variety is an essential to life. The handles of knives swallowed by jugglers have been digested, the jugglers continuing in health, while an ass fed solely upon rice died in about fourteen days.]

† From παρα near, and ους the ear.

The third is the *sublingual*, placed beneath the tongue, and both those discharge their secretion on the floor of the mouth. This secretion is known under the name of saliva, or spittle, and its evident use is to moisten and form into a paste the food as it is chewed, which without this would only be reduced to a dry powder extremely difficult to swallow. The saliva is poured into the mouth most abundantly at the time of meals, when it is most wanted. The quantity afforded to one single meal is stated at about six ounces, but this of course must be a very rough guess, as it will be greatly altered by the more or less stimulating nature of the food, the quantity of moisture it contains, and other such circumstances. The influence of the mind over the salivary glands is well marked. The mouth *waters* when we see, or with some even when they read of, a savoury dish, and that the same feeling extends to lower animals any one will admit, who has seen a dog looking wishfully at a joint of meat roasting before the fire, with his head placed to one side, and a long clear string of saliva hanging from his lips. These glands are abundantly supplied with nerves, and an intimate connexion seems to exist between their action and the action of certain glands in the stomach, of which we shall have occasion to speak afterwards. This is evinced by a case mentioned by Doctor Copland, in which a maniac, attempting to commit suicide, missed the principal blood-vessels, but divided the œsophagus, or gullet. In the attempts to preserve his life, food was introduced into his stomach by a tube, to prevent the reopening of the wound which would necessarily follow any attempt at the ordinary mode of swallowing. As soon as the food had reached the stomach, an abundant secretion took place from the salivary glands of the mouth, though of course there was no attempt at mastication. This is interesting, as showing the sympathy established between parts intended to assist in the same operation.

The saliva is a clear viscid fluid, consisting in a great measure of water, containing a little albumen, from which it derives its viscidity, and some salts. In the natural state of the tongue and organs of taste this saltness is not perceived, but after fevers, when the thick black crust, which in them so often covers the tongue, has peeled off, and left the tongue, as it were, almost raw, the extremities of the nerves of taste distributed to the tongue become remarkably sensible, and then it is very common to hear patients complain of a salt taste in their mouths. This liquid serves not only to make into a paste the food when chewed, but also to keep the organs of taste in that state of moisture necessary for the proper execution of their functions*. We may, therefore, expect to find the glands from which it comes large and numerous in those animals whose food requires long and laborious chewing, and on the other hand diminished, or altogether absent, where the food is swallowed down as taken, or where the tongue, hard and horny, must be totally deprived of all discrimination of tastes. And such is really the case: the ruminating animals are well known to be those whose food requires the most continued mastication, and in them we find the whole mouth, as it were, set round with these glands, and even new ones added, which are not to be found in man. The carnivorous animals, such as the lion and tiger, who greedily swallow their prey after a few hasty cuts with the teeth, are much worse provided in this respect; while many fishes who swallow their prey whole, and in whom, as we have said, the teeth are rather organs of prehension than of mastication, are totally devoid of anything that can properly be called a salivary gland.

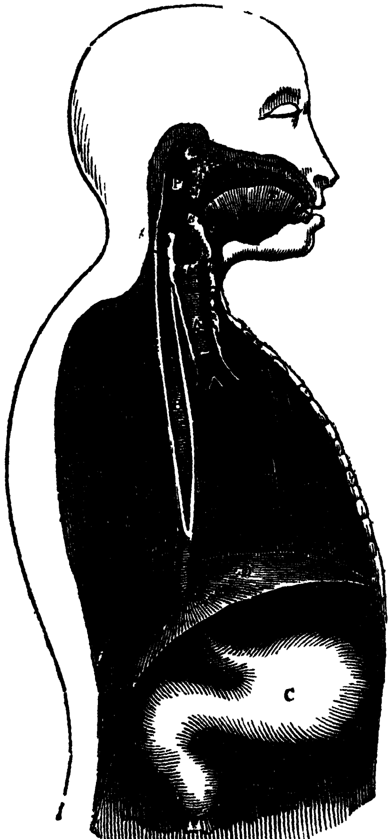
The influence of situation is also to be observed here. The camel has an apparatus found in no other animal, for moistening the back part of its throat, over and above the abundant supply of salivary glands which it possesses in common with other ruminantia. How beautifully suited to the wants of this "ship of the desert!" The ostrich, of all birds, has the most abundant salivary apparatus. "They are collected," says Cuvier, "in a crescent-shaped mass, which runs along the edges of the tongue, and forms the greatest part of its bulk.

[* When the tongue is dry, as in fever, taste cannot be excited.]

Their moisture is poured out from a crowd of orifices pierced on the inferior surface of this organ." Now compare with these inhabitants of "the barren and dry land," those of their own class which are most directly opposed to them in their habitations; with the camel compare the whale, which equally with itself belongs to the great class Mammalia; with the ostrich compare the water-fowl, which can equally claim the name of a bird, and we shall find in these latter, the salivary glands, either quite obliterated or so reduced in size, as merely to mark the place which in other animals they would occupy. In serpents, it is one of these glands that is used for the secretion of poison, but the expulsion of this poison is always determined by a voluntary act of the serpent, and connected with the erection of the fang; and it is remarkable, that though so deadly when instilled into a wound, it is perfectly harmless when swallowed, as we learn from the experiments of Fontana.

During mastication, then, the parts of the mouth are in continual action. The tongue presses the food under the teeth, the side muscles prevent it collecting between them and the jaws, the lips close to prevent it falling out, and the salivary ducts bring a constant supply of liquid to moisten and soften it. When the food has undergone all this, it is then, but not till then, fit for deglutition or swallowing. This is what we have next to consider.

Immediately behind the mouth is placed a funnel-shaped bag, P, termed *pharynx*, surrounded by muscles. The lower end of this terminates in the gullet, or œsophagus, B, leading directly to the stomach. In front of this gullet is placed, just at the root of the tongue, E, the opening of the windpipe, A, and the peculiar little lid, *e*, termed *epiglottis*, which shuts down when anything is to be swallowed, so as to prevent the least crumb or drop from getting in. In the interval that separates, as it were, the mouth from the pharynx, hangs down a moveable arched curtain, which any one may see in himself by the assistance of a looking-glass. It is in the form of a double arch, from the centre of which hangs the long moveable glandular body, *u*, called from its resemblance to a grape, *uvula*. A little further back, we can still perceive, by the aid of the looking-glass, another pair of arches joining these at the point from which the uvula springs, but separated from them below,



Cut showing Progress of Food from Mouth to Stomach; opening of Windpipe; posterior Nostrils, &c.

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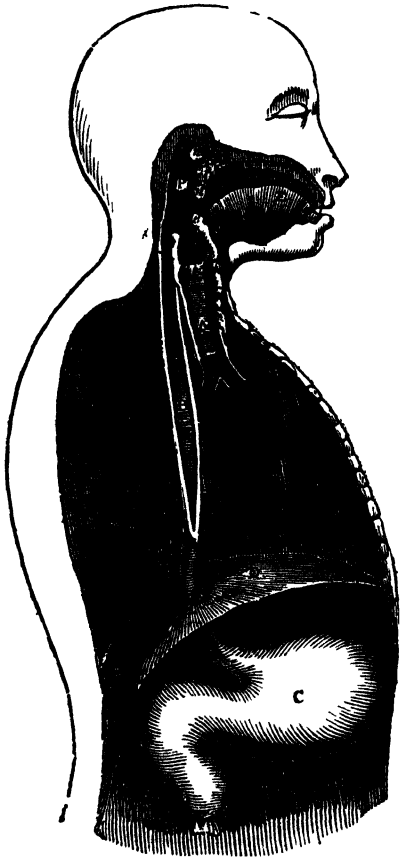


Cut showing Progress of Food from Mouth to Stomach; opening of Windpipe, posterior Nostrils, &c.

and in this interval are placed the tonsils, which are so often swelled in a cold, accompanied by a sore throat. These tonsils are glands pouring out a mucous secretion, and their use in this place is to lubricate the food and assist it in its passage downwards. Behind and above these arches the passages from the posterior nostrils open also into the pharynx at the point *n*, and during the act of swallowing, these curtains, carried back by their muscles, are applied against these openings, so as to prevent any of the food getting into them. If, in the act of swallowing, a strong exertion be made, such as a burst of laughter, this barrier will be forced, and the food partly expelled through the nostrils. The same often occurs in the act of vomiting. The returning smoke through the nostrils is very common, and can be acquired by any one who thinks it worth his while to practise it. It is merely necessary to make the preliminary motions of swallowing, and when the smoke is got as far as the pharynx, then suddenly to cease. The velum drops, and the smoke, by the slightest compression, is returned through the nostrils, the only passages now open to it. A reference to the above cut will at once make this plain. Besides the openings we have already mentioned, in this funnel-shaped bag, there are two more placed towards its side and upper part. These are the tubes leading from the ears. We shall have occasion to mention their uses when speaking of the organs to which they lead. At present, we shall only say, that inflammations propagated along them, explain to us why a slight deafness is so often combined with colds affecting the glands and lining membrane of the throat. The pharynx extends to about the middle or even the lower third of the neck, and here it terminates in the gullet, just as a funnel might terminate in a tube inserted into its narrowest end. The gullet is a muscular cylindrical tube placed behind the windpipe, and between it and the back-bone. In this situation, it runs along the neck, and getting into the chest, begins to deviate slightly towards the left; still, however, keeping close to the back-bone. It runs behind the heart and lungs, and penetrating D, the diaphragm or great muscle that separates the chest from the belly, it terminates by entering the stomach, C, close to its left upper extremity. It has two muscular coats, by means of which the food is carried to the stomach, and it is lined with a continuation of the same smooth cuticular membrane that we see on the inside of the mouth. This lining membrane suddenly changes its qualities and appearance as soon as it enters the stomach: but it is from its continuity with the general lining membrane of the intestinal canal, that physicians judge of the state of the latter, by the appearances observed on the surface of the tongue.

We are now called to observe the progress of deglutition. The morsel, when sufficiently chewed and mixed with saliva, is collected by the assistance of the lips, cheeks and tongue, from all parts of the mouth. It is placed on the back of the tongue; the jaws are closed; the tongue, pressing against the palate, forces the morsel backwards towards the pharynx; at the same moment, the pharynx is drawn rather upward and forward* to meet it; the windpipe is closed by the epiglottis, over the back of which the morsel must pass; the constrictor muscles of the pharynx seize hold on it, and drive it into the œsophagus; the circular muscles of the œsophagus now come into play, and acting in succession from above downwards, they with great rapidity drive the morsel along the whole tube until

* This motion is principally produced by the *digastric* or two-bellied muscle, to which we before alluded, and which has the singular conformation of a fleshy belly at each end, and the tendon in the centre. The object of this is obvious to any one who looks at the muscle. The part on which it is chiefly to act, is the top of the gullet, which is here supported by a bone called U-shaped (hyoid), because it assumes something of the form of this letter, sending its branches along the sides of the passage, and having the windpipe attached to its rounded extremity, which is in front. The *digastric* muscle arises in the front from the chin, and behind from a hard projection which may be felt a little posterior to the ear. Its branches descend something in the shape of a V, and just at their angle are implanted into the sides of the U-shaped bone, having previously passed through a noose left for them between the fibres of another muscle. For both these purposes, it was necessary the tendon should be in the middle, as the fleshy belly always grows thicker when a muscle contracts, and, therefore, would constantly be squeezed by the noose, or would tear its fibres asunder: it would also be very clumsy to attempt attaching it to so small a bone. Both these difficulties are avoided by the present arrangement.

it is safely lodged in the stomach. This will show that the food does not descend, as is commonly supposed, by its own weight. Were this the case, how could a horse swallow, whose head, in grazing, is much lower than his stomach? It also explains the feat performed at Sadler's Wells, by the tumbler, who, standing on his head, used to drink a glass of wine to the great astonishment of our forefathers, who could not imagine how he got it to go up. We have seen, then, how the food is prepared for and carried to the stomach; our next inquiry must be into the nature of the changes it there undergoes.

Chapter IV.

DIGESTION.

Part II. *Of the Stomach, and what takes place there. Of Hunger, Thirst, and Food.*

The stomach is an organ that varies much in size, form and structure, according to the food of the animal. These varieties are always shared by the rest of the intestinal canal; and as they are in direct relation with the varieties of the teeth, we can from the latter, which we may call external, draw certain conclusions respecting the former, which are internal. Now, as the whole animal frame is powerfully influenced by the nature of the digestive apparatus, without which, in fact, no animal body can exist, the wonderful importance of the teeth, as an index to the whole structure, becomes at once evident. As flesh, having been already part of an animal body, seems more ready to enter into such a combination again, carnivorous animals have a small simple stomach of little power or muscular force. The intestinal canal also is short, slender, and not much convoluted, or folded on itself. We need scarcely add how suited this, to the light and agile forms necessary for beasts of prey. In graminivorous animals the reverse is the case. Everything seems here done to detain the food for as long a period as possible, in order that time may be afforded for extracting all the nutritious matter it may contain. And the nature of vegetable food, little prone to putrefaction, favours this design. The stomach increases in complexity, ascending through the non-ruminant up to the ruminant animals. In these latter, there are actually four stomachs, the internal surface of which is rendered as extensive as possible, by being thrown up into numerous folds and wrinkles. The intestines are long, and frequently twisted, so as to afford constant interruptions to the onward passage of the food. In consequence, their bulk is generally great, their bodies unwieldy, and their motions slow. Were such animals as the elephant or the ox to attempt living by the chase, the lesser and more active animals would escape from their grasp; they would soon die of hunger, or be driven to their natural food, the fruits of the earth.

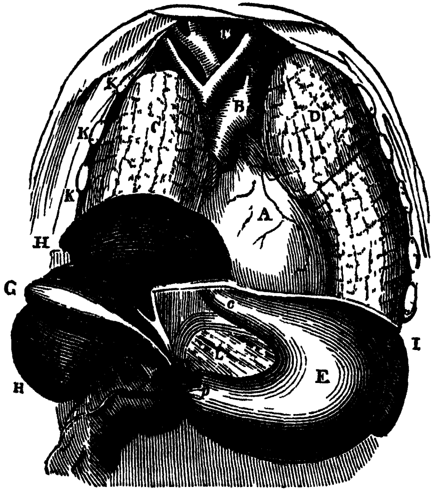
The human stomach will be found, as it were, a medium between those opposite extremes. Some of its provisions appear suited to animal, some to vegetable food: and thus we have an additional proof that man is an omnivorous animal. It is capable, in its natural state, of containing two or three pints of fluid, and resembles a bag stretched across the upper part of the abdomen from left to right. Its left extremity is the largest, and close to this the œsophagus enters.

In the subjoined cut we see the form of the stomach when moderately distended, its situation at the upper part of the abdomen, the mode in which the œsophagus terminates in it, forming what is called its *cardiac** orifice, and its own narrowing and termination in the duodenum, or first part of the intestine, which is its *pyloric*† orifice. We may also observe

* *Cardiac*, next the heart; from καρδια, the heart.

† *Pyloric*, from πυλη, a gate, and ουρος, a guardian, from the old idea that this orifice acted like a porter, to prevent the passage of anything improper into the intestines.

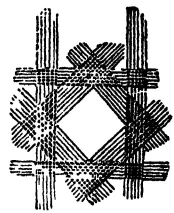
the greater curvature, which being free, is thrown forward when the stomach is full, and as a large artery runs along its edge, any cutting instrument entering the abdomen at this time, would be peculiarly dangerous, from the exposed situ-



Stomach in *situ.*

A The heart, contained in its own sac, termed the *pericardium.*
B The aorta, or great artery of the body.
C The right lung.
D The left lung.
E The stomach; of which *c* is the cardiac, and *p* the pyloric extremity.
F The duodenum, or first part of the intestine.
G The gall-bladder, from which we see the duct through which the gall or bile is conveyed into the duodenum.
H H The liver, which in its natural state would lie down, covering part of the stomach and duodenum, but is here represented as drawn up so as to show these parts and the gall-bladder which is on its posterior surface.
I The diaphragm, through which the œsophagus penetrates just at *c* to become the cardiac end of the stomach.
K K K Ends of the ribs which have been cut through in removing the front of the breast, so as to give a view of the parts within.
L The pancreas, or sweetbread.
T The trachea, or windpipe, which immediately after divides, sending a branch to each lung.

ation of this vessel. M. Larrey, indeed, mentions having seen a soldier, after dinner, receive, by accident, a wound with the point of a sword, which, to all appearance, was of so little depth as not to excite any alarm. To his astonishment, however, the man sunk with extreme rapidity, in spite of all attempts to rally him; and on opening him after death, the whole cavity of the abdomen was found filled with blood, discharged from an opening in this vessel. When the stomach is empty, the great curvature hangs down, and the vessel is then quite out of the way of such an accident. The lesser curvature is above, running between the cardia and pylorus. The coats of the stomach may be reduced to three, whose office is distinct and well marked. Externally, it has a serous coat; that is, the general serous lining of the abdomen folds itself over the stomach, in like manner as it envelopes the liver, the intestines, and all other contained parts having a certain power of motion amongst themselves. And this, it will be remembered, was before stated, as the general use of serous membranes, to afford a smooth and lubricated surface, by which neighbouring organs should glide freely one over the other. This, then, is the first coat; but besides enveloping the stomach, it is continued on beyond its greater curvature, and hangs down like an apron over the intestines, dividing itself on its return to contain between its folds the arch of the colon, or great intestine. This extension of the serous covering is termed the *omentum*, or caul. It is generally loaded with fat, but in the intervals presents its true appearance of a thin transparent membrane. Every one is familiar with the use made of it by butchers in adorning the front of their lamb, veal, and other young meats. A prolongation of this same coat towards the liver, is termed the lesser *omentum*. The second coat is the muscular, which is perhaps best seen by inflating the stomach, drying it, cutting it open, and then holding it between you and the light. In this way, muscular fibres may be seen running along its sides in great numbers, and a variety of directions. It has been usual to class them into three orders, the first of which are longitudinal, or run from the cardia along the sides and curvatures to the pylorus; the second transverse, or cutting these at right angles; while the third seem to wind round in an irregularly cylindrical manner, giving the stomach its peculiar vermicular motion, while it depends for contraction in length and breadth on the two former orders of fibres. The stomach, however, does not from all these receive a perfectly continuous investment; it is rather a sort of surrounding network, in the intervals of which the other coats appear; and Doctor Knox and Sir David Brewster, having taken a part of a fresh stomach, macerated it, placed it between two plates of glass, and in this position interposed it between them and the rays of a very bright sun, were enabled to perceive an arrangement of fibres around the interstices, of which this is a magnified representation.



We see here the longitudinal fibres, the transverse cutting them, and the irregularly cylindrical taking off the corners of the intercepted space, so as to present in miniature, what occurs on a large scale in the camel's stomach, where, as we shall have occasion to see afterwards, those very little interstices become enlarged into the receptacles, by means of which it retains the supply of water necessary for its thirsty pilgrimage. The fibres are found in greatest number about the two orifices, particularly the lower or pyloric. The pylorus is nothing more than a fold of the internal coat projecting into the stomach itself, or forming, as it were, a screen between it and the duodenum, perforated in the centre, and surrounded by a strong band of circular muscular fibres. This internal coat is the last we have to consider. It is of greater size than any of the rest; consequently, to accommodate itself to them, is folded up into a great number of wrinkles. It has been usual to describe it as furnished with a number of fine processes standing up like the pile of velvet, which were termed *villi*, and thence the name of *villous* coat as applied to this. More accurate observation, however, has not proved the existence of these villi, at least in the stomach ; we shall, therefore, use the term *mucous* coat, which the secretion that constantly bedews it, renders sufficiently appropriate.

These several coats are, of course, connected by layers of cellular membrane, which some have, therefore, described as separate coats. That connecting the muscular with the internal or mucous, has more particularly been designated as the nervous coat. The term, however, is calculated to lead to a false notion, nor is there anything so distinctive in this layer as to require a peculiar name. It is the seat of a great number of little glands, which pour their secretions into the stomach during the work of digestion. The branches of nerves and blood-vessels, with which the stomach is supplied in great abundance, interweave themselves also in this situation, so as to make an inextricable net-work. Their final termination is in the inner coat of the stomach, which thus is vascular and nervous in a very high degree. It is from the extremity of the minutest arteries that the gastric juice, so necessary in the work of digestion, is supposed to be poured. Some, indeed, imagine a peculiar set of glands for its secretion, but without sufficient support from anatomy.

Very different accounts have been given respecting the nature and appearance of this secretion, which may in some measure be accounted for by the difficulty of procuring it pure and unmixed with the mucous, salivary, and other secretions, generally existing along with it in the stomach. Its qualities also would appear, from the experiments of Spallanzani, and some later by Magendie, to be altered by the nature of the food which it is required to digest. Thus the former never found it in the least acid in birds of prey, serpents, frogs, or fishes. Crows gave an acidulous gastric juice only when fed on grain ; and the same was the case in dogs, herbivorous animals, and domestic fowl. Carnivorous birds threw up pieces of shell and coral without alteration, which, from their chemical composition, any acid would certainly have acted on; and Spallanzani himself, having swallowed certain calcareous substances in tubes perforated to admit the action of this juice, found their weight and size remain unaltered as long as he used a purely animal diet; but when he fed on vegetables and fruit, a slight diminution was observable, as if they had been immersed in weak vinegar. The solvent power of the gastric juice, then, is its first and most characteristic property. This power is so great in the dog, as to enable its stomach to digest bones, extracting the animal and nutritive parts, and leaving the earthy residuum, from which the fæces acquire the well-known white and clayey appearance that, from the older chemists, gained them the absurd name of *album græcum*.

An apparently opposite power, yet equally well marked, is that of coagulation. This power has been well known for a great period of time, since the infusion of the stomach of the calf has been in all ages used to coagulate milk. For this purpose it is simply washed and dried, in which state it is found to preserve this quality. Dr. Fordyce states that six or seven grains of the inner coat of a calf's stomach thus treated, when infused in water, yielded a liquor that coagulated more than a hundred ounces of milk; that is to say, more than six thousand times its own weight. Dr. Young relates, also, that having washed in water, and afterwards in a dilute alkaline solution, a similar part, he still found it capable of coagulating milk to a very considerable degree. It is evident how much we are dependent on this power during infancy, when the whole food taken being fluid, it should be absorbed all together, as swallowed, though much of it may be useless for nutrition, did not this power act, and throwing down in a solid form what is truly useful, afford that in a separate state to be acted on by the digestive functions. A third quality of this gastric juice, and the last we shall at present notice, is its anti-putrescent power. Dr. Fordyce found that the most putrid meat, after remaining a short time in the stomach of a dog, became perfectly sweet. The juices of maggots, and animals who live on meat in the last state of decay, are perfectly free from any putrid taint: and Spallanzani ascertained that the gastric juice of the dog will preserve veal or mutton perfectly fresh, and without loss of weight, for thirty-seven days, at a time of year when the same meats, immersed in water, yielded an unpleasant smell on the seventh day, and by the thirtieth were in a state of the most offensive putridity. This peculiar antiseptic property suggested the idea of applying it to wounds of a peculiarly bad and gangrenous disposition. The experiment was made by Jurine and Carminati, the latter of whom also used it internally, and, it would appear, with some success. From the close similarity of saliva, and the much greater facility with which it can be procured, M. Richerand was tempted to use that as a substitute. He had under his care a person with an obstinate sore on the inner ankle of his left leg. Notwithstanding the external application of powdered bark, and of compresses soaked in the most detergent fluids, the sore was improving very slowly, when he bethought himself of moistening it every morning with his saliva. From that time the patient evidently mended, and his wound, contracting daily, at last became completely healed.

We are now prepared to understand what takes place in the stomach on the arrival of the food there. During the progress of the meal, the stomach appears nearly passive, yielding to the food, which, by its bulk, distends it. When, however, the process is complete, it begins to react. At first, a few slight and irregular contractions of the muscular fibres take place; these, by degrees, increase in strength and regularity, until at last a well-marked vermicular motion is established, contracting the stomach in all directions, and moving its contents from the greater towards the lesser extremity. The gastric juice, the mucous, and other fluids, are in the mean while poured out plentifully into the cavity, and if the food be in a short time examined, it will be found that a thin layer of it all round, where it is in contact with the coats of the stomach, has become softened and mixed with the fluids. This is the first step towards disgestion, and this is an order which is always accurately observed. At whatever period we make the examination, the change will be found greatest in the food in contact with the stomach, and diminishing exactly in proportion as we recede from this. When the external layer is thus perfectly saturated, it is moved on by the muscular contractions of the stomach towards the pylorus, while the next layer is presented to undergo the same process. If, before the digestion of a meal be complete, fresh food be introduced, it is always found placed perfectly distinct from the remains of the former. Thus Dr. Wilson Philip informs us, that in the stomachs of more than a hundred and thirty rabbits which he examined, and which had been killed at various stages of digestion, the old food was never mixed with the new, but invariably lay next the coats of the stomach, containing the new in its centre, as if it were necessary that the former should be fully digested before the latter was commenced on.

From the food being constantly moved on, we should, of course, expect to find that which was best digested in the vicinity of the pylorus, and such is the case. And here it seems more fully imbued with fluids, and more completely deprived of all distinguishing character, still, however, accurately observing the rule, that the part near the circumference is more digested than that near the centre. In a healthy state, and when the food is such as to agree, this process goes on without the production of any air or gas. But when the stomach is weak and disordered, flatulence, sourness, and eructations, all attest the failure of its powers. Rest is well known to be favourable to this process, though it by no means follows that a moderate degree of exertion interferes in persons of good health and vigour. Sir Busick Harwood took two pointers, as nearly as possible of equal strength. Having given them both a full meal, he left one at rest, and took the other out to beat the fields. At the end of two hours he had them both killed, and found, in the dog that had remained at home, all the food *chymified*, that is, put through the first stage of digestion, as we have described, while in the stomach of the other dog the food remained almost as taken.

From all which, we may see the wisdom of the old proverb, "After dinner sit awhile."

During digestion, both apertures of the stomach are closed; the vital powers seem to leave the surface of the body and concentrate themselves on the important work that is going on; there is, therefore, a slight chill on the surface, and after dinner every one naturally draws round the fire. The length of time required to clear the stomach after a meal is, of course, extremely various, being influenced by the nature of the food, the state of health, the quantity of mastication employed, and many other circumstances. However, as an average, we may say that a substantial meal is disposed of, by a healthy person, in four or five hours. This is a point to which persons troubled with indigestion should particularly attend, as it is clearly of importance that the stomach should be allowed to clear itself of one meal before it is called on to renew its functions by the presence of fresh food. We also see the importance, to such persons, of using food that the stomach can dispose of nearly in the same time, as otherwise one ingredient of a meal might be quite digested and fit to be passed on when another was only beginning to be acted on by the gastric juice. Thus the stomach is distracted in its operations, having one part of its contents to pass on, and another to retain for further maceration. This is of so much importance, that Dr. Abercrombie declares he would almost disregard the quality of a dyspeptic patient's food, provided it be of the same kind, and not of too great a quantity.

The matter into which the food is changed by this first process, is a gray, uniform, pulpy mass, of a faintish and slightly acidulous taste. Notwithstanding the powerfully solvent qualities of this fluid, it is well known to have no effect on living bodies. Thus, certain worms live and thrive with impunity in our stomachs, and in spring time we find the whole internal surface of the stomach of the horse loaded with the young of a certain kind of insects, termed by jockeys "botts," which find this situation most suited for their growth, and hold to the internal membrane by means of two sharp hooks, with which they are furnished, until, having got through their first or *larva* stage here, they let go their hold, and following the course of the alimentary passage, are brought into light towards the end of May or June, just as they are about to undergo their transformation into a *chrysalis.* This peculiar property of living matter also serves to protect the coats of the stomach itself from being acted on by this very powerful agent. When the property of which we speak no longer interferes, when life is suddenly withdrawn, and, at the same time, a quantity of this fluid happens to be just poured out, corrosion does take place, and, under such circumstances, John Hunter first observed the singular fact of the stomach being dissolved in its own juices. That this is not the result of disease, he concluded, from its occurring to him first in a person who had been suddenly killed by a blow of a poker, just after having eaten a very hearty meal. Upon opening him he found the food partially digested: but the stomach also was dissolved at its great end, and a great part of its contents had escaped through the hole thus formed, and lay loose in the general cavity of the abdomen.

In pursuing the inquiry, he examined the stomachs of a great number of fishes, who may all be said to die violent deaths, and all up to the moment in perfect health, while from their rapacious disposition their stomachs are commonly full. In these animals we see the progress of digestion most distinctly; for, their teeth being, as we have said, organs of prehension, not of mastication, they generally swallow their prey whole. This prey is often another fish, larger than their stomach can contain, and in such cases the part of it which is in the stomach is softened and digested, while the rest, which remains in the œsophagus, is perfectly sound and untouched. In many of these he found "that this digesting part of the stomach was itself reduced to the same dissolved state as the digested parts of the food." The circumstance has since been frequently observed, and it is found most constantly to occur in persons who have been killed suddenly, while in good health, more particularly if it should be soon after a meal. The habit of affording criminals (if they are inclined for it) a full meal just before execution, has afforded many opportunities of repeating and verifying this observation. Doctor Wilson Philip, in his extensive and valuable experiments on animals, has not neglected to notice this fact. He says, "This I have often observed in rabbits, when they have been killed immediately after eating, and allowed to lie undisturbed for some time. On opening the abdomen, we have found the great end of the stomach soft, eaten through, sometimes altogether consumed, the food being only covered by the peritoneum, or lying quite bare for an inch and a half in diameter, and part of the contiguous intestines, in the last case, also consumed, while the cabbage which the animal had just taken lay in the centre of the stomach untouched, except on its surface." The reason of all this is now sufficiently obvious. The food taken just before death is the natural stimulus to the secretion of the gastric fluid. This is poured out in great quantity, and speedily saturates the superficial layer of food with which it is in contact. In the natural state of things, the muscular action of the stomach would have moved on this layer, and presented another for the action of the digestive juices: but death has put an end to motion, and the gastric fluid, finding no fresh matter presented to it, turns its action against the coats of the stomach, no longer possessed of that vitality which enabled them to resist its influence. Under these circumstances, they are corroded; an irregular jagged hole is left, and the contents escape through it.

That the motion of the stomach is in one uniform direction, is concluded from the appearances in the stomachs of animals covered with hair. In the calf, for instance, which licks its skin with its tongue, and then swallows the hairs thus detached, balls of hairs are constantly found in the cavity of the stomach. On examining these, the hairs are found to lie in one uniform direction; those of each hemisphere seeming to arise from one common centre, round which they assume a circular arrangement, corresponding to what would appear to be the axis of motion. This regularity could not be produced if there was not a regular motion in the stomach. A remarkable opportunity of observing the motions of the human stomach occurred to M. Richerand, in the wards of the Hôpital de la Charité at Paris. The patient, who was a female, had, several years before, by a fall against the threshold of a door, severely bruised the *epigastric* region. This is the upper part of the abdomen, immediately below the breast-bone, and answers to what we generally term the pit of the stomach. The part remained painful and discoloured for a long time, until one day, during a violent fit of vomiting, it burst, and some of the contents of the stomach were discharged through the rupture. The opening was at first very small, and would only suffer fluids to pass, but it gradually enlarged, so that when she came into the hospital it was an inch and half in length, by an inch in breadth, and the solid food came away through it freely. "Three or four hours after a meal, an irresistible desire obliged her to take off the lint and compresses, by which the fistulous opening was covered, and to give vent to the food which her stomach might happen to contain. It came out rapidly, and there escaped at the same time a certain quantity of gases." She was unable to sleep until she had emptied her stomach, which she cleansed by swallowing a pint of infusion of camomile. In the morning, the stomach appeared of a vermilion colour, its surface wrinkled with folds, covered with mucus, and containing a small quantity of a ropy, frothy fluid, like saliva. The vermicular motion in this case was observed to have two directions; the one natural, towards the pylorus; and the other, which we may suppose peculiar to the circumstances of the disease, towards the fistulous opening. The poor woman lingered for some time in an emaciated condition, supported only by the small quantity of food the passed on to the pylorus. For though the absorbents of the stomach might take up a certain portion of the food th and convey it for the support of the body, yet it must needs have been but very imperfect nutriment, not having as yet undergone the action of the bile, the uses of which in digestion we shall have to mention afterwards. Yet, even in this poor woman's case, suffering under this melancholy accident, was exemplified a most beautiful and careful provision for the preservation of life. To understand this, it is necessary to remark, that in its natural state the stomach is attached merely at its extremities; in other respects it is a loose floating bag in the cavity of the abdomen. Now, if in this state an opening were made into it, its contents would be poured into this cavity, their presence there would excite violent inflammation, and death would follow in the course of a few hours. Why did not all this take place in the case of this poor woman? Because here nature (so to speak) had warning. The constitution found that an injury had been inflicted too great for it to repair. It was necessary that the part injured should die and be cut off. To avoid this was impossible; the next thing, therefore, was to guard against its being the cause of further damage. For this purpose the external, or *serous*, coat of the stomach which had shared in the injury became inflamed. The nature of serous membranes when inflamed, is to throw out a thick glutinous matter, termed coagulable lymph. By means of this the stomach became adherent to the front of the abdomen, which we know is lined by a similar membrane: this, of course, having equally suffered, had equally assisted in the process. The stomach now, then, was no longer loose but attached; and when the injured part had sloughed away, yielding to the force of the effort in vomiting, a direct opening was left between the stomach and the external air, the parts around it were found to have grown together, and no further injury arose from the discharge of its contents, than that consequent on their too speedy departure from the system.

[There is only one case on record of perfect recovery following an external wound of the stomach, the opening remaining unclosed. Alexis St. Martin, a young Canadian of French descent, while engaged in the service of the Canadian Fur Company, in 1822, was accidentally wounded in the side by the discharge of a musket. Dr. Beaumont, to whom we owe all the facts connected with the case, saw the man half an hour after the accident. He found all the coats of the stomach torn through; and the food, which had been taken for breakfast, pouring out through an orifice large enough to admit the fore-finger. So complete was the recovery that, in the course of a few months, a natural *valve* had formed, which entirely prevented any efflux from within, but admitted of being easily pushed back by the finger from without. Here then, for the first time, were all the processes of healthy digestion unveiled; and Dr. Beaumont spent 700*l.*, during eleven years of observation, in supporting and experimenting upon St. Martin. He found that the gastric juice does not continue to be secreted during the intervals of digestion; not accumulating, as had been previously supposed, to be ready for acting upon the next meal: that the quantity of the gastric juice is always in proportion to the quantity of aliment naturally required by the system; and that if an excess of food be taken there will be a deficiency of gastric secretion to digest it: that exciting and depressing passions produce a visible alteration in the villous coat of the stomach—that tissue now becoming red and dry, and, at another time, pale and moist: that bodily excesses are followed by parallel effects: that in fever no gastric juice is secreted, &c. &c. Of a number of inferences drawn by Dr. Copland from these and other experiments, the following are of most general interest:—1. That the gastric juice is a clear transparent fluid, without odour, a little salt, and perceptibly acid. 2. That this juice is secreted by distinct vessels. 3. That it is never found free in the stomach, but is always excited to discharge itself by food or other irritants. 4. That it is modified in quantity, and, probably in its intimate nature, by the quantity and nature of the food. 5. That solid food is easier of digestion than fluid; animal than vegetable; farinaceous than other kinds of vegetable food. 6. That the continued use of spirits *always* causes organic disease of the stomach; and, lastly, that the quantity of food generally taken is more than the wants of the system require.]

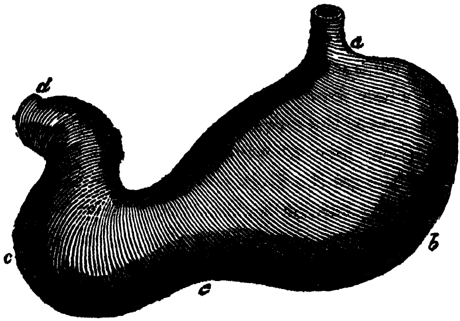
We have used the term "nature" above in compliance with common custom, but all our readers must have felt how utterly inexpressive is such a term. What is nature, or what is the constitution, but the result of general laws, pre-ordained by a Being, wise as he is beneficent, who, in the midst of judgment, remembers mercy, whose tender care is over all his works? Who but He could provide not only for the maintenance of the body in health, but for its reparation in disease? And how beautifully is the law suited to the arrangement! Serous membranes when inflamed adhere; mucous membranes when inflamed ulcerate. Now, had the serous membrane been made internal, and the mucous external, of the coats of the stomach; or had the serous been placed in the centre, and surrounded by the muscular fibres; or had it not found another serous membrane opposite it lining the abdomen; in short, had any arrangement but the present subsisted, the law would have been useless, and death would have been inevitable. The exquisite pleasure with which an humble admirer of the ways of Providence contemplates a provision so wise, so simply beautiful, so full of tender foresight, is worth years of philosophic scepticism and heartless unbelief.

When the motion of which we have been speaking is inverted, vomiting results. In this case, the muscular fibres contract from the pylorus towards the œsophagus, so that the food, in place of being moved on through the former, is returned by the latter. It would appear, however, that the muscular fibres of the stomach are not of themselves sufficient to overcome the resistance offered by the circular fibres which close the œsophagus, but require to be assisted by the diaphragm, (represented in our cut, letter I,) and the external muscles of the abdomen. That in ordinary vomiting, such assistance is afforded, every one's recollection of his own experience on such occasions, may afford sufficient proof; or ocular demonstration of the violent action of the abdominal muscles may be had by noticing a dog or cat when sick. But not contented with this, some physiologists have resorted to the cruel experiment of cutting away these muscles, and then giving the animal an emetic, and observing its fruitless efforts, under such circumstances, to discharge its stomach, an effect that was immediately produced when they substituted pressure with their hand for the action of the parts removed. Some have advanced that the stomach is quite passive in vomiting, and that the act wholly depends on the pressure exercised by those other parts. But this doctrine goes too far, though M. Magendie endeavoured to prove it by the singular experiment of removing the stomach from a large dog, substituting for it a bladder, which he attached to the œsophagus, and then having excited vomiting by the injection of tartar emetic into the veins, he showed that the abdominal muscles and diaphragm were able to discharge the contents of the bladder as if it had been a real stomach. But the experiment was evidently fallacious. The stomach is, by its vital power, capable of resisting the effects of such pressure, otherwise it would be discharged every time we made a strong effort and held in our breath, or every time that a sailor laid himself across a yard-arm. But there are certain muscular fibres which, embracing like a running-string the termination of the œsophagus, close it under ordinary circumstances, and prevent the backward passage of anything through it. These fibres were evidently cut away in M. Magendie's experiment, therefore the peculiar action of the stomach, necessary to overcome their resistance, was not required, so that he only proved, what every one will allow, that if you squeeze a bladder, into the neck of which you have inserted an open tube, its contents will be discharged through this tube. But this is evidently not the situation of the human stomach. We had occasion to notice, in speaking of swallowing, the means by which the food was prevented getting into the windpipe, or the back of the nostrils, where they open into the pharynx. It is evident these provisions only answer for the downward progress of the food; on its return they are of no manner of use. The most important danger, therefore, that of the matters vomited getting into the windpipe, is guarded against by persons always making a very full inspiration previous to the act of vomiting, and coughing immediately afterwards, so as to dislodge any irritating substance that may be lodged about the upper part of the throat. The full inspiration is also of use in pushing down the diaphragm, (see plate,) which is thus made to press more forcibly on the stomach. The other circumstance is not of so much consequence, and no provision seems made against it, so that we often see part of the fluids ejected pass through the nose. The causes of vomiting, Dr. Bostock reduces to three classes: 1. Irritating matters acting directly on the stomach itself; 2. Irritations applied to other parts with which the stomach sympathizes; and, 3. Mental impressions, the effect of which depends, in a great measure, on association, and affords one of the most frequent illustrations of the influence of mind on body. Under the first of these heads, all emetics, undigested food, and such like matters, will come. The second is more curious, and affords many exemplifications of what we term sympathy. Thus, wounds on the head generally produce sickness of stomach. Dr. Wollaston refers sea-sickness to an accumulation of blood on the brain, caused by the descending motion of the vessel; and M. Saussure, in his *Voyages dans les Alpes*, reports that many of his companions were seized with nausea and vomiting as soon as they had reached a certain height; where, from the increased rarity of the atmosphere, it has been supposed that the circulation of the brain must also have been affected. [Sea-sickness has not been satisfactorily referred to any one cause; and, although various hypotheses have been advanced, the evidence of facts still remains of a negative character. It does not depend upon the confused impressions conveyed to the brain through the medium of the eye, because the blind are sick at sea; nor upon the continual motion of the contents of the stomach, for neither abstinence nor repletion avail; nor upon fear, for Nelson was confined to his berth for several days by this affection, and Sir John Franklin was never able to take the command of his ship until he had passed the Bay of Biscay; nor upon an accumulation of blood upon the brain, as in Wollaston's theory, because the recumbent position is a source of relief. And, as regards the external cause, the descending motion of the vessel cannot be assigned as it, for old seamen who were not sick in their ship have been known to suffer after rowing in a small boat for several hours; and the writer has observed that the motion that accompanied *a head swell without wind* affects the stomach sooner than any other; he has seen nearly all the crew refuse food after a continuance of this motion, and has himself suffered after having been quite well during a previous fortnight of bad weather. To understand this motion, the centre of gravity of the ship may be supposed to be continually describing a figure of eight sideways, without progression, thus, ∞. A more accurate observation of the relations between the nature of the motion and its proportional effect upon the stomach might lead, perhaps, to more positive results.] The third class, including all cases of sickness arising from disgust, unpleasant recollections, terror, and other such causes, is also of extreme interest, but would require a chapter, rather than a paragraph, did our limits allow of it.

There is another species of inverted motion to which we must now proceed, and which leads us to some very curious provisions in the animal œconomy. This is Rumination. Some men have been known to possess the power of bringing up their food after it had been swallowed, and submitting it a second time to the process of chewing. In a case of this kind, mentioned by Sir Everard Home, the individual swallowed his food voraciously, and without chewing. About a quarter of an hour after the meal was terminated, he used to bring up a morsel from the stomach by a slight effort. This was chewed and swallowed, and after a little interval, another was brought up, and underwent the same process. Blumenbach mentions that he knew four men possessed of this power. They all assured him that they had a real enjoyment in doing it; and in two of them it was perfectly voluntary, so that they could abstain from doing it at pleasure. Rumination, however, is much more perfect in some other animals, and the apparatus of stomachs prepared for its performance is both singular and beautiful. The final cause why certain animals ruminate seems not yet fully ascertained. Aristotle, ingenious even in his mistakes, having observed that the ruminants best known to him, such as the deer, the cow, the goat, were provided with horns, but wanted the incisor teeth of the upper jaw, suggested that the materials of the latter were employed in forming the former, and the want of the organs thus defective was supplied by such an apparatus of stomachs as should send the food up for second mastication. But we cannot admit this mode of reasoning, as it is evident such a provision would rather remedy a deficiency of grinder than of incisor teeth. Further observation also has shown his facts not to be so universal as he had supposed. The llama has two incisor teeth in its upper jaw, yet has all the apparatus for rumination, while the elephant, which has none, manages to digest without this process. Sir Everard Home took much pains to show that, during digestion, the stomach of man, and generally of carnivorous animals, divided itself by a contraction of the muscles into two cavities; the one, towards the left side, or the entrance of the gullet; the other towards the right, or the passage into the intestines*. This he termed the *hour-glass*

* How far this opinion is correct seems yet rather undetermined. It was advanced before Sir E. Home's time, by Haller and Cowper: it is admitted by Meckel, and defended by Bostock. But at the time Sir E. Home stated it, it was attacked by Dr. Macartney, in that most excellent article MAMMALIA, Rees's *Cyclopædia*; and his views have received much support from the late observations of MM. Tiedemann and Gmelin, celebrated German Physiologists.

contraction, from its dividing the stomach somewhat in this shape.



Sketch of Stomach, with Hour-glass Contraction.

a is the cardiac orifice, and *b* the cardiac cavity.
d the pyloric orifice, and *c* the pyloric cavity.
e marks the situation and extent of the contraction.

The first of these cavities he names *cardiac*, from its vicinity to the heart; the second, *pyloric*, from its vicinity to the pylorus.

Now this contraction, which is only temporary in man and carnivorous animals, becoming permanent in others, as the beaver, the hare, the rat, forms the first step towards the perfect division observed in ruminating animals, in which there are actually four distinct stomachs. In further examining this matter, he ascertained that the liquids are in a great measure confined to the cardiac cavity, and absorbed from that when in too great abundance. The solid food freed from these is then passed on to the pyloric extremity, where it is generally found drier and more reduced to the state of that pulpy mass termed *chyme*. This, he observes, shows how the process of digestion may go on in the stomachs of men who drink after dinner several quarts of different liquors. A weakness, also, of these muscles, rendering them unable to contract effectually, would account for the inconvenience suffered by many persons affected with indigestion, from using even a moderate quantity of drink at their meals. In such case the liquid would spread itself over all parts of the stomach, which would thus be prevented from acting properly on its solid contents. As some animals, in whom this contraction is permanent ruminate occasionally, particularly when fed on harder food than ordinary, this may give us some idea of the mode in which this same circumstance occurred in those men of whom we have spoken above. In the horse and the ass the division of the stomach is rendered very clear by the cardiac portion being lined with a regular cuticle, while the pyloric presents the proper villous surface. The cardiac portion is here, then, evidently but a receptacle in which the food undergoes a sort of previous maceration and softening before it is passed on to be digested in the latter. This cuticular lining is also found in part of the stomach of the kangaroo, which combines in itself this provision, with the cardiac prolongations, or pouches, such as occur in the hog, or the elephant, and a complexity approaching nearly to what we see in the ruminants. Under certain circumstances, kangaroos do ruminate. Sir Joseph Banks, who had several of these animals in his possession, found this to be the case when they were fed on hard food. It is not, however, their ordinary habit, as those which were so long kept at Exeter 'Change were never detected in the act.

We have now arrived at the ruminating animals, in whom the complexity of the digestive organs has reached its utmost. In the ox, the food, when swallowed, descends first into a large cavity, termed the paunch, and the animal generally continues to eat until this cavity is quite full. The food here, under the influence of heat and moisture, suffers a sort of maceration; and as the drink is contained not in this, but in the second stomach, fermentation occasionally occurs here, when a large quantity of green food, such as clover, rich grass, or other young vegetables has been taken in. In such cases much air is disengaged, and the animal swells up enormously, the paunch pressing on all the other organs, so as not unfrequently to destroy life. The readiest remedy is to plunge a knife into the left loin of the animal, which penetrating the paunch, will give exit to the wind in prodigious quantities. This expedient, though apparently so dangerous, is seldom known to be followed by bad consequences.

It is generally in this stomach that those hair balls, of which we spoke before, occur. Similar balls made of the fibres of plants are also found; and the bezoar*, once so famous, is now known to be nothing more than a stony concretion found in the first or second stomach of the wild goat, antelope, and other similar animals. The second stomach communicates so freely with this first, that were it not for its difference of structure it might be considered as forming part of it. It is known under the name of the *honey-comb*, which well describes its appearance, and is situated like a shelf within the first. The drink descends into this, by which it is enabled to moisten the food as it receives it from the paunch, and so mould it into little pellets, suitable to be sent up through the gullet for the process of a sound chewing. This regurgitation is facilitated by the mode in which the gullet terminates. It opens just at the junction of the first and second stomachs, so that on its left side it discharges into the former, while at its right it receives from the latter. But the most curious provision is, the double muscular band which is continued from its extremity to the opening of the third stomach, which opening it brings forward close to the termination of the gullet, when

* The *bezoar* was long supposed to have most powerful virtues as an antidote in cases of poisoning. Its use extended until it came to be looked on as a remedy for almost every disease; but it proved unequal to its high character, and from having been extolled as good for everything, is now neglected as good for nothing. The first person by whom it was mentioned was Avenzoar, an Arabian physician, and his account of it was sufficiently amusing. He says that the stags of his country were very fond of eating serpents: this propensity, however, subjected them to the danger of being poisoned, to guard against which, as soon as their repast was finished, they used to run into the water until up to their nose: here they used to stand until the effects of the poison worked off, by means of a humour that oozed from their eyes, which gradually hardening and becoming coagulated, formed the bezoar-stone. This, when quite hard, was thrown off by the animal rubbing himself against the trees.

the morsel is to be swallowed a second time, forming itself, also, at the same time, into a tube, so as to prevent any portion escaping into either of the other two cavities*. As long as the animal is fed on milk only, this band is constantly folded in like a tube, leading from the end of the gullet to the third and fourth stomach. The two first cavities are, at this period, closed up, for, not possessing any proper gastric juice, they have no power of coagulating milk, which we have above shown is the first step towards its digestion. This power, however, is possessed in the highest degree by the fourth stomach, into which, therefore, the milk is directly carried; and while the animal continues on this food there is no rumination. But as soon as solid food begins to be swallowed, it forces open, as it were, the sides of the tube at the end of the gullet, escapes into the cavity of the first stomach, which then commences its duty, and thenceforth the animal ruminates.

It is scarcely necessary to draw attention to so very obvious an instance of prospective design. The young animal is furnished with two additional stomachs, of no use to it in early life, but which become necessary as it advances towards maturity. We may, however, learn from it to be cautious how we deny that a part can have use, because we do not immediately perceive it.

The third stomach, which is the smallest, is termed *manyplies*, from the multitude of folds made by its inner membrane, which lying one over another, like the leaves of a book, have also procured for it the name of book-tripe. Between these folds the food sent down after the second mastication is made to pass, and as they take a semi-circular direction, its stay in this cavity is prolonged as much as possible. The number of these folds, or leaves, is about forty in the sheep, and one hundred in the ox. This opens directly into the fourth stomach, which is the true digesting stomach, furnished

* M. Flourens, who has opened the stomachs of many living sheep while digestion was going on, gives a somewhat different account of this part of the process. His views will be found in the *Annales des Sciences Naturelles*.

with a villous coat, with solvent gastric juice, and the other necessary accompaniments.

So far we may be considered as describing the digestive apparatus, not only of the ox, but of the sheep, goat, deer, and all ruminants with horns. A still more complicated structure occurs in the camel, dromedary, and llama, which are without horns. The most accurate accounts we have of this are, perhaps, Cuvier's examination of the stomachs of a llama, and Sir Everard Home's of those of a camel. We shall rather extract from the latter, inasmuch as the habits of the animal are better known, and also, because Sir E. Home had the advantage of examining a full-grown animal, while Cuvier's was only in its fœtal state. The differences, however, were really very trifling.

In 1805 the curators of the Hunterian Museum at the London College of Surgeons had an opportunity of purchasing a camel, which was in a dying state. They gladly availed themselves of the opportunity thus afforded of furthering our acquaintance with the peculiarities of its structure, which we only had an opportunity of learning before through the medium of a dried preparation made by Mr. Hunter.

They appointed Sir E. Home, as professor of comparative anatomy to the college, and some other gentlemen, to examine and report on the appearances found on dissection.

The camel, the subject of the following observations, was a female, brought from Arabia, twenty-eight years old, and said to have been twenty years in England. Its height was seven feet from the ground to the tip of the anterior hump.

At the time it was purchased it was so weak as to be hardly able to stand. It got up with difficulty, and almost immediately knelt down again. By being kept warm and well fed, it recovered so far as to be able to walk, but was exceedingly infirm on its feet. It drank regularly every second day six or seven gallons of water, but refused to drink in the intervening period. It took the water slowly, and by mouthfuls, until it had done. The quantity of food it consumed daily was, one peck of oats, one of chaff, and one-third of a truss of hay.

In the beginning of February, 1806, it began to shed its coat, and cold winds coming on in March, it suffered much, refused its food, and was reduced to an extreme state of debility. In this state it was thought advisable to put an end to its misery; and it occurred to the committee that if this was done soon after it had drunk a quantity of water, the real state of the stomach, that adapts it for its travels in the desert, might be ascertained. On the second of April, by giving the animal hay, mixed with a little salt, it was induced to drink three gallons of water, not having taken any the three preceding days, nor shown the least inclination to do so.

Three hours after drinking, its head was fixed to a beam, to prevent the body falling after death; it being an object to examine the intestines with as little disturbance from their natural situation as possible. In this situation it was immediately killed, by dividing the spinal marrow close to the head with a sharp double-edged poniard. In two hours the cavities of the chest and abdomen were laid open.

The first stomach, or paunch, was the only part of the contents of the abdomen that appeared in view. Towards the left side it was quite smooth, but towards the right it was irregular, and wrinkled in such a manner, as to show that there was a collection of cells at that place. It was evident to the feeling, that these cells contained air, but no part of the solid food with which the general cavity was distended. More cells were noticed in the posterior and lower part of the cavity, and these felt as if filled with fluid. To ascertain this, an opening was made, and about a pint of water, of a yellowish colour, but unmixed with any solid matter flowed out.

The first cavity was now carefully laid open on the left side, to avoid interfering with these cells, and the solid contents were all removed. It was then observed that the water contained in the cells of the second cavity was quite pure, while that in the cells of the first was tinged by its solid contents. No part of the solid food, however, had entered these cells, nor was any of it found at all in the second cavity: these cavities having their orifices so constructed as to prevent the food from entering them, even when empty.

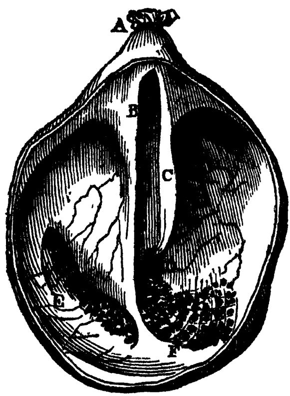
On measuring the capacities of these different reservoirs in the dead body, they were as follows:

The anterior cells of the first cavity were capable of containing one quart of water when poured into them; the posterior cells, three quarts. One of the largest cells held about a wine-glass full: and the cells of the second cavity about four quarts. This, however, must be considered as much short of what these cavities can contain in the living animal, since there are large muscles covering the bottom of the cellular structure to force out the water, which must have been contracted immediately after death, and by that means had diminished the cavities. By this examination it was proved, in the most satisfactory manner, that the camel, when it drinks, conducts the water in a pure state into the second cavity; that part of it is retained there, and the rest runs over into the cellular structure of the first, acquiring a yellow colour in its course.

This confirms the account given by Buffon, in his examination of the camel's stomach, as well as that of travellers, who state that when a camel dies in the desert, they open the stomach and take out the water that is contained in it to quench their thirst.

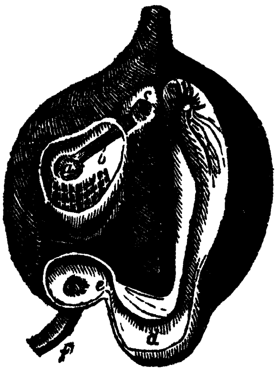
It appears singular, that after this fact was so clearly demonstrated, and so explicitly stated, M. Rudolphi, a continental physiologist of great distinction, should advance the opinion that the liquid found in the cells of the camel's stomach was not the water swallowed, but a certain watery secretion made from the sides of the stomach; and that on no better grounds than that he believed such to be the case in a plant (*Nepenthes distillatoria*), in certain receptacles of which a like watery matter is found. It only shows that ingenious men sometimes take great pains to go wrong, and that the labours of our English physiologists are not sufficiently studied or appreciated by their continental brethren.

That the second cavity in the camel contained water, had been generally known: but by what means the water was kept separated from the food, so as to be sufficiently pure for drinking, had not been ascertained. Neither was it known, as the second cavity was evidently merely a receptacle for liquids, by what means the offices of the second cavity in horned ruminating animals were provided for. These offices, it will be remembered, were to receive the food after it had been macerated in the first stomach, to supply it with moisture, and mould it into pellets fit to be sent up through the gullet for a second chewing. A view of the first stomach, as it appeared when laid open, will explain these points.



First Stomach of the Camel, together with opening of second Stomach.

Now in this cut we observe, that from the termination of A, the gullet, run two strong muscular bands; the one of which, B, is continued quite across the paunch, making a sort of partial division, while the other, C, runs only as far as the opening of the second stomach, D, and turning short to the right, passes through its upper part, and terminates at the opening of the third stomach. Beyond the opening of the second stomach, we observe a certain number of transverse muscular bands running from the great longitudinal ridge, B, and gradually losing themselves on the sides of the stomach. They are crossed by others, so as to form themselves into cells, each capable of admitting water, and, by contracting their orifices, of preventing the entrance of solid food. Similar cells, but smaller, are observed at E, the right side of the cavity.



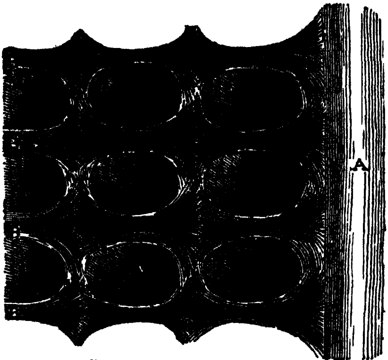
Second, third, and fourth Stomachs of the Camel.

a opening from first to second stomach.
b second stomach; *c* third stomach.
d e fourth stomach, partially separated by a contraction.
f the duodenum, or commencement of the intestines.

The structure of the second stomach is also of this cellular nature, except a smooth passage on its upper part, continued along the side of the muscle C, and assisting it in conveying the food to the orifice of the third. It is clear, then, that food coming along the gullet will, when matters remain as at present, drop into the great first cavity. But the muscles B and C, being under the command of the will, the animal, when it drinks, can cause them to contract towards each other, by which means the canal between them is narrowed and converted almost into a tube, that conveys the liquor direct from the extremity of the gullet into the second cavity; and when the cells of this cavity are full, the rest runs off into the cells F of the first cavity immediately below, and afterwards into the general cavity. We are now prepared to answer the question, How is the food prepared for regurgitation? When first swallowed, it is received in the smooth part of the paunch; from this it is gradually transferred, after maceration, &c., to the cellular part at F. Here it is supplied from the cells with the necessary moisture, formed into pellets, and being situated exactly at the bottom of the canal B C, is by a slight muscular effort thrown into it, and thence conveyed along the gullet up to the mouth. We also see, that when these cells are empty, they can readily receive a fresh supply from the second stomach, which is situated just over them; and this explains the mechanism that enables the camel at one time to take in water enough for several meals, to supply it to each at the required time, and in just proportions, and to preserve it pure and unmixed with its food, until the necessity calls for it. But we have not yet seen all the uses of our muscular bands. The food is in the mouth; it has undergone its second mastication, and is now to be swallowed again. The bands contract themselves into a tube, but c contracts also in its length. By this it draws forward the opening of the third stomach, *c*, into the second, *b*, closes the muscular bands that separate the cells in this latter and enables the morsel to pass over them into the third, which in the camel being very small, soon transmits it into the fourth, *d*, where digestion finally takes place.

The only thing that now remains to be observed respecting this, is the nature and structure of the cells; and Mr. Clift's very excellent sketch leaves us nothing to desire on this point.

Here A represents part of the long muscular ridge that traverses the entire stomach; B the transverse muscular bands that run from it, and which, being cut at right angles by other bands, form the cellular cavities. It is evident, that by their contraction the mouth of the cells would be closed, while the contraction of the muscular fibres which we perceive running at the bottom of the cells would tend to make them shallow, and so discharge the water they might contain. But we would



Cells in the Camel's Stomach.

more particularly wish to draw attention to the close similarity observable between this and the magnified view of the mode in which the muscular fibres of the human stomach intersect, as shown at page 71.

This illustrates an observation often made, and which, indeed, there are many things tending to confirm, viz., that classes of animals seem framed after a certain model or design, certain parts of which are developed in some species, and the remaining parts in others: the rudiments, however, of all these parts are to be found in all the animals of the class, even where we cannot conceive their existence to be of any possible use, except as showing the type.

This doctrine, though ingenious and probable, is by no means supported on a sufficient number of observed facts, to enable it as yet to rank as an established general truth. It will immediately recall to the recollection of the classical reader Socrates' doctrine of *Archetypes*, more fully dilated on by Plato; and it is sufficiently interesting to observe how a truth has been at remote periods almost reached by the rays of knowledge, and then laid for centuries in the shadows of ignorance; how Hippocrates obscurely propounds the doctrine, the demonstration of which has immortalized Harvey, and how a passage in Seneca has seemed to many almost prophetic of the discoveries of Columbus*.

On a comprehensive view, then, of the stomachs of the ox and the camel, it appears that in the ox there are three stomachs formed for the preparation of the food, and one for its digestion. In the camel there is one cavity fitted to answer the purposes of the first two in the ox; a second employed as a reservoir for water, having nothing to do with the preparation of the food; a third, so small and simple in its structure, that we can scarcely attribute to it any particular office, except as a sort of ante-chamber to the fourth, which is the true stomach, and that in which digestion takes place.

In the stomachs of ruminating animals, the processes which the food undergoes before it is converted into *chyme*, are more complex than in any others. It is cropped from the ground by the fore-teeth, then passses into the paunch, where it is mixed with the food in that cavity; and it is worthy of remark, that a certain portion is always retained there; for although a bullock is frequently kept without food seven days before it is killed, the paunch is always found more than half full; and as the motion in that cavity is known to be rotatory, by

* It has been suggested that a short explanation of these allusions may be necessary. The doctrine of Archetypes was, that previous to the existence of the world, and beyond its present limits, there existed certain Archetypes—the embodyment (if we may use such a word) of general ideas; and that these Archetypes were models, in imitation of which all particular beings were created. Thus that the general idea or image of a man had a real existence, to which all individual men bore a resemblance. The passage in Seneca is the well-known one in his *Medea*.—Act iii. v. 375.

Venient annis
Sæcula seris, quibus oceanus
Vincula rerum laxet, et ingens
Pateat tellus, Typhisque novos
Detegat orbes; nec sit terris
Ultima Thule.

Which means that "in future years a period shall come when the limits of the world shall be extended, new lands discovered, and Thule no longer considered the remotest region of the earth."

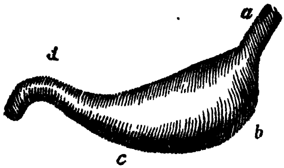
For the passage from Hippocrates, see the Chapter on the Circulation of the Blood.

the hair-balls found there being all spherical or oval, with the hairs laid in the same direction, the contents must be intimately mixed together. The food is also acted upon by the secretions belonging to the first and second cavities, for although they are lined with a cuticle, they have secretions peculiar to themselves. These secretions are ascertained by Dr. Stevens' experiments to have a solvent power in a slight degree, since vegetable substances contained in tubes were dissolved in the paunch of a sheep.

The food thus mixed is returned into the mouth, where it is masticated by the grinding-teeth; it is then conveyed into the third cavity, and after a short delay here, is transmitted to the fourth. The changes which are produced on the food in the three first cavities, are only such as are preparatory to digestion; it is in the fourth alone that that process is carried on. The upper portion of this stomach is furnished with *plicæ*, or folds, and answers to the cardiac portion of the human stomach. The gastric glands pour out their solvent fluid here, and act on the food; and it is from the presence of these glands in the stomachs of different animals, that their existence in the human stomach has been inferred. In the upper part of the fourth stomach of the deer, small orifices are seen in the internal membrane, leading to cavities which appear to be the opening of these glands. In the lower portion, the formation of *chyme* is completed. It terminates at the *pylorus*, which separates it from the intestines. In some of the whale tribe there would appear to be a still greater complexity, as we find Mr. Hunter describing five, and even seven, stomachs in these animals. But, in truth, they are to be looked on as so many pouches or divisions of one cavity, rather than as separate or distinct organs; neither is there sufficient diversity in their functions to entitle them to this latter consideration.

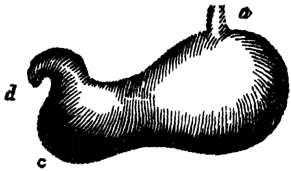
Those singular animals, the *ornithorhynchi*, brought from the New Continent, afford, in their digestive organs, the link that connects the stomachs of quadrupeds with those of birds. And, as if they were in every respect to contradict our preconceived ideas, we find the gastric glands in them congregated about the pylorus, instead of occupying the cardiac extremity of the stomach, as in other animals. An idea of the gradation may be had from this sketch.

Fig. 1.



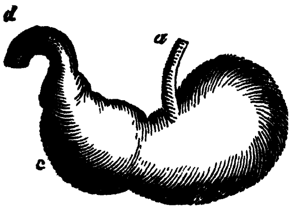
LYNX.

Fig. 2.



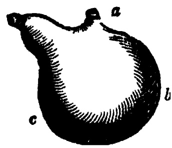
MAN.

Fig. 3.



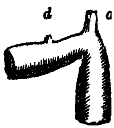
HARE.

Fig. 4.



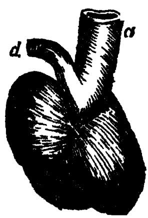
ORYCTEROPUS, OR CAPE ANT-EATER.

Fig. 5.



ORNITHORHYNCHUS, OR DUCK-BILLED ANIMAL.

Fig. 6.



TURKEY.

This scale scarcely requires explanation. In each of the figures, *a* is the gullet, *d* the duodenum, *b* the cardiac portion of the stomach, *c* its pyloric portion. In the three first figures we see how the cardiac portion swells more and more to the left of the gullet, as the food, being less digestible, requires to be longer detained. The three following figures show well the gradation between *mammalia* and birds, in which we should chiefly observe the approximation of the two orifices of the stomach, so that at last they appear to meet at a common point.

Another circumstance worthy of note here, is the accurate relation preserved between the form of the stomach and nature of the teeth. In the lynx (No. 1) the teeth are in great perfection, the incisors, the fangs, and the grinding-teeth being all present and well developed. In man (No. 2) the three kinds of teeth are also to be found, but of smaller size, the fangs having dwindled into eye-teeth, as they are no longer intended to be the means of catching and killing prey, and the grinding-teeth being somewhat flattened and modified to suit the admixture of vegetable with animal food. In the hare (No. 3), and other gnawing animals, the fangs are quite gone, nothing remaining but the long incisors in front, and the grinders behind. It is true, that at a late meeting of the Académie des Sciences, M. Geoffroy St. Hilaire proposed considering the front-teeth of the *rodentia* as canine rather than incisor-teeth, but this was merely in consonance with a theory of his own, besides, it is indifferent to our present argument what they may be called. In No. 4, the orycteropus, or Cape ant-eater of Pennant, the teeth are still further reduced, there being neither incisors nor fangs, but simply six grinding-teeth on each side in each jaw, and those of a very imperfect kind, having no distinct root or crown, and resembling small cylinders perforated with minute tubes. The imperfection is still greater in the duck-billed platypus (No. 5), which, in place of teeth, has merely two hard horny prominences towards the base of the bill at each side. Finally, the beak of the bird (No. 6) is totally deprived of teeth, and a single glance at the scale will show how, as the organs of mastication thus decline, the provision for retaining the food in the stomach becomes more complete, while a moment's reflec-

Hunter states, by wanting the peculiar cartilaginous or horny lining. The object of its strength is to enable them to break the shells of the small *mollusca*, on which they feed. The stomachs of some *crustacea*, as the crab and lobster, present the peculiarity of being framed on a skeleton, and furnished with teeth, which are wanting in the mouth. Insects present this organ in all the before-mentioned varieties; the earwig rivals the *crustacea* in having the upper orifice of its stomach furnished with a double row of teeth; and the mole-cricket resembles the *ruminants*, in having no less than four distinct and separate cavities.

But we must return to our most important subject, the human stomach, and consider some points connected with it, on which we have not yet touched. These are the sensations of hunger and thirst, and the kinds of food most suited for our use.

Hunger has been very differently explained. Some ascribe it to an uneasiness arising in the stomach from its being empty and unoccupied; others to the rubbing together of the internal coats of its opposite sides; others to the dragging of the liver, now no longer supported by a full stomach; others to the action of the gastric fluid on the coats of the stomach. This last theory seems most favoured by Dr. Wilson Philip, who adduces, in support of it, the following case. "A person was induced to remain four-and-twenty hours without food, and then, in place of indulging his appetite, to provoke vomiting. A quantity of a clear, glairy fluid was brought off, which was presumed to be the gastric juice, and the person no longer felt any desire to eat." But the gastric juice can only act on the coats of the stomach by its bulk, or its chemical properties. The former clearly is not the cause of hunger, as then a person would be most hungry when the stomach was most full; and as for the latter, we have shown above that gastric juice can only act on dead matter. Besides, many persons lose their appetite when the regular time of their meal is past, though we cannot suppose that at the same time the gastric juice has disappeared from their stomachs. [Dr. Beaumont, however, denies that the gastric juice is secreted, except upon the application of food or some other stimulus.] Neither is the mere sense of emptiness sufficient to account for the feeling of hunger, which we know is increased by the application of cold to the surface, and instantly by swallowing cold liquids. The explanation by friction is equally unsatisfactory; because friction, if it does really occur, cannot be greater than that of the sides of the stomach against its contents immediately after a meal, when the organ is in great action, but at which time hunger does not exist. Hunger has been attributed also to a sympathy of the stomach with a general feeling of want in the system. But hunger is removed as soon as a due proportion of food has been swallowed, and long before it is digested, and carried into the general system. Thus fowls are satisfied when their crops are filled, although their food is not even ground preparatory to digestion until it reaches the gizzard; and ruminating animals cease to collect fresh food before they begin to chew that with which their stomachs are distended. From these considerations Dr. Elliotson supposes that hunger may be a sensation connected with the *contracted* state of the stomach. We know that as the stomach becomes empty, it contracts, not by the falling in of the sides, but by the regular action of its circular fibres. It always then maintains its cylindrical form, and we have had occasion to see this remarkably exemplified in some *cholera* cases, in which the stomach was so shrunk in as to resemble, at first sight, a portion of the small intestine, yet was its form preserved. Dr. Elliotson further supports his opinion, by the observation that such things as we may suppose to increase the contraction, also increase the appetite. Thus a draught of cold liquid, which cannot but contract the stomach, and corrugate its inner coat, increases hunger; and acids, bitters, and astringents, have the same effect, and from their nature may be supposed to act in the same way. Again, it is diminished by heat, and everything that relaxes. It ceases as soon as the stomach is filled, no matter whether the substances used be nutritive or not. The Otomacs, during the periodical inundations of the rivers of South America, when the depth of the waters almost entirely prevents fishing, appease their hunger for two or three months, by distending their stomachs with prodigious quantities, a pound and upwards in the day, of a fine, unctuous, strong-smelling, yellowish-gray clay, slightly baked, and destitute of all organic substance, oily, or farinaceous. The Kamtschatkans sometimes appease their hunger by distending their stomachs with saw-dust, for the want of something better. This, however, we know now to contain some particles capable of being digested.

On the whole, no single cause seems as yet sufficient to account for all the facts connected with hunger. We must, perhaps, look to a combination of several of those we have mentioned, and, above all, acknowledge the powerful influence of habit and the nervous system. The faquirs and dervises, who are, by their vows, obliged to long fasts, blunt the sensibility of the nerves by the free use of opium and tobacco, which they find to diminish the pangs of hunger. The same object is attained amongst some tribes of northern Asia by a girdle braced tightly over the stomach, and laced behind with cords, drawn closer as the uneasiness increases. Some attribute this to the principle on which pressing on a limb lessens the communication of pain from its extremity: Dr. Elliotson accounts for it by the fact, that a tight bandage diminishes the pain arising from strong muscular contraction; and this, we have shown, is the mode in which he accounts for hunger.

Thirst is a still more imperious call than hunger, and is much less patiently endured. The blood as it circulates is constantly pouring out its watery particles in the form of perspiration, exhalation from the lungs, the saliva, the secretions that moisten the serous membranes, and many other such ways. As it parts with these, its saline particles become more concentrated, the blood itself more stimulating, the jaws and throat become parched and dry, and we are thus admonished that a further supply of drink is necessary to the system. The use of salted food hurries the demand for this in two ways, both by increasing the quantity of saline matter in the circulation, and by stimulating the salivary glands so strongly, as to produce too copious a flow of that liquid, which is thus sooner exhausted. A traveller exposed to the scorching heat of summer, finds it advantageous to mix spirits with his water, which by itself would not suffice to produce that secretion from the salivary and mucous glands necessary to moisten the mouth. And, on the same principle, for persons affected with fever, in whom, from the stoppage of the secretions, the thirst is very intense, the physician directs either the suspension of some sapid or farinaceous matter in the drink, toast-water, barley-water, &c., or the mixture of an acid, lemonade, imperial, and the like. Violent passions that totally destroy the desire for food, on the contrary increase that for drink. Rage and terror dry up the mouth and throat, and cause violent thirst; and the worthy Vicar of Wakefield, when his son Dick was reciting the elegy on the death of a mad dog, called to his wife for a bottle of gooseberry wine, adding as a reason, "For grief, you know, Deborah, is dry."

A singular proof of the influence which agitating passions have in the suppression of the salivary secretion, is thus mentioned by Mr. Annesley, in his admirable work on the *Diseases of India:*

"The secretion of the saliva seems to be under the influence of the same mental emotions as affect the functions of the stomach. Fear, anxiety, and various other depressing passions, diminish digestion, and, most probably, produce this effect, by stopping the secretion of gastric juice. Observation shows us that they have a decided influence in lessening, or even in entirely arresting the secretion of saliva; a circumstance not unknown to the observant nations of the east. In illustration of this, it may be mentioned that the conjurers in India often found, upon this circumstance, a mode of detecting theft among servants. When a robbery has been committed in a family, a conjurer is sent for, and great preparations are made. A few days are allowed to elapse before he commences his operations, for the purpose of allowing time for the restitution of the stolen property. If, however, it be not restored by the time fixed, he proceeds with his operations, one of which is as follows. He causes a quantity of boiled rice to be produced, of which all those suspected must eat; and after masticating it for some time, he desires them all to spit it upon separate leaves, for the purpose of inspection and comparison. He now examines this masticated rice very knowingly, and immediately points out the culprit, from observing that the rice which he has been masticating is perfectly dry, while that which was masticated by the others is moistened by the saliva."

The length of time during which perfect abstinence can be borne, without death following, is not well ascertained. Indeed, we may wonder that men have attempted to fix any particular period, unless they could first show that digestion and assimilation were equally rapid in all. The effects of a protracted abstinence are, a diminution of the size of the body, and a prostration of strength, which soon become apparent; discoloration of the fluids, especially the blood; suppression of all discharges from the bowels though those from the kidneys continue, and it is remarkable that they are increased if the body be frequently drenched with water; extreme sensibility; sleeplessness; intolerable thirst; painful sensation in the region of the stomach; these, however, cease after a few days, leaving only a weakness and sense of sinking. But a material alteration in the mind is also taking place. Imbecility first comes on; this is succeeded by ferocity. Each looks with horror and aversion on his fellow-sufferer. Men become wild, quarrelsome, turbulent, regardless of their own fate and that of their neighbours. Reason yields her seat: idiotcy follows verocity; or, delirium coming on, the sufferer dies raving mad. It is only this can account for the horrible atrocities committed in such cases. The shipwrecked sailors, in the extremity of starvation, draw lots which shall die to feed the rest; women, pressed by the same feeling, have devoured their own children, as we read in

Josephus, happened at the siege of Jerusalem; and in Holy Writ, when Ben-hadad besieged Samaria; and Captain Franklin was assured, in his journey to the Polar Sea, "that men and women are yet living, who have been reduced to feed upon the bodies of their own family, to prevent actual starvation; and a shocking case was cited to us of a woman who had been principal agent in the destruction of several persons, and amongst the number, her husband and nearest relatives, in order to support life."

The strong and robust die the soonest from want of food, for in them digestion is most powerful; and from the energy of all the vital functions the supply is most quickly exhausted. The knowledge of this fact, for which he was probably indebted to Hippocrates, has enabled Dante, true to nature, in his thrilling episode of Ugolino, to depict the father as perishing the last, after having witnessed, in all the agonies of rage and despair, the sufferings and death of his four sons who were imprisoned with him. The opinion that this order was not accidental or poetical, is strengthened by his making the father die on the *eighth* day, the very period at which Hippocrates declares abstinence to be necessarily fatal. That it was not an actual description of what did occur, is also certain; for Morgagni tells us, that when this unfortunate family had been shut up, the keys of the prison were flung into the Arno, that no one should witness or assist at the heart-rending spectacle of their mortal agony.

A tradesman, impelled by a succession of misfortunes, retired to a sequestered spot in a forest in Germany, and there resolved to starve himself to death. He commenced putting his determination in force the 15th of September, 1818, and was found eighteen days after, still living, although speechless, insensible, and reduced to the last stage of debility. A small quantity of liquid was given him, after which he expired. By his side was found a pocket-book and pencil, the former containing a daily journal of his state and sufferings up to the 29th of September, four days before his death. He had constructed a little hut of bushes and leaves. On the 17th of September he complained of suffering from cold; on the 18th his thirst was so intolerable that, to appease it, he licked some dew from the surrounding vegetables. On the 20th he found a small coin, and with difficulty reached an inn, where he purchased some beer; the beer failed to quench his thirst, and his strength was so reduced, that he took three hours to accomplish the distance, which was but two miles. On the 22nd he discovered a spring of water, but, though tormented with thirst, was obliged to forbear drinking, from the agony the cold water caused in his stomach, exciting vomiting and convulsions. The 25th made ten days since he had taken any thing, except beer and water. During that time he had not slept at all. On the 26th he complained of his feet being dead, and of being distracted by thirst; he was too weak to crawl to the spring, yet being dreadfully susceptible of suffering. The 29th of September was the last day on which he made a memorandum.

The most extraordinary cases of protracted abstinence have been met with in weak and infirm women, living in obscurity and inaction, and in whom life, nearly extinct, just showed itself in a scarcely perceptible pulse, and a slow indistinct respiration. One of the best authenticated of these is, that of Janet Macleod, published in the *Philosophical Transactions* for 1777, and certified by Dr. Mackenzie, the physician who drew up the report, and by the sheriff depute and other magistrates of Ross-shire. The girl had been healthy until the age of fifteen, when epileptic fits and fever reduced her to the lowest state of debility. Her appetite gradually diminished, until at last she refused all kind of sustenance; her jaws became closely locked, so that it became necessary that her father should open them with a knife, when they attempted to make her swallow anything. It was, however, in vain. She constantly rejected whatever was offered to be put into her mouth; and from Whitsuntide, 1763, for a period of four years, they never could ascertain that anything passed down her throat, except a pint of water, which she drank once at a draught, and a very small quantity of water, from a mineral spring in the neighbourhood, with which they filled her mouth at another time. During this period she generally lay on her side without moving, her eyes closed, her pulse beating faintly, her legs contracted, and bent backwards and upwards. Towards the end of the fifth year her jaws became unlocked, she appeared a little more lively, and partook occasionally of a small quantity of oaten or barley-cake, crumbled in the hollow of her hand, and moistened with milk. She was able to leave her bed, but the account does not proceed so far as to say whether she ever reached any degree of health and strength.

Cases of enormous gluttony have been most common in the other sex. At the age of seventeen, Tarrare, a Frenchman, born at Lyons, was able to eat a quarter of beef in twenty-four hours. Having left his parents, and travelled towards Paris, sometimes begging, and sometimes stealing, he attached himself then to a show, and soon gained great celebrity by devouring a huge basketful of apples, for which one of the spectators had undertaken to pay, and afterwards swallowing a quantity of flints, corks, and other such substances. Being admitted into the Hôtel-Dieu, on account of violent colics brought on by these tricks, he was narrowly prevented swallowing the watch, chain, and seals of M. Giraud, the house-surgeon. At the commencement of the revolution he joined the mob, and procured, by this means, enough of food. When the war broke out, he entered the army. His comrades, having at first the means of procuring themselves better food, allowed him to devour their rations; but this did not last long, and Tarrare, nearly famished, fell ill, and was admitted into the hospital at Sulzer. Here he was recognised by M. Courville, who had formerly seen him at the Hôtel-Dieu, and who now took him under his charge for the sake of observing so singular a case. He had a fourfold allowance, but not content with that, proceeded to eat up what was left by the other patients, the waste of the kitchen, the poultices, and every thing that came in his way. He devoured dogs and cats, until, as M. Percy assures us, they fled at the sight of him. In the presence of M. Lorenze, physician-general to the army, he seized a large cat alive, by the throat and paws, tore open its belly with his teeth, sucked its blood, and devoured it, leaving nothing but the skeleton. In a few hours after he threw up the fur, just as birds of prey do. Large snakes he was fond of, and despatched them with the greatest facility; and one day he gobbled up, in a few minutes, all the dinner prepared for fifteen German labourers, which consisted of four bowls of curd, and two immense dishes of dough boiled in water with salt and fat.

It occurred to M. Courville that he might be made useful in conveying letters requiring secrecy, when there was danger of their falling into the hands of the enemy. He proposed to him to swallow a lancet-case, in which he had placed a sheet of white paper. This Tarrare readily did, and returned the case next day with the paper unsoiled. He was now taken before the general (Beauharnois), in whose presence he swallowed thirty pounds of raw liver, and afterwards the case, in which the general had placed a letter to one of his colonels that had been taken prisoner. Tarrare was not very fortunate in this embassy. He was caught by a Prussian outpost, and as nothing could be found on him, was beat as a spy, and imprisoned for about thirty hours. Disgusted with this unhandsome treatment, he declared, on his return, that he wished to be cured of his omnivorous propensities, and accordingly was readmitted into the hospital, where opium, tobacco, and various other remedies were tried without success. His insatiable appetite still continued, and he was in consequence obliged to have recourse to the most disgusting means of allaying it. Sewers and slaughter-houses were ransacked; he disputed their prey with the dog and the wolf; and at last strong suspicions of cannibalism caused him to be driven from the camp. From this time he was not heard of until four years after, when M. Percy found him at the hospital of Versailles in the last stage of a consumption, no longer voracious, but weak, wasted, and labouring under a purulent diarrhœa. He shortly died, and his body almost immediately became a mass of putridity.

He was of the middle height, thin and weak. His cheeks were wan and furrowed, and when distended enabled him to conceal in them ten or twelve good-sized eggs or apples. This approach to the cheek-pouches of bats, apes, hamsters, and other ravenous animals, deserves notice. On being opened, his stomach was found to be of an immense size, and, as well as all the intestines, in a state of suppuration. During life he was always offensive, hot, and in a sweat. When he had eaten but moderately, he was able to wrap the skin of his belly almost round his body. After a full meal, he used to retire to a corner, and fall into a brutal state of insensibility.

The principal facts of this case may be considered illustrative of most cases of excessive gluttony, so that we need not add any more*. But a remarkable instance of the power which the stomach has of preserving itself from the injuries of foreign bodies, is found in the following singular account of a man who lived ten years after having swallowed a number of clasp-knives. To render it still more interesting, we shall quote the description drawn up by the man himself, while in Guy's Hospital, and read, after his death, to the Medical and Chirurgical Society of London, by the late Dr. Marcet. It is headed,

"*Narrative of John Cummins, drawn up by himself.*—A miraculous recovery of a seaman, who swallowed a number of knives at three different times, as you see in this little book."

The little book begins by informing us, that in the month of June, 1799, he and some of his shipmates, being at Hâvre, went into a tent and saw a man swallow a knife, for which sight they paid a livre each. On their return to the ship, they

* In the third volume of the *Transactions of the Royal Asiatic Society* is an account by Major General Hardwicke of a Hindú, who, in his own presence, ate up an entire sheep, and was said to find no difficulty in finishing two at a single repast.

sat down and "began to enjoy the former part of the night as follows:—After drinking very hearty, one of the company opened the story concerning the above play-actors, which, he repeated, that it was an extraordinary affair to swallow knives. The author made answer directly, and told him that he could swallow knives as well as they could. The company present took notice of the above answer being made so quick, and for the curiosity of the circumstance, made a serious inquiry if he was man enough to perform what he had already stated. He did not like to go against his word, neither was he anxious to take the job in hand; but by having a good supply of grog inwardly, he took his own pocket-knife and tried it first, which slipped down his throat with great ease; and by the assistance of some drink, and the weight of the knife, conveyed it into his stomach. But still the spectators seemed not satisfied with one, but made further inquiry if he could swallow any more. He replied in a word, 'All the knives on board the ship.' By this answer there were three more knives presented upon the table, which he swallowed in a few minutes, the same way as the former. And by this bold attempt of a drunken man, the company was well entertained for that night." In the course of two days after he passed three of the knives, but never could ascertain what became of the fourth. However, it never gave him any pain or uneasiness, "and shortly after he took his departure from France, and never thought on swallowing any more knives for the space of six years; after which you shall see as follows:"—

"Boston, March 13, 1805, was in company, where he gave his report of his success in swallowing knives in France, in June, 1799. Two or three of the company told him plain to his face, that it was impossible for any man to do such a thing, and that it was nothing but false report, which he took it very highly affronted; but, after considering a short time, told the company he was the same man still, and, if it was agreeable, that he would satisfy their curiosity. One small knife was presented to him, which he swallowed instantly: in the course of that night he swallowed five more, which made six in all. Next morning he had a thousand visitors, but gave very few of them admittance. It happened in the course of that day that he swallowed eight more, and six the night before, which made fourteen; and that was the 14th of the month; so he had swallowed a knife for every day the month was old. Next morning was the 15th; he was taken very ill, with constant vomiting and pain in his stomach. Directly he was brought to Charleston Hospital, and betwixt that period of time and the 28th following, was safely delivered of his cargo, and the whole of them are preserved in the infirmary of that city." His next fit of swallowing was brought on in nearly the same manner, on board H. M. S. Isis, December 4th, 1805; and in the course of that night he swallowed five knives.

"Next morning, being the 5th day of the month, the ship's company were anxious to see the performance renewed the second time; by the encouragement of the people, and the assistance of good grog (and his lot was ordained to be miserable after, in consequence of the same), he swallowed nine that day to his own knowledge; and the spectators informed him afterwards that he swallowed four more, that he knows nothing about: they were all clasp-knives, and some of them very large." Next day he was obliged to apply to the surgeon, and continued for a long time an invalid, occasionally suffering much pain, which was always increased just before he passed parts of the knives.

"June 12th, 1807, he was discharged this ship in consequence of his complaint, and likewise being found at the survey unserviceable; after which he was admitted into Guy's Hospital, under the care of Dr. Babington. Great many never believed such a circumstance. After five weeks being in the hospital, was presented out, and was in lodgings for the space of five weeks; but finding himself getting worse, was obliged to make the second application, and was re-admitted under his physician again."

There is little to be added to this narrative, which was found in the pocket of the unfortunate man after his decease, but that he became gradually worse, and died, March 1809, in a state of extreme emaciation. On opening his stomach, between thirty and forty fragments were found in it, being evidently pieces of handles, blades, and back-springs of knives. They are preserved in the Museum of Guy's Hospital.

Many disputes have arisen respecting the kind of food on which man should naturally subsist; but these disputes tend to nothing, for man would be in vain adapted for living in all varieties of climate, were he not also capable of using great variety of food. Thus many at present live solely on potatoes, dates, or other vegetables. The wandering Moors have scarcely any other food than gum. The inhabitants of Kamtschatka, and many other shores, scarcely any other than fish. The shepherds in the province of Caraccas, in South America, on the banks of the Oronoko, and even some tribes in Europe, live almost wholly on flesh. Some barbarous nations devour raw animals; some eat spiders, and different species of crustaceous and molluscous animals. Many South American tribes eat clay as a luxury; the Guajeroes, on the west of the Rio de la Hache, carry a little box of lime, as sailors do a tobacco-box; and German workmen at the mountain of Kiffhönser spread clay instead of butter on their bread, and find it very satisfying, and easy of digestion.

The articles of diet generally employed by every nation and class of society are much determined by the facility with which they are procured. Animal food we find more used in cold climates, and vegetable in warm. A mixture of the two, however, is considered more agreeable, and, at the same time, better suited to our necessities. Dr. Prout reduces all the articles of nutriment used by the higher animals to three classes; the saccharine, oily, and albuminous. The first comprehends sugars, starches, gums, and some other analogous principles; the second, oils, fats, alcohol, &c.; the third, other animal matters, and vegetable gluten, so abundant in wheat. He was led to this theory by observing that milk, the only article actually furnished and intended by nature as food, is essentially composed of three ingredients, the oily, butter; the albuminous, curd, cheese; and the saccharine which is found in the whey. From this he was by degrees led to the conclusion that all the alimentary matters, employed by man and the more perfect animals, might probably be reduced to the same three general heads. And this conclusion has been favoured by a course of experiments which he has since instituted. It remains to be proved whether animals can live on one of these classes exclusively, and Dr. Prout seems inclined to deny the possibility of this. But he must have forgotten the fact mentioned by Hasselquist, of the caravan of Abyssinians, who, having exhausted all their provisions in the desert, would have starved, had they not found among their merchandise a stock of gum, on which they subsisted for upwards of two months. There is no doubt, however, that the food used by us is, in general, a mixture of two, or all three, of those classes of nutriment; and the imitation of this mixture is the object of all our cookery and art in the preparation of our food. "Thus, from the earliest times, instinct has taught us to add oil or butter to farinaceous substances, such as bread, which are naturally deficient in this principle. The same instinct has taught us to fatten animals, with the view of procuring the oleaginous in conjunction with the albuminous principle, which compound we finally consume, for the most part, in conjunction with the saccharine matter, in the form of bread or vegetables. Even in the utmost refinements of luxury, and in our choicest delicacies, the same great principle is attended to, and the sugar and flour, the eggs and butter, in all their various forms and combinations, are nothing more than disguised imitations of the great alimentary prototype, *milk*, as presented to us by nature."

We have delayed long on the stomach and its contents, yet we are very far from having exhausted so copious and interesting a subject. Our limits would warn us to conclude, yet we cannot do so without returning to the case of Alexis St.

Martin, detailed at page 81, for the purpose of showing the practical bearing of Dr. Beaumont's experiments as regards the food of man. We have stated that Martin's stomach, having been perforated by a musket-shot, healed, the aperture not becoming closed; and that, in course of time, a valve grew down over it, which completely retained the food, unless it was intentionally lifted up, in which case the food, at any period of its digestion, could be extracted and examined. This, of course, enabled Dr. Beaumont to ascertain, with much precision, the relative digestibility of different kinds of food; and the following may be taken as a condensed view of the results of his experiments.

Of Farinacea.—Rice boiled soft, was perfectly converted into chyme in an hour; sago in one hour forty-five minutes; tapioca, barley, &c., two hours; bread, fresh, three hours—stale, two hours; sponge-cake, two hours thirty minutes.

Of Vegetables.—Cabbage, raw, two hours thirty minutes—boiled, four hours (vinegar much assisted its digestion); potatoes, roasted, two hours thirty minutes—boiled, three hours thirty minutes; carrots, boiled, three hours fifteen minutes; beet, boiled, three hours forty-five minutes; turnips, boiled, three hours thirty minutes; beans, boiled, two hours thirty minutes; parsneps, boiled, two hours thirty-one minutes.

Of Fruit.—Apples, sour and hard, two hours fifty minutes—mellow, two hours—sweet and ripe, one hour thirty minutes; peach, mellow, one hour thirty minutes.

Of Fish and Shell Fish.—Trout, boiled or fried, one hour thirty minutes; cod-fish, cured and boiled, two hours; oysters, undressed, two hours fifty-five minutes—roasted, three hours fifteen minutes—stewed, three hours thirty minutes; bass, broiled, three hours; flounder, fried, three hours thirty minutes; salmon, salted and boiled, four hours.

Of Poultry, Game, &c.—Turkey, roasted, two hours thirty minutes—boiled, two hours thirty-five minutes; goose, wild, roast, two hours thirty minutes; chicken fricasseed, two hours forty-five minutes; fowls, domestic, boiled or roast, four hours;

ducks, tame, roast, four hours—wild, roast, four hours thirty minutes.

Of Butchers' Meat, &c.—Soused tripe and pig's feet, fried or boiled, one hour; venison steak broiled, one hour thirty-five minutes; calf's or lamb's liver broiled, two hours; sucking pig, two hours thirty minutes; mutton, broiled, three hours—boiled, three hours—roast, three hours fifteen minutes; beef, fresh, broiled, three hours—roasted, three hours—lightly salted and boiled, three hours thirty-six minutes—old, hard, salted, four hours fifteen minutes; pork steak, broiled, three hours fifteen minutes—lately salted and boiled, four hours thirty minutes—stewed, three hours—roast, five hours fifteen minutes; veal broiled, four hours—fried, four hours thirty minutes.

Varieties.—Eggs, raw, two hours—roasted, two hours fifteen minutes—soft-boiled, three hours—hard-boiled or fried, three hours thirty minutes; custard, baked, two hours forty-five minutes; milk, two hours; butter and cheese, three hours thirty minutes; suet, four hours thirty minutes; oil, somewhat longer; apple-dumpling, three hours; while calf's-foot jelly was digested in little more than half an hour.

Such are the principal of Dr. Beaumont's facts, obtained as the means of numerous results: in many points they confirm, in others, differ from the tables of Doctors Paris, Prout, Wilson Philip, &c. They all, however, agree, that venison is one of the most easily digested of meats, that white fowls are in general more so than brown, beef than veal, and boiled meat than meat dressed in any other way. Oily food is peculiarly indigestible, and it was only consequent upon the use of such, that Dr. Beaumont found bile to enter the stomach during digestion. From subsequent experiments made out of the body, he ascertained the fact (which at once explained the above), "that oily or fatty food is sooner digested, when there is a small admixture of bile with the gastric juice." Of course, such food should be cautiously abstained from, by all persons labouring under bilious complaints.

We now proceed to trace the food in its further downward course.

Chapter V.

DIGESTION.

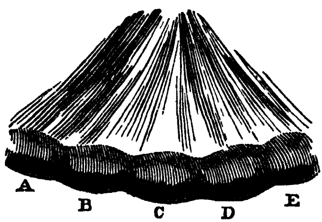
Part III. *Of the Intestinal Canal, and what takes place there: —of the Liver, Pancreas, Spleen, and Kidneys.*

The food we left at the pyloric end of the stomach, after being properly acted on by the gastric juice, and reduced to that grayish pulpy mass termed *chyme.* When the food, thus altered, is presented to the pylorus, the muscles of this latter relax; the ring widens; and a free passage is allowed the food from the stomach into the first part of the intestines.

That part of the alimentary canal, which extends generally in a very tortuous course, from the lower orifice of the stomach to the vent, or *anus*, is called the intestines. It is usually divided into the small intestines, and the great intestines; each of these are subdivided into three parts, those of the small intestines, named *duodenum*, *jejunum*, and *ileum;* while those of the great intestines are called *cæcum*, *colon*, and *rectum.* The order in which we have named them will show how these parts succeed each other as we pass from the stomach towards the vent.

There is always a relation observed between the form and size of the great intestines, the small intestines, and the stomach. It is generally true, that the intestinal canal is shorter in carnivorous, and longer in herbivorous animals, as compared with the length of the body. Omnivorous animals, such as man, hold a middle rank in this respect. There are, however, some exceptions to this rule; the seal has very long, and the sloth very short, intestines. In man the small intestines are about twenty-six feet long, or from four to five times the length of the body; the great intestines six feet, or one length of the body: the latter are termed *great*, from their superior diameter. The whole intestines, then, in man, may be said to be six times the length of the body, while in the lion they are but five times, and in the ram extend to twenty-seven times its entire length. As we go through the classes of vertebrated animals, these proportions diminish. In birds, the intestinal canal is to the length of the body, as two, three, four, or rarely, five to one. It is hardly twice the length of the body in many reptiles, and not so much in the frog; while in some fishes the alimentary canal is continued straight from the mouth to the vent, and therefore does not equal the length of the body. This is the case with the lamprey, skate, and shark.

Like the stomach, the intestines have three coats. The outer, derived from the serous membrane, binds them all to the back-bone, yet with so long a bond as to give them considerable freedom of motion. Inside this we find the muscular coat, consisting of fibres in a longitudinal and circular direction, by which the motions called *peristaltic* and *vermicular* are produced. It is by these motions that their contents are urged forward; and the mode in which this is done may be understood from this sketch.



Let A B C D E be different portions of the intestine, in the first of which, A, is contained a part of the alimentary mass, which has been softened down and formed into a pulp. Notice of its presence there is given by the nervous filaments with which this part is supplied. In consequence, the muscular fibres of A contract, and pass its contents into B; they do not, however, immediately relax, for B being now stimulated, contracts in turn. If, then, A were to relax immediately, as much of the contents of B would go back into A as forward into C.

But A remaining contracted, B discharges itself into C: A then relaxes, and B remains contracted until C has passed on its contents to D. If the motion be made back from C to B, and B to A, this is termed *anti-peristaltic*, and such, we have reason to believe, accompanies the inverted motion of the stomach in vomiting, for the bile, which naturally does not enter the stomach, is, at such times, discharged from it in the greatest abundance.

A singular effect that sometimes results from irregular contractions is, that one part of the intestine is swallowed within the other. This is called *intus-susceptio*. Thus, if some acrid or irritating matter have got attached to the inner coat of A, one portion of an intestine, A shall contract itself very powerfully

in the endeavours to get rid of it, but discharging nothing into B, there will be no inducement to B to contract; it will, therefore, remain open, and any further contraction of the longitudinal fibres will cause A to slip within B. The inner coat of B is now sensible of something within it, consequently B contracts, and squeezing tightly the vessels of A, stops it circulation; mortification comes on, and death ensues.

The arrangement of the longitudinal muscular fibres varies in the *colon*. In place of being distributed in a regular order round the intestine, they are collected into three bands, which, being shorter than the intestine, cause it to appear puckered up. The intervals between these bands, being weaker, yield more readily to distension, forming cells or *sacculi*. The fæces, when dry, readily assume the form of these cells, as may be well observed in the horse, goat, and sheep.

Within the muscular coat is a layer of fine condensed cellular structure, so distinct, as often to be described as a separate coat, under the title of *vascular*, from the quantity of blood-vessels that ramify in it; or *nervous*, from a mistake, perpetuated from the old anatomists.

The true internal coat, however, which is finely spread over this, is the most curious part of the whole structure; for by its means is the nutriment separated from the food as it passes along, and conveyed into the mass of the blood. This coat is termed *villous*. It has a soft fleecy surface, and, being of greater extent than the other exterior coats, is thrown into circular folds, which hang into the intestine like imperfect valves, with their concave edge floating. They have the name of *valvulæ conniventes*. Their use, as described by Sir Charles Bell, is "to increase the surface exposed to the aliment; to enlarge the absorbing surface; and, at the same time, to give to it such an irregularity, that the chyle may lodge in it and be detained." The *villi*, from which this coat has its name, are a number of extremely fine, short, filaments, that appear like a fine down on its surface. They are so minute, as not to be easily observed without the aid of a magnifying-glass: yet [illegible] them consists of an artery, vein, filament of a nerve, an[illegible]sorbent vessel. When there is nothing in the intest[illegible]re [illegible], relaxed, and hanging down; but when the f[illegible]notice of its presence to the nervous filament, the a[illegible]omes stimulated, more blood is sent into it, the *villus* is erected, and the absorbent is seen with open mouth collecting [illegible] white milky nutriment, the course of which we shall ha[illegible]e further when speaking of the absorbent system.

Around and between the bases of the villi are placed innumerable small glands, pouring out a watery mucous secretion, which assists the passage of the food, by presenting to it a constantly lubricated surface. From the presence of these glands, this coat has also been denominated the mucous coat; and the student will always bear in mind that it is still a modification of the external skin, which, at first, folded over the edges of the lips, acquires new properties in the mouth; is thence continued as a soft, spongy, delicate lining through the œsophagus, drawn into longitudinal folds by the contraction of the circular muscles; at the great end of the stomach is wrinkled, while numerous glands, placed beneath it, pour out their secretions, and gastric juice is exhaled from its surface, somewhat as perspiration is from the external skin; towards the pylorus it assumes, in many animals, the *villous* appearance, caused by the minute ends of the vessels throwing it up like so many little nipples; these are extremely numerous in the small intestines; gradually diminish as we approach the large; until, at last, when we come to the *rectum*, we find it again a smooth, spongy lining, exactly as it was in the gullet, and prepared again to give up its peculiar character, by being once more continuous with the external skin, which occurs on the edges of the vent.

From this description of the structure of the intestines we shall readily understand a division of much importance in the nature of purgative medicines. Some, as rhubarb, act by stimulating the muscular coat to contract; the *peristaltic* motion becomes more active, and the solid contents are evacuated. Saline remedies, on the contrary, have their action on the mouths of the mucous glands; they excite them to discharge a large quantity of a watery fluid, as salt placed in the mouth produces a large flow of watery saliva; and this fluid, mixing with the solid contents of the intestines, dissolves them down into a thin fluid mass, which is easily passed forward. In some cases, however, the solid contents have become too hard and solid to be thus acted upon, and they remain, causing much irritation and disturbance, when an ignorant physician imagines the bowels must be totally clear, because his patient has had abundant watery evacuations.

So much for the intestines generally; but before we examine their functions more particularly, we must speak of some organs which now become connected with the digestive process. For, when the *chyme* has passed the pylorus, and got into the duodenum, it becomes mixed with the bile and pancreatic fluid, which are both poured in through ducts opening into this part of the intestine; and, at the same time, a considerable change is observed to take place in it, and a separation into two parts, the one white, rich, and nutritive, called the *chyle*, the other the bulky indigestible residuum forming the *fæces*. It becomes necessary, therefore, to inquire how far this change depends on the admixture of these fluids; and this inquiry will be assisted, by examining the nature of these fluids and the organs by which they are secreted.

The Liver. The first of these is the liver, by which the bile is formed from the blood, with which it is abundantly supplied. This is the bulkiest of all the viscera; it lies on the right side, close up under the ribs; attached at top to the *diaphragm*, while its lower part, stretching towards the central line of the body, lies in front of where the stomach passes into the duodenum. On the posterior side of the liver is placed the gall-bladder, in shape like a pear, and serving as a reservoir in which to keep the bile until it is required in the duodenum. The duct leading into the duodenum is generally met and joined to the duct bringing the pancreatic fluid, so that they both pour their contents on the *chyme* at the same place.

It has long been a matter of dispute whether the liver forms its bile from arterial or venous blood. To understand this question, it is necessary to state, that while most other organs receive only arterial blood and return venous, the liver receives both arterial and venous blood, and the latter in a very peculiar manner. For the general rule of the circulation is, that arteries, setting out from the heart, divide and subdivide as they advance, until they have attained an extreme degree of minuteness; veins, on the contrary, commencing where these terminate, gradually unite into trunks, and those into larger trunks, till at last they return the whole blood of the body into the heart, by two large conduits; one from the head and upper extremities, the other from the trunk and lower extremities. To this general rule there is a curious exception as regards the liver. The veins from the stomach, spleen, great and small intestines, unite to form a trunk. This, in place of running towards the heart, or uniting itself to some other trunk, runs into the liver. It enters it between two of its lobes, which form something like a *gate* for its reception, whence its name *vena portæ*, and immediately commences dividing and subdividing itself in the substance of the liver, as though it had been an artery. Now a large artery (the *hepatic*) also enters the liver, and branches out as usual.

The liver, then, has two sources of supply; it has but one product, the bile: the question, then, is simply this, from which source of supply is the product formed? Minute researches into the nature of glands, seemed to show that secretion takes place in extremely minute vessels; now it was thought that the dispute respecting the bile would be settled, by ascertaining whether the minute vessels in which it was secreted were continuous with the final subdivision of the artery or the vein. Upon this speculation, therefore, the anatomists set to work with knives and magnifying glasses. Some pursued up the artery to its minutest branch; others the vein. Some sliced the liver across, and tried what they could see in the section; others cut it longitudinally. Some examined it raw, some boiled, some macerated in water, in spirits, or in acids. After much trouble in this way, it appeared that each of them saw what he liked to see, but, unfortunately, could seldom make any one else see it. It was agreed, then, that this would not decide the point; and another mode was hit on. One gentleman made a very fine injection of size or paint, and forcing it with a syringe into the vena portæ, found it returned by the biliary ducts and the hepatic veins, which are employed in returning from the liver all the blood that remains after the bile has been formed, and the organ nourished. Here was "confirmation, full as strong as proofs in Holy Writ." The blood of the vena portæ not only sufficed for the biliary secretion, but filled the hepatic veins. The poor hepatic artery was in danger of having nothing at all to do, but that, fortunately, another gentleman took it into his head to drive his paint injection through it, when, lo! the biliary ducts and hepatic veins became filled with equal facility. In short, all these systems of vessels communicated so freely, that, by using a certain degree of force, from any one you could fill all the rest. Experiments on living animals were next had recourse to. Some tied the vein, and said that stopped the secretion of bile; others tied the artery, and reported the same results. In most cases the unfortunate animals, made the subject of experiment, were so injured by the operations, or by the subsequent inflammation, that they afforded no fair grounds for inferring what might or did occur in their natural condition. Argument, now, was the last resort; and those who have studied the question most, seem to think with Sir Roger de Coverley, that "much may be said on both sides."

One party urged that the unusual distribution of the vein argues its application to an unusual office; that this office in the liver is evidently the secretion of the bile; that the artery has enough to do in supplying nourishment to the organ; that the venous blood, containing more *carbon* than the arterial, is fitter for the elaboration of bile, which abounds in this principle; and, finally, if the vein be not for this use, for what use is it? To all this the other party replied, that every other secretion is formed from arterial blood, therefore analogy would say the same for this; that the size of the hepatic artery, almost equal to one supplying an entire limb, is too great to suppose its blood exhausted in nourishing the liver, but that enough for secretion must remain; that the use of the novel distribution of the vena portæ is to prevent the blood returning in too great quantities, or with too much violence on the heart, or, perhaps, as maintaining a reservoir of blood, for the extraordinary necessities of the system, out of the immediate range of circulation; that the point respecting the greater or less quantity of carbon scarcely deserves notice; and, what is most important, that in *mollusca* there is no vena portæ, yet bile is secreted, and that two instances have occurred in London where the vena portæ never entered the liver, in which, consequently, the whole secretion must have been made from the blood o the hepatic artery.

Such was nearly the state of the question when we com menced to write; but an admirable paper read by Mr. Kiernai before the Royal Society, and published in the last number o their *Transactions*, has finally settled the question, and proved on the indisputable authority of anatomical demonstration that the bile is secreted from venous blood alone; that thi venous blood is, in part, that brought by the *vena portæ*, ii part that brought by the hepatic artery, become venous afte having contributed to the nutrition of the organ; that, there fore, both sources contribute to the formation of the secretion and that if one of them were cut off, its place might, to a limited extent, be supplied by the other. He has, also, fully explained the apparent anomaly in the cases above alluded to; but his explanation involves too much anatomical reasoning to be rendered intelligible to our readers. On the whole, his paper is one of the most valuable contributions that has been made of late years to human Physiology; and we feel no doubt that Pathology will derive equal benefit from one which he promises on the diseased appearances of the liver.

The fact of the liver being employed in removing from the system the superfluous *carbon*, has caused it to be considered in some measure subsidiary to the lungs, in which we know the same takes place, the air which enters them returning loaded with *carbonic* acid, a combination of *carbon* with oxygen. Many things tend to strengthen this idea. The heat of the body depends on the formation of this carbonic acid; but if the external heat be sufficient, there is less necessity for internal heat, less carbonic acid is formed, more carbon is left to be got rid of by the liver, the bile becomes acrid, and the liver deranged. This accounts for the frequency of liver-complaints in hot climates. In the fœtus, for whom the heat of the mother's body must be sufficient, the lungs are small and collapsed; while the liver is large, extending much further down than it does in the adult, and a quantity of bile is secreted, as we always find much greenish matter, termed *meconium*, in the bowels of the infant when born. If we trace the scale of animals, also, we shall find that as the lungs diminish, the liver, having a greater share of business, enlarges; frogs, who give out little carbonic acid, have more imperfect lungs and larger livers than sparrows, who give out a great deal; and in fishes, and *mollusca*, such as snails, oysters, that breathe by gills, Mr. Lawrence informs us that "the liver is very large, consists of several lobes, surrounds the stomach and intestines, and opens by several mouths into these cavities."

The nature and appearance of bile are tolerably well known. It is of a greenish-yellow colour, but varies much in this respect; sometimes deepening into a brown; sometimes brightening into a green. It is a viscid fluid; and this quality is much increased by a short stay in the gall-bladder, where absorption of its more liquid particles would seem to take place. It is sometimes found to contain animalcules; and a species of worm, called *fluke*, existing in the gall-bladder and ducts of sheep, causes amongst them the disease, termed the rot. Its taste has become proverbial, "bitter as gall." Chemists have discovered in it a peculiar principle, named *picromel* (πικρος bitter, μελι honey), from its combining a bitter with a sweet taste; and on this they suppose many of its properties to depend. They also speak of a green resinous part, but without much certainty.

Of the use of the bile we shall speak when we have said a few words of the *pancreas* and *spleen*.

*The Pancreas** is better known in animals by the name of sweet-bread. It is a long narrow gland, placed behind the stomach and across the back-bone. It resembles very much a salivary gland, and the fluid it exudes approaches closely in its nature to saliva. It has been extirpated without the animal's health appearing impaired. The duct from it opens into the duodenum, along with, or immediately by, the duct from the

* *Pancreas*, all fleshy; from παν, all; and κρεας, flesh.

the whole secretion must have been made from the blood of the hepatic artery.

Such was nearly the state of the question when we commenced to write; but an admirable paper read by Mr. Kiernan before the Royal Society, and published in the last number of their *Transactions*, has finally settled the question, and proved, on the indisputable authority of anatomical demonstration, that the bile is secreted from venous blood alone; that this venous blood is, in part, that brought by the *vena portæ*, in part that brought by the hepatic artery, become venous after having contributed to the nutrition of the organ; that, therefore, both sources contribute to the formation of the secretion, and that if one of them were cut off, its place might, to a limited extent, be supplied by the other. He has, also, fully explained the apparent anomaly in the cases above alluded to; but his explanation involves too much anatomical reasoning to be rendered intelligible to our readers. On the whole, his paper is one of the most valuable contributions that has been made of late years to human Physiology; and we feel no doubt that Pathology will derive equal benefit from one which he promises on the diseased appearances of the liver.

The fact of the liver being employed in removing from the system the superfluous *carbon*, has caused it to be considered in some measure subsidiary to the lungs, in which we know the same takes place, the air which enters them returning loaded with *carbonic* acid, a combination of *carbon* with oxygen. Many things tend to strengthen this idea. The heat of the body depends on the formation of this carbonic acid; but if the external heat be sufficient, there is less necessity for internal heat, less carbonic acid is formed, more carbon is left to be got rid of by the liver, the bile becomes acrid, and the liver deranged. This accounts for the frequency of liver-complaints in hot climates. In the fœtus, for whom the heat of the mother's body must be sufficient, the lungs are small and collapsed; while the liver is large, extending much further down than it does in the adult, and a quantity of bile is secreted, as we always find much greenish matter, termed *meconium*, in the bowels of the infant when born. If we trace the scale of animals, also, we shall find that as the lungs diminish, the liver, having a greater share of business, enlarges; frogs, who give out little carbonic acid, have more imperfect lungs and larger livers than sparrows, who give out a great deal; and in fishes, and *mollusca*, such as snails, oysters, that breathe by gills, Mr. Lawrence informs us that "the liver is very large, consists of several lobes, surrounds the stomach and intestines, and opens by several mouths into these cavities."

The nature and appearance of bile are tolerably well known. It is of a greenish-yellow colour, but varies much in this respect; sometimes deepening into a brown; sometimes brightening into a green. It is a viscid fluid; and this quality is much increased by a short stay in the gall-bladder, where absorption of its more liquid particles would seem to take place. It is sometimes found to contain animalcules; and a species of worm, called *fluke*, existing in the gall-bladder and ducts of sheep, causes amongst them the disease, termed the rot. Its taste has become proverbial, "bitter as gall." Chemists have discovered in it a peculiar principle, named *picromel* (πικρος bitter, μελι honey), from its combining a bitter with a sweet taste; and on this they suppose many of its properties to depend. They also speak of a green resinous part, but without much certainty.

Of the use of the bile we shall speak when we have said a few words of the *pancreas* and *spleen*.

*The Pancreas** is better known in animals by the name of sweet-bread. It is a long narrow gland, placed behind the stomach and across the back-bone. It resembles very much a salivary gland, and the fluid it exudes approaches closely in its nature to saliva. It has been extirpated without the animal's health appearing impaired. The duct from it opens into the duodenum, along with, or immediately by, the duct from the

* *Pancreas*, all fleshy; from παν, all; and κρεας, flesh.

liver. The use of the *pancreatic* fluid is not very well known. Some suppose that it modifies the acrimony of the bile, others that it assists in preparing the nutritive part of the food for absorption.

The Spleen is of an irregular figure, and dark purple colour, situated at the left side of the abdomen, close up under the ribs, as the liver is at the right, and attached at top to the diaphragm, and by its side to the great curvature of the stomach. It is of a peculiarly soft, yielding, spongy structure; composed almost entirely of vessels which admit of being readily emptied, or as readily distended with blood, by which it is capable of suiting itself to the condition of the neighbouring parts. Thus it has been observed to swell up and enlarge when the stomach was empty, and to be contracted when this organ was full. From this, and its close connexion with the stomach by means of vessels (*vasa brevia*) which pass between them, it has been generally considered as intimately connected with digestion. Some have supposed it to act as a sort of fomentation, or application of heat and moisture to the end of the stomach, and thus to promote its action. Others have said, that as the stomach, when digesting, requires more blood than when empty, the spleen acted as a reservoir, in which the blood was retained until the stomach, becoming full, pressed on the spleen, and so compelled it to discharge the blood necessary for its use. But we have no proof that the stomach can so compress the spleen; nor is the spleen always situated so immediately in its neighbourhood as to render this probable. The frog, for instance, has the spleen in the mesentery; and, in ruminating animals, the spleen is attached to the paunch, or first stomach, so that, if pressed on by this, it would be giving out blood when no digestion at all was going on, as this does not commence until the food has got into the fourth stomach. Another opinion has been, that it served as a counterpoise to the liver, on the opposite side of the belly; Hewson thought it made the colouring matter of the blood; Sir Everard Home, that it received the liquids direct from the stomach; Erasistratus, that it was of no use at all; and Paley could find no better use for it than as a pad or stuffing to assist in packing all the other viscera, and keeping them comfortable in their places. All these theories have been refuted, or, from their absurdity, not considered worth refutation. There remains one, not often insisted on, yet supported by some reasons, and, what is better, by some facts.

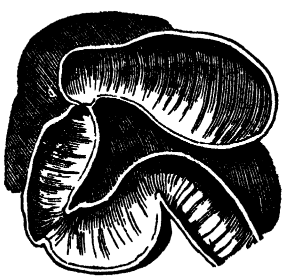
Let us suppose any given quantity of blood, say ten pints, necessary to the performance of the functions, and the maintenance of life. Suppose that exactly this quantity were contained in, and filled the circulatory system, it is clear that any sudden accident, such as a rupture of a vessel, or a wound, by which half a pint or a pint of blood was lost, would suspend life, or leave the person in a low, exhausted condition, from which his recovery would be tedious and uncertain. In short, the operation of bleeding would, under such circumstances, be more dangerous than the disease it was intended to remedy. To avoid this, a greater quantity of blood is preserved in the body than is immediately necessary, and the superfluity is placed in communication with the general circulation, though not in the immediate line of it, in certain reservoirs, from which it can be drawn, should the system require it. We have before hinted that the liver may perform such a function in consequence of the mode in which the *vena portæ*, carrying all the blood of the intestines, is divided in it, and it is now suggested that the spleen would be admirably adapted for a like purpose.

The most accurate examination of its structure would show it to consist of nothing but vessels, capable of great dilatation and subsequent contraction, according as they are required to hold a greater or less quantity of blood. In the cold fit of ague, when the blood, leaving the surface, is concentrated towards the trunk, this organ enlarges exceedingly to receive the torrent, which, if poured on the stomach, liver, or lungs, would be attended with imminent danger. When reaction sets in, and the hot stage is fully established, the blood again rushes to the surface, which now becomes red, heated, and swollen, till relieved by a copious perspiration, in which the fit ends; while the spleen again shrinks and collapses to its ordinary size. If, however, the fit be frequently repeated, the spleen is not completely emptied each time, an accumulation and deposition take place in it, and it becomes permanently enlarged and hardened. This state of the spleen, familiarly known by the appropriate name of *ague-cake,* is of common occurrence in Lincolnshire, and other places where agues are rife. There is no ground for supposing it an organ of secretion. No secretion from it has ever been discovered, nor any duct by which such secretion could be conveyed. Sir Everard Home's idea, that it formed the medium by which liquids were conveyed directly into the circulation, he himself gave up on subsequent experiments; to say nothing of the fact mentioned by Blumenbach, that the spleen is of good size in several warm-blooded animals who never drink. Its veins run direct to the liver, which, in the view we have taken of them, would show a community of function. Dr. Lind mentions, that in the bilious intermittent fevers of Bengal, where the liver is often inflamed and swollen, so as not to admit the venous blood to enter it as freely as usual, the spleen constantly becomes enlarged, and shows itself to be performing additional work; and MM. Leuret and Lassaigne having applied a ligature on the *vena portæ* of a dog, and examined its spleen two hours after, found it to weigh a pound and a-half, while it ordinarily weighs but two ounces.

It would be impossible to consider the matter fully here, but we think we have shown a probability that the liver may be an organ performing two functions; one, the removal of carbon from the system, in which it assists the lungs; the other, the detaining, in a state of slow transit, a certain quantity of blood, ready to be given out should there be a call for it, and this office it shares with the spleen. We have already shown, that as the lungs become more imperfect, or fail to perform their office, the liver becomes larger and more active;

but becoming larger, it is of course rendered, at the same time, a more capacious reservoir, therefore has less need of the assistance of the spleen; consequently, as nothing useless is left in the animal economy, "the spleen," as Mr. Lawrence informs us, "gradually diminishes in size from the mammalia to fishes," but this is exactly the order in which the liver increases. In mollusca, in whom the liver is of great magnitude, the spleen does not exist at all. Other arguments may be adduced, from the symptoms that accompany inflammation of this organ, but it will be sufficient to have alluded to this, and we shall now return to our *chyme*, which we left entering the duodenum.

The duodenum derives its name from being, by old anatomists, described as the first twelve (*duo-deni*) fingers' breadth of the intestine, measured from the *pylorus*. It is now better and more anatomically defined, but the old name still remains. It is much larger than any other portion of the small intestines; its functions and diseases are both of the greatest importance, and by several anatomists it is raised to the rank of a second stomach. It takes its course towards the right side, from the orifice of the stomach lying across the back-bone, and above the pancreas; it then turns down, and having gone a short way in this direction, makes its third turn towards the left, so as to terminate at the back-bone, nearly under the place where it had commenced. This will be more clearly understood from a reference to the annexed figure.

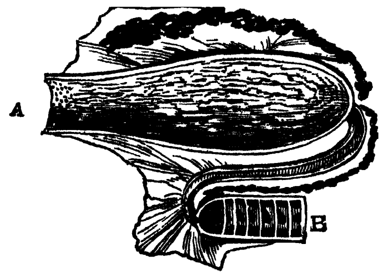


The Duodenum, or commencement of the Intestinal Canal.

The ducts from the liver and pancreas open into it just where it is turning downwards, and at this point a remarkable change is observed in the food. In place of the gray uniform pulpy mass which we found at the pylorus, an evident separation into two parts has taken place. The bile also seems to undergo decomposition, and one of its parts unites with the nutritive part of the food, which now swims at the top, in the form of a white creamy fluid, while the other, or proper bilious part is found mixed with the more solid remaining parts, and seems destined, by its bitter and acrid qualities, to stimulate the intestines to unload themselves of the fæces. So far the changes produced by the bile, seem almost entirely chemical, and Dr. Prout states, that having mixed chyme with bile, out of the body, almost the same appearances were observed. "A distinct precipitation took place, and the mixture became neutral." He could not, however, clearly ascertain the formation of an *albuminous*, or nutritive principle, which he attributed to the absence of the pancreatic fluid. It does not appear, however, that bile is absolutely necessary for this separation of the *chyme* into *chyle* and excrement. Nutrition continues to take place in jaundiced patients, in whom, from the stoppage of a gall-stone in the ducts, or inflammation, or pressure of the neighbouring organs, not one particle of bile can enter the duodenum. In such cases, the bile, after being formed, is reabsorbed and carried into the blood, causing the general yellowness of skin; while the fæces, devoid of this principle, are perfectly white and clayey, and the intestines, wanting its stimulus, become sluggish in their actions, from which arises that costiveness so generally attendant upon this disease.

The next step is the taking up this nutritive matter, which we have seen separated by the bile, and this is entirely a vital process. The folds of mucous membrane, of which we have spoken as hanging into the intestine, are immersed, as it were, in this creamy fluid; the little vessels on their surface commence sucking it in, and have been actually seen in the fact by Sir Charles Bell, who has seen the little white flakes stopping up their orifices.

Jejunum and Ileum. By far the greater part of the absorption takes place in these, principally in the first, as we here find those mucous folds most abundant*. The use of these folds seems to be, not only to increase the extent of the absorbing surface, but to cause some delay to the food in its passage, and thus afford further time for the absorbents to act. In some fishes the little delay thus afforded seems sufficient, without the necessity for convolutions. Thus the small intestine of the blue shark presents this appearance, where we



Stomach and small Intestine of the Blue Shark.

A, the stomach. B, the small intestine, with its spiral valve.

see these folds transformed into a regular spiral valve. The intestine runs almost in a straight line to the vent; these valves, therefore, are necessary to prevent the food from passing too rapidly through it; they also very much enlarge the absorbing surface.

As the contents of the small intestines are urged along by muscular contraction, they are thus gradually deprived of their liquid particles, become drier, and approach more in their properties to fæcal matter.

The great intestines. Arrived at these, the mass has lost

* The mode in which these parts are distinguished is, by calling the upper two-fifths of the small intestine (measured from the duodenum) *jejunum*, and the lower three-fifth ileum. The name *jejunum* is said to be derived from *jejunus*, hungry; because this part of the intestine is generally found empty. The experience of old anatomists differs entirely from ours, for we have as often found it full.

almost all its nutritive particles. In animals, however, that live on food difficult of digestion, this is not altogether the case. To give an opportunity for extracting any that may remain, these intestines are made very winding and voluminous. The cœcum and colon in the goat, whose food, so unlike the substance of our bodies, is with difficulty assimilated to it, measures more than twenty feet; while in the lion, feeding on flesh, they do not measure four feet. The absorbents, however, are not found in any number opening into this part of the canal, so that not much nutriment can be acquired here. This accounts for the difficulty in supporting a person by nutritive injections, as is sometimes attempted to be done, when, from a very irritable state of the stomach, or some other cause, the patient is unable to swallow. These injections can never, under ordinary circumstances, reach higher than the cœcum, for a valve placed at its entrance, and opening only downwards, admits matter from the small intestines, but bars all return.

What remains after this last absorption is excrement; and when a sufficient quantity of it is collected, its bulk stimulates the *rectum*, or lower part of the whole canal; the muscular fibres of this contract; the muscle which holds it closed at its termination, relaxes; and by the assistance of the abdominal muscles, useful in this as in vomiting, the fæcal mass is discharged. This is materially assisted by the structure, already noticed, of the internal membrane at this place. It has become soft, spongy, and abounding in mucous glands; the secretion from which, elicited in great abundance at this time, helps to lubricate the mass, and so facilitate its expulsion.

Sir Everard Home had an idea that the fat might be formed in the large intestines, and made some experiments to support this theory. A piece of muscle, digested for some days in bile, appeared fatty on the surface. Something of the same kind occurred in fæces that had been long retained. Ambergris*,

* De Blainville questions this, and says some persons assign the production of ambergris to a sort of *sepia*, which, during life, has a strong ambreous smell. But he does not quote his authorities.

which is of a rich fatty nature, is well known to be the contents of the great intestine of the whale, when from disease the excrement has been long retained; and lumps of fat have occasionally been passed by persons in ill-health. He mentions some other circumstances of the same kind, but has not succeeded in making out his case.

Gases of different kinds are found along the course of the alimentary canal, either proceeding from the decomposition of the food, or, as is more probable in many cases, secreted into the canal. Careful analyses of these in different parts have been made. It would appear that oxygen and nitrogen are found in most abundance towards its commencement; carbonic acid and hydrogen towards its termination. Carbonic acid, however, is by others stated to be found in greatest quantities in the stomach. The oxygen and nitrogen are, probably, the constituent parts of the atmospheric air, which must be swallowed at each movement of deglutition, or mixed with the food during mastication. Some animals possess the power of swallowing air to a remarkable degree. It is by means of this that the sea-urchins swell out their skins, so as to erect the prickles with which they are covered, and which thus serve them as a defence against sharks and other voracious fishes: and it is the same faculty that enables the *nautilus*, thus rendered lighter than water, to move gracefully on its surface.

Light as a flake of foam upon the wind,
Keel-upward from the deep emerged a shell,
Shaped like the moon ere half her horn is fill'd;
Fraught with young life, it righted as it rose,
And moved at will along the yielding water.
Worth all the dead creation, in that hour,
To me appeared this lonely *nautilus*.

We have now traced the food from its entrance to its exit; we have seen it chewed and mixed with saliva in the mouth; swallowed by the tongue and gullet; changed by the stomach into *chyme;* by the duodenum, when mixed with the biliary and pancreatic fluids, into *chyle;* its nutritive parts absorbed from the small intestines; and the remainder finally converted into excrement in the large. Before we proceed to inquire what becomes of the absorbed part, which would lead us to the consideration of a new set of vessels, let us say something respecting what we may term the liquid excrement, the urine, and the organs by which it is secreted and contained.

An important difference is to be observed between secretions. Some, when formed, are applied to a further use in the system; such are the bile, the saliva, and these are proper secretions. Others seem merely formed to remove from the system matters which, if remaining in it, would be injurious, and these, when formed, are quickly discharged: they are more properly termed *excretions*, and of this kind is the urine.

The urine, then, is one of the means of purifying the system, and, in all the *mammalia*, is secreted by the kidneys, and conveyed into a bladder, from which, when a sufficient quantity to stimulate it is collected, it is expelled. It usually appears as an abundant watery secretion, of a pale-yellow colour, salt taste, and peculiar smell, not disagreeable in the urine passed by a healthy person. The smell to which the name *urinous* is generally given, is not that to which we allude, for it, in fact, arises from the decomposition of the urine which takes place with great rapidity as soon as it is exposed to the air. This proneness to decomposition arises from the great number of ingredients it contains, amounting according to Berzelius, to seventeen, while Fourcroy and Vauquelin swell the number to no less than thirty. In short, it seems to be a sort of sewer to the body, through which everything useless is drained off. We shall find it vary much, according to the times at which it is examined; and physiologists have, with a view to this, divided it into urine of the drink, urine of the *chyle*, and urine of the blood.

Urine of the drink is that which is passed soon after having drank in great abundance; and this is considered the most imperfect, as many of the qualities of the liquid drank may often be detected in it; and it seems as if the liquid had passed through the body without being much modified in its course.

Some liquors, it is known, produce this secretion more abundantly than others, such are infusions of broom-tops, of juniper-berries, or of flax-seed. Urine of the *chyle* is that which is voided a short time after a meal is digested. It differs, notably, from the other in quantity, density, colour, and odour. Its quantity is less, its density greater, because its solid contents are increased, its colour deeper, and its odour more peculiar, and less referrible to the matters taken in. The urine of the blood, however, is that in which all its characters are more perfect. This is the urine passed in the morning, after sleep, during which the system, left to itself, and undisturbed by external influences, has full time to throw out, by the kidneys, all such matters as it requires to get rid of, and which are thus found, in their due proportion, in the secretion. It is this that chemists prefer to analyze. It consists of water, a great number of salts from which it frees the blood, a peculiar matter termed *urea*, an acid called *uric*, or *lithic*, which causes it to redden vegetable blues, and mucus, together with some other animal matters.

M. de Blainville says, that urine passed from the kidney of a living animal is much thicker and more viscid than when it is discharged from the bladder. He concludes, therefore, that the salts, the animal matter, &c., are separated from the blood, in a concentrated form, by the kidneys, and that the chief part of the water is added by exhalation from the lining membrane of the bladder*. This lining membrane is nothing more than the skin turned in through the urinary passage, modified exactly as the skin is when it becomes the lining membrane of the mouth, furnished with mucous glands, exuding a secretion by which it is continually moistened, and applied over the whole internal surface. The watery exhalation which takes place from this, is exactly analogous to perspiration from the external skin, and as one of these increases, so the other diminishes.

[* Compare this vital phenomenon with the physical fact. If a bag, made with any organic membrane, vegetable or animal, be partly filled with some thick fluid, and the whole immersed into a vessel containing a thinner fluid, the latter will pass across the membrane to mix with the former.]

A horse at rest in his stable passes urine abounding in water; but take the same horse, fatigue him in the course, excite violent transpiration from the pores of the skin, and then his urine will be thick and viscid, often to such a degree as to produce difficulty in passing it. On the other hand, in the disease termed *diabetes*, in which the patient will sometimes pass thirty or forty pints of urine in twenty-four hours, the skin is dry and hard, and the most powerful sudorifics fail to produce any moisture on it. The secretion is increased by cold and damp air, preventing transpiration from the skin; and diminished by hot and dry air, by abundant fluid discharges from the bowels, and by dropsy, in which the water seems all directed in a wrong course, and which is often cured by increasing the flow from the kidneys. The constant state of action in which the cutaneous exhalants are kept in warm countries, accounts for the frequency of skin diseases, such as leprosy, yaws, ring-worm, in these situations: while the urinary organs being over-worked in damp, cold climates, shows why they are more frequently affected amongst us.

If the urine be carefully examined with a good magnifier, we shall see extremely small shining crystals floating through it. These are crystals of *uric* acid, held in solution, while the urine is in the body, by the quantity of warm fluid in which they are immersed; but should anything tend to cool that fluid, such as a foreign body getting into the bladder, or should they be secreted in too great quantity to remain dissolved, they are precipitated in a solid form, and, according as they unite in small grains or in one large mass, give rise to gravel or stone, perhaps amongst the most painful diseases that flesh is heir to. These concretions are at other times formed from the salts which we said were contained in the urine, and diet seems to have no little influence in determining to which of these classes the stone shall belong. Abundant animal food, rich soups, and indulgence in wine, tend to the formation of *uric* acid, and this is generally the gravel that accompanies gout; while the alkaline concretions occur more frequently in children, in weakly persons, and such as live much upon vegetables*. Now, as the dispositions induced by these means are directly opposed to each other, and a stone formed under one of them would be, if not very large and firm, actually dissolved by the urine secreted under the other, it is evidently of the highest importance that the diet of persons labouring under this disease should be particularly attended to. Medicines are used with the same intention, and if resorted to at the commencement, may succeed in dissolving the newly-formed *calculi;* at a later period, however, these are not so easily acted on, and an operation becomes necessary for their removal. It was at one time thought that the injection of certain solvent fluids directly into the bladder might suffice in all cases to destroy the stone; but it was found, that when of sufficient strength to do this, they were also of sufficient strength to act most injuriously on the delicate lining membrane of the bladder, and so induce a most dangerous inflammation.

Certain substances have peculiar effects on the urine. Rhubarb gives it a peculiar tinge; asparagus, as every body knows, a peculiar fetid odour; and turpentine, a smell like violets.

The urine seems to be converted into a means of defence for certain animals, by being endued with a peculiarly offensive smell. This is most remarkable in the fox, the pole-cat, and the mouffette†, an animal allied to the same family. Birds

* Dr. Wollaston, who has made very interesting researches respecting the influence of different kinds of food on the composition of the urine in birds, found that in a chicken, fed solely on herbs, the *uric* acid was but a very small fraction in a hundred parts; it was rather more in a chicken allowed to feed at large in a farm-yard; in a pheasant fed on barley, it amounted to fourteen per cent.; almost formed the entire urine in a hawk fed on flesh; and altogether in a brown gull fed on fish.

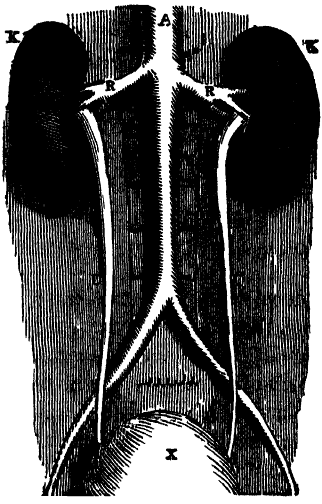
† The American *skunk* seems of all animals the best provided in this respect. It will not run from a man; and indeed exhibits no sign of fear at the sight of any animal, however powerful. If it perceives itself about to be attacked, it curves its back, raises its hairy tail in a vertical position, and then ejects, with considerable force, its urine, which is mixed with such an insupportably fetid liquor, produced by certain *glands* for the purpose, that neither man, dog, nor any animal, however fierce, will venture to touch it. Washing, scouring, or baking, have been tried in vain, to eradicate the smell from clothes once infected. Major C. Hamilton Smith, who had often seen the animal, informs us, in Griffith's edition of Cuvier, that the owner of the New York Museum had a suit of

have no bladder, but the lower part of their intestine ends in a bag, called *cloaca*, which serves not only to receive the fæces, but also the urine from the kidneys, and the eggs from the ovaries. It thus answers the purpose of *rectum*, *bladder*, and *uterus* or *womb*. They have, therefore, no distinct passage for evacuating the urine. It is voided along with the fæces, and is that dull white matter which we observe always forming part of them. It is very little fluid, which M. de Blainville attributes to its not having been in a bladder; and he mentions this fact as a proof of his theory, that the urine is indebted to the bladder for its watery parts. It is composed in great part of uric acid, and hardens quickly on exposure to air. In serpents and lizards, the urine is still more solid, and hardens almost into a stony mass. Frogs again present us with a bladder, and consequently their urine again becomes liquid. The cuttle fish has a pouch opening near the vent, which, from its situation, is by some considered as a urinary bladder. It contains a quantity of deep black fluid, said to be the colouring principle of Indian ink; and this it discharges, when pursued, so as to darken the water around it, and thus favour its escape. This use of it, as a means of defence, certainly bears an analogy to what we mentioned above respecting the fox and the pole-cat. If this reasoning be admitted, we must consider as urine the beautiful purple liquor afforded by the *murex*, and used amongst the Romans to dye their richest robes. This liquor is, when in the animal, of a yellowish-white colour, and only obtains its regal tint when exposed to the action of light.

It is scarcely necessary to describe the shape or colour of the kidneys. Every one has seen a sheep's kidney, and the human kidney much resembles it, except that it is longer, and, perhaps, flatter. These are what are called *symmetrical* organs, that is, there are two of them similarly situated, one on each side. The other organs of which we have spoken are not sym-

clothes completely ruined by a few drops; "after washing they were hung upon the roof of his house, full fifty feet high, and yet could be very distinctly smelt some distance off in the streets, or the square near the house."

metrical. Thus the liver is placed all to one side of the body, the spleen to the other, and so on. The kidneys, KK, are placed in the loins, one on either side of the back-bone, VV, towards which their notched side is turned. Into this the blood is conveyed by RR, the *renal** arteries, and it is from this blood that the materials for the urine are derived. The blood that remains is returned by means of the veins, while the urine passes along two canals, UU, called *ureters*, into the bladder X.

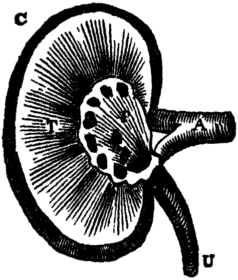


Kidneys, Ureters, and Bladder.

The kidneys are generally enveloped by a quantity of loose cellular membrane, in which abundant depositions of fat take place. Their internal arrangement is curious. If we make a horizontal section of one, we shall observe that it seems composed of a number of lobes joined together within a general envelope. Each of these lobes is composed, externally, of what is termed the *cortical* part. The arteries all direct themselves towards this, and when arrived at it, subdivide until their

* From the Latin *ren*, a kidney.

branches become extremely minute. In these minute branches the urine is secreted; and inside this *cortical* part we perceive what is termed the *tubular* part, composed of a number of minute ducts conveying towards a central point the liquid which has thus been secreted. The ducts gradually unite, and terminate in a little process like a nipple. The number of



Section of Lobe of a Kidney.

A The artery of the kidney.

C The cortical part in which the urine is secreted.

T The tubular part, through which it is conveyed into

P The pelvis, whence it descends through U, the ureter, into the bladder

these in each kidney varies from twelve to eighteen. They discharge the urine through little funnel-shaped ducts, termed *calyces* or *infundibula*, into a membranous bag, called *pelvis*, situated in the notch of the kidney, and with which the *ureter*, or canal to the bladder, is directly continuous. Concretions sometimes are found in this *pelvis*, forming the disease called stone in the kidney: or becoming detached, and attempting to pass down the ureter, they will stick on the way, giving rise to most distressing symptoms. In such cases, recourse is generally had to narcotics for allaying the pain, and to warm baths, fomentations, and such other means as may induce the parts to relax and so suffer the stone to pass. The *ureters* terminate in the bladder, towards its neck; the urine is constantly passing down in drops as it is secreted, and its return into the lower part of the *ureters* is prevented by their opening obliquely through the coats of the bladder, which thus act as a valve. These coats are very similar to the coats of the stomach, but the external or *serous* coat only covers the upper and back part of the bladder. This is of the greatest moment to the surgeon, as it enables him to perform operations on this organ, with much less danger than if he had to cut into a *serous* sac. The muscular coat of the bladder is composed of a number of strong fibres, the general direction of which is longitudinal. Some speak of their forming a *sphincter*, to close the neck of the bladder. We have not seen anything sufficiently distinct to deserve the name, nor does such a provision appear necessary, the parts around being of such a full, plump nature, as easily to yield when a liquid was forced through them, but as readily fall together again when the liquid no longer flowed. The muscular fibres are excited by the full state of the bladder. They contract, and its contents are discharged through the *urethra*. This passage differs in length in the different sexes. Its lining membrane, continued on, becomes the third, or internal coat of the bladder. It is constantly bedewed with a mucous secretion, that serves to defend it from the action of the urine. It is to the exhalation, also, from this, that, according to De Blainville, the urine is indebted for much of its watery particles.

Having now traced both the solid and liquid excrements to their final expulsion from the body, let us return to see what becomes of the nutritive part of the food.

Chapter VI.

OF ABSORPTION.

Not only is there a constant addition of new particles to the system, supplied by the food, and conveyed by certain ducts, but there is, corresponding to this, a constant removal of old particles, which, having done their duty, require to be taken away, and their place occupied by others. Both these offices are performed by a system of vessels, which we have now to consider, termed Absorbents; and they are distinguished into *lacteals* and *lymphatics*, according as they are generally employed in the former or the latter function.

It will be remembered we left the food just when it had been divided into its nutritive and excrementitious portions, and tracing the course of the latter, had reserved the former for future consideration. To this we must now direct our attention.

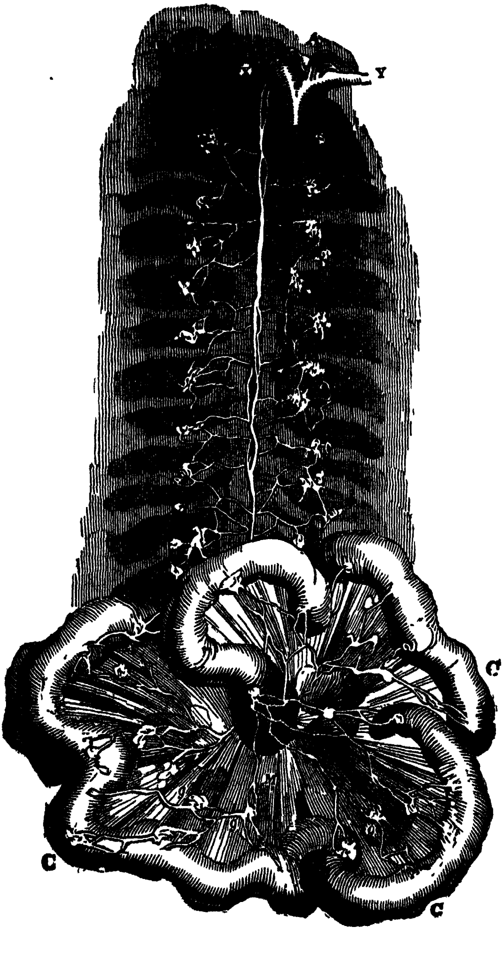
Asellius, in 1622, being engaged in dissecting a dog, which he had opened soon after it had fed, observed a series of vessels, which were neither arteries nor veins, but filled with a white milky fluid, running along that fine transparent membrane, called *mesentery*, which, as we have said, binds the intestines to the back-bone. Delighted with his discovery, he denominated these newly-found vessels *lacteals* (*lac*, milk), and, in order to trace their connexions and uses, he opened another dog the next day, but, to his great disappointment, could not observe the smallest white vessel. He began to consider what could be the cause of this, and then remembered that the last dog had been opened after a whole night's fasting, while the first had previously had a good meal. He therefore fed a third dog abundantly, and having opened him, found "everything more manifest and brilliant than in the first case." The vessels therefore were themselves transparent; they owed their whiteness to the *chyle* contained in them, and presented at once the course by which this was conveyed from the stomach towards the circulation. As this was a matter very much disputed at the time, Asellius gave his whole attention to the subject; he made numerous dissections of living animals, in all of which he was able clearly to point out his new vessels. Their origin from the intestines was undoubted, from their containing the *chyle;* but he did not succeed in making out their termination. This he supposed to be at the liver, which was then looked on as the organ in which the formation of blood out of chyle was perfected.

In 1649, however, Pecquet, a French physician, being engaged in cutting out the heart of a dog, noticed a quantity of white creamy fluid, pouring out from one of the large veins which he had severed just where it joined the heart. Struck with the oddity of seeing a white fluid in the blood, he thought at first that he must have opened into some abcess, and that this was *pus* which it contained. But, after some examination, failing to find one, he commenced pressing the parts about, to see whence it might come; and on pressing the mesentery, the *lacteals* of which happened to be full of *chyle*, a large quantity of it was at once discharged from the vein. This set him on looking for the mode of communication, and he soon found that the *lacteals*, in place of running to the liver, discharged themselves into a slender duct, which he named *thoracic* *, and which, ascending close to the back-bone, conveyed their contents into the left *subclavian* vein, just before it opened into the heart. Observations on this class of vessels became rapidly multiplied. They were found arising in greatest number from the small intestines, and at last their little mouths were discovered opening on the *villi*, and attracting to themselves the *chyle* by a peculiar vital power of selection. Their extreme minuteness, also, qualifying them to act as capillaries, may favour the ascent of the liquid. Before joining the thoracic duct, they pass through a number of *ganglia*, or firm reddish masses, placed generally at the union of a great number of vessels. In these glands it is supposed some further change takes place, by which the *chyle* is more animalized and more fitted for becoming part of the blood. The number of these glands in the mesentery is about a hundred. We represent some, and the course of the lacteals through them.

The little vessels are furnished with valves, formed by folds of their internal membrane, and arranged in pairs, with their convex side turned towards the intestines, so that any fluid can pass upwards to the *thoracic* duct, but nothing can return, as the valves would prevent it. These valves are another means by which the *chyle* is caused to advance towards the blood;

* Because the principal part of it is found in the back of the *thorax*, or chest, close on the back-bone.

for, if we suppose the lacteals, loaded with *chyle*, to be pressed, as they would be, by the action of any of the neighbouring muscles, it is clear their contents cannot remain stationary, as



this would be contrary to the laws of fluids under pressure, neither can they go backwards, the valves preventing this, therefore they must go forwards, that is, towards the thoracic duct. This duct itself opens into the vein by a valve, which, while it permits the discharge of the *chyle*, prevents any blood entering; and it is this structure that so long kept us in ignorance of this set of vessels, as, without it, the injections which were constantly thrown into the arteries and veins by old anatomists would readily have entered and filled these also.

In the engraving, the heart and lungs, diaphragm, liver, spleen, stomach, &c., are all supposed to be removed. Nothing remains but a fold of intestine, C C, attached to the back-bone by the mesentery, M, the white lines on which represent *lacteals* arising from the intestine, and after passing through some of the glands, *g g g*, directing themselves towards the back-bone, where, by their union, they form A A, the thoracic duct.

This may be traced up along the back-bone until arrived at the top of the chest, where it bends down and discharges its contents into Y, the *subclavian* vein, just where this latter unites with X, the carotid, to form S, the superior *vena cava*, which we know passes directly into the heart. Numerous *lymphatics*, *b b*, may be observed running from each side to join the thoracic duct in its ascent. The dark shades behind them indicate the ribs.

If we now understand the nature of the *lacteals*, we shall have little difficulty in extending our views, and comprehending that vessels exactly similar in nature and structure are to be found in all parts of the body, but as there is no *chyle* for them to carry, they are loaded with a clear, transparent watery fluid, which has gained them the name of *lymphatics* (*lympha*, water). This transparency both of themselves and their contents, caused the discovery of them to be delayed for some years after the lacteals were known. Rudbeck seems entitled to the honour, though Joliffe and Bartholin have their several supporters. Since their time, some of our countrymen have been amongst the most distinguished investigators of the absorbent system. We may mention Dr. William Hunter, Monro Secundus, Cruikshank, and Hewson.

The *lymphatics* have their origin by open mouths on all the surfaces of the body. Thus they commence at the pores of the skin, on the internal surface of the bladder, in the cavity of the abdomen, &c. They are generally arranged in two principal series, the one just beneath the skin, the other deep among the organs of the body. They almost all tend towards the thoracic duct, where their fluid is mixed with the chyle, and conveyed along with it into the subclavian vein. Mr. Bracy Clarke, however, has noticed the important fact, that some of them discharge themselves into the veins nearest them without passing by this longer route. As the lacteals passed through glands, so also do the *lymphatics* and some of these can frequently be seen forming a knotty chain along the necks ot children affected with scrofulous diseases. As they advance, the lymphatics unite to form larger trunks, but not with the same regularity as the veins, for sometimes after uniting, we see them again divide. Finally, however, they are reduced to three or four great trunks, which run to the thoracic duct. This duct is a vessel of considerable size, and arises from the union of the lymphatic trunks of the lower extremities with those of the abdomen. At the place of junction there is generally observed a dilatation like the bulb of a thermometer-tube, and this has got the name of *receptaculum chyli*. This is more distinct in the dog and the turtle than in man. The duct is sometimes double, or divided into many branches, to which attention should be paid in making experiments, as persons tying one branch have occasionally proceeded to argue as if, by that, they had totally prevented the chyle from entering the blood.

It was the opinion of the old anatomists, that absorption took place by the veins, but the discovery of this system of vessels operated a material change. The lacteals evidently took up the chyle from the intestines; from analogy it was concluded then that the lymphatics took up their contents from the several surfaces on which they opened. Thus mercury rubbed on the skin will produce salivation; other medicinal substances, narcotic or purgative, may be made to produce their appropriate effects in the same way. Through what channel could they reach the system, if not through the lymphatics? In consequence, the name of *absorbents* was given to these vessels as indicative of their action. The old doctrine, however, was not altogether resigned, and many believed, that though the lymphatics did absorb, yet they were very much assisted in their function by the veins. And this is nearly the opinion held at the present day. For a time the veins were completely excluded from all co-operation. John Hunter filled portions of the small intestines with milk, which he confined so as to produce a degree of distension of the part; the milk was quickly observed to distend the lacteals, but no trace of it could be found in the veins. Similar experiments were made on other parts. He poured a solution coloured with indigo into the *peritoneum*, and saw the lymphatics fill themselves with it; so that the question was considered as finally set at rest. But M. Magendie has rendered the old opinion again probable, and shown it to be likely that the veins do absorb. In an experiment made along with M. Delille, he divided all the parts of a dog's leg except the artery that carried the blood to it, and the vein by which it was returned. He then inserted into the paw a quantity of upas poison; in four minutes its effects were visible on the animal, and in ten minutes it proved fatal. In this case it was supposed that no communication could exist between the paw and the body of the animal, except through the vein; and therefore, that here the vein must be admitted to have been the absorbing organ. But as it was suggested to him that lymphatics generally accompanied the course of veins, and that it might be said some small ones had crept up along the coats of the vessels which he left undivided, he determined to make his experiment totally unexceptionable. With this view he made the preliminary steps as before, and having introduced two small tubes into the vessels, he completely divided them, so that the only connexion now remaining was the current of blood passing through those tubes. The poison, however, produced the same effect as before. This seems decisive, yet there are still sources of error. If he inserted the poison, as would appear possible from his account, into a wound made in the paw, it is clear that he might then have been introducing it into the blood through the open extremity of a vessel, but this would not be the vein, in its natural condition, absorbing. It is also possible that some lymphatics might have existed in the paw, which, in place of running towards any trunk leading to the thoracic duct, discharged themselves into the nearest vein, and that thus the vein merely conveyed the blood, while the lymphatic absorbed it. Mr. Abernethy traced lymphatics to veins. Those who feel interested in pursuing this argument further, will find good accounts of the experiments made on each side, with remarks on the sources of inaccuracy to which they were liable, in Bostock's *Physiology*, or Elliotson's edition of Blumenbach's *Physiology*, a work of all others the most likely to interest and instruct the medical student.

To us it appears clear that the lymphatics do absorb, whether they are assisted by the veins or not; and as the lacteals continually carry into the circulation new particles, which, being deposited in different parts, serve for the nourishment of the organs; so the lymphatics constantly take up from all parts of the body those particles, which, having performed their duty, are now superfluous, and convey them also to the circulating current, where, by a new process, they are fitted to undergo new combinations, or else are expelled from the system by means of the secretory organs. That this change is really going forward we have the clearest proof from Du Hamel's experiments on bone. He fed a pig with madder for a few days, and found its bones deeply tinged of a pink colour. Confining it then to a different food, the pink colour went off. On examination it was found that the pink colour adhered to the earthy part of the bone, and consequently that this, the hardest material in the body, was deposited and absorbed within a very short time. Now, the deposition is made from the minute branches of arteries, the absorption by the lymphatics. The two processes are going on together, and in due proportion to each other. Should either preponderate, disease is the result. Thus, should the fluid that constantly moistens the serous sacs be exhaled faster than absorbed, a collection of it takes place, constituting dropsy. On the other hand, should the absorbents at any particular part of the surface take away faster than the arteries lay down, a breach of continuity is the consequence, and an ulcer is formed. Advantage of this is taken in treating certain tumours, from which a firm and equable pressure cuts off or diminishes the supply of arterial blood necessary to their growth, while the absorbents continue to remove. The tumours are thus rapidly diminished, and disappear. This end is accelerated by the use of bleeding, low diet, and other means calculated to diminish the power with which the blood is sent towards the diseased part. Absorption is also of so much use in determining the figure of the body, that John Hunter used to call it "the modelling process." When a bone is broken, and the edges placed together, they are found, after a time, united by a hard irregular bony mass, forming a protuberance, like a wen, around the regular bone. The more distant the period at which we examine it, the less we find this protuberance, until at last it is completely removed, and the whole bone restored to its original shape.

How far matters can be absorbed from the skin has given rise to some controversy. We before mentioned that certain medicinal substances proved efficacious when applied to it, but as, in these cases, friction is always used, it is doubtful how far this might have tended to lay bare the extremities of the vessels, and even have forced some of the matters into them. It was asserted that the simple immersion of the body in water gave an addition of weight, in consequence of some of the fluid being absorbed. This was denied by Seguin, who maintained that while the skin remained entire no absorption could take from the surface; and he ingeniously attempted proving his opinion by immersing the body in baths holding in solution certain salts, which if taken into the system, would manifest themselves by their peculiar effects. For instance, he used solutions of corrosive sublimate, which, if absorbed, would produce salivation. This he never found to occur.

Dr. Currie accurately weighed a person before and after immersion in a warm bath, without detecting any difference; he therefore concluded there had been no absorption. Dr. Bardsley made the same experiment, with the same result, but drew a directly opposite conclusion; for, said he, as under such circumstances the exhalation from the lungs must be much increased, the absorption from the surface must evidently be great to counterbalance it, else there would be a loss of weight. Dr. Edwards has embraced the same side, and, by the accuracy of his experiments, seems to have decided the question. He experimented on a lizard, previously reduced by exposure to air, which had caused a great loss of its fluids by transpiration. He then placed it in water, so as to immerse only the tail, hind legs, and hinder part of the body. It was afterwards weighed at distant intervals, and found gradually to have increased in weight, until it had regained its original size and plumpness. This absorption was not mere imbibition, limited to the surface; the water penetrated deeper, and was distributed through the system*.

* [1. M. Dutrochet put some albumen, or white of egg, into a wide glass tube, and carefully poured water upon it from above; but the line of demarcation between the two fluids remained distinct; therefore, albumen has no affinity for water. M. Dutrochet, however, *separated the same fluids by a membrane*, and the water passed across it, and speedily mixed with the albumen. 2. M. Dutrochet took the blind-gut of a chicken, filled it half-full with 196 grains of milk, and having carefully tied up its open extremity, immersed the whole in water. At the end of thirty-six hours the bag was quite swollen, 117 grains of water having been imbibed. From this period a gradual *diminution* of weight took place; in thirty-six hours fifty-four grains of watery fluid had passed out of the little bag, and the milky fluid which remained had become putrid. So long as the fluid within was denser than that without, absorption or imbibition continued; but no sooner had decomposition rendered a portion of the milk thinner and more limpid than the water itself, than that portion was poured out into the surrounding medium. There is a large class of experimental facts similar to the above, in all of which a more limpid fluid will pass across any organic mem-

There are one or two other facts which tend the same way. In *diabetes*, the weight of urine passed in twenty-four hours, sometimes exceeds the weight of food and drink taken, by more than the loss of weight in the body during the same time. Whence, then, can the surplus be derived, but from absorption? The practical application of the doctrine is often witnessed at Newmarket, where a jockey who is anxious to keep himself below a certain weight, to which he very nearly approaches, will, on the morning of the race, much more readily eat a hearty meal than venture on a glass of spirits, the stimulus given by which to the action of his absorbents would, he well knows, particularly if the air be damp, soon put him beyond his appointed bounds.

We have now traced the food through its various stages. We have seen it chewed and mixed with saliva in the mouth; swallowed by the muscular action of the *pharynx* and gullet; mixed with a solvent juice in the stomach, and gently acted on by its vermicular motion, until converted into a pulpy grayish matter, termed *chyme;* passed from that into the *duodenum*, where, by the action of the bile and pancreatic juice, it was separated into *chyle* and excrement; we observed the latter as, urged on by the *peristaltic* motion of the small intestines, it proceeded, gradually losing its fluid particles, and becoming more consistent as it approached the rectum, from which it was discharged; returning, then, we saw the *chyle* taken up by the numerous mouths of the *lacteals*, opening at the summits of the *villi* of the small intestines; from these it passed into the mesenteric glands, the office of which is not well

brane to mix with one that is less so. 3. M. Poiseuille endeavoured to introduce water into glass tubes of an extremely small calibre, but invariably failed. No sooner, however, had he thickened the water with albumen, or gum, or gelatine, than the denser fluid readily traversed the same tubes, through which no artificial power could force it in its pure and limpid state.

The first of these experiments teaches us that the tenuity of external media is one essential condition of their absorption by organic membranes; and the second that the same condition is necessary for the excretion of the same. The third experiment tells us that the viscidity of vital fluids, so far from clogging the extremely minute canals through which they pass, as our preconceived ideas had led us to suppose, is, indeed, one essential condition of their circulation.]

understood; afterwards into the thoracic duct, by which, finally, it was conveyed into the current of the blood.

Our next inquiry, therefore, must be into the nature of the blood, the means by which it is supplied to all parts of the body, and the uses to which it is supplied.

Chapter VII.

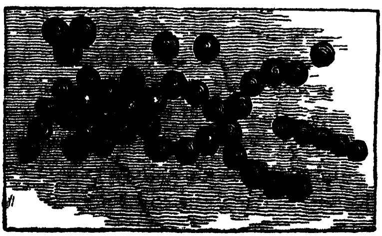
THE BLOOD.

If we take a frog alive, and place his foot under a good magnifier, taking care to spread out the toes, so that the light may traverse the fine web between them, we shall distinguish the blood flowing through the vessels by which the part is supplied. After the eye is a little accustomed to this novel and pleasing spectacle, in which we detect Nature, as it were, engaged in her secret works, we begin to observe that matters of different kinds seem to pass through the vessels. Towards their sides is a thin watery current, generally limpid and colourless, while in their centre, apparently borne forward by this current, is a column, more or less dense, and formed of jelly-like globules, irregularly collected together. Should any impediment to their onward passage occur, they become collected in numbers at the place of the obstacle, the vessel is distended, this distension causes pain, their numbers produce increased redness, the effort to get them forward calls forth increased action of the arteries, giving a feel of throbbing, more blood is sent to the place, more heat given out, and the whole part swells. Such a condition of the part is called Inflammation. From this inspection we have learned that the blood consists of two very different parts, the watery fluid, and the globules, or little round balls of jelly-like matter that swim in it. As long as the blood continues in circulation these two parts continue mixed, so perfectly, as to present the appearance of a simple fluid, generally red, but varying in its shade in different animals, and also in different parts of the same animal. But when withdrawn from the circulation, and allowed to stand, it soon affords a proof that our microscopes did not deceive us, by separating into two portions,—the fluid, termed *serum*, and the solid, formed by the coagulation or running together of all the globules, to which the name of *crassamentum* or *clot* is given. The redness we find all entangled in this latter, leaving the *serum* free, and nearly colourless.

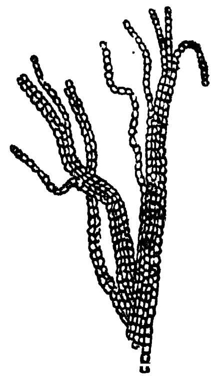
So far we have an analysis made for us by nature; we are now obliged to call in the aid of art.

The clot floats in the serum, so that we can take it out; and by letting it drain, have it almost quite distinct and separate. In this state it appears a red spongy mass, the colour and consistency being generally best marked towards the bottom. If we now expose it to a stream of water, we shall soon see the colour washed away, and nothing left but a white jelly-like mass, to which the name of *fibrin* is given. It is evident, then, that the globules of blood consist of two parts, to the one of which it owes its consistency, to the other its colour. We may separate them in another way, which Ruysch first taught us. He used to stir, with a small bundle of twigs, the blood while congealing: the pure and colourless *fibrin* collected on the twigs, while the colouring matter remained behind, mixed up with the *serum*. It was from the fibrous, stringy appearance assumed by the coagulated part in this experiment that it obtained the name of *fibrin;* the colouring matter has since been named by the French *hœmatosine* (from *αἷμα*, blood). The next point was to consider how the little globules we have mentioned came to form fibres or strings. This has involved so much microscopic investigation and discussion, that we almost fear to enter on the question, particularly as we consider such investigations to be peculiarly liable to error. The idea most ordinarily followed, and which is supported by Sir Everard Home, M. Bauer, MM. Prevost and

Dumas, and others, is, that the globule is formed of a central part, which is the true *fibrin* or *lymph*, surrounded by an envelope of colouring matter. Globules, similar to the central part, are to be found in the *chyle*. This also contains serum, therefore nothing is wanting to form it into blood but the colouring matter, which it is supposed is given by the lungs. According to others, the colouring matter forms distinct globules, and, in addition to both these, M. Bauer has discovered a third kind of globule, formed altogether of *lymph*. This is the most important part of the blood. From its plasticity it seems eminently adapted for closing up bleeding vessels, uniting parts that have been separated, and repairing such as have been injured or destroyed. In consequence of its general utility, we find it generally diffused. Globules are found, and coagulation takes place perfectly in the blood of the lobster and other white-blooded animals, in which the colouring matter is totally deficient. Previous to coagulation a vapour is given off by the freshly-drawn blood, which has a very peculiar smell, and is found to consist chiefly of water, holding in solution some animal matter, which gives it a great tendency to putrefy. When coagulation commences, the *fibrin*, or centre parts of each globule, exert, according to Sir E. Home, a mutual attraction. They burst from their coloured envelope, and run together in an irregular manner, but so quickly, as to entangle the coloured envelopes, which are thus made parts of the clot. The mode in which the globules ran together in M. Bauer's microscope is thus represented by himself.



Struck by the appearance of elongation produced by some of these collections of globules, and aware that the chemical composition of fibrin and muscular fibre was the same, Sir Everard Home induced M. Bauer to extend his inquiries to the formation of this latter. The difficulty of procuring a single fibre caused some delay, but at last one was procured from the thigh of a roast chicken, and on being submitted to the magnifier, presented exactly the *wished-for* appearance of a number of globules, connected together in a right line.



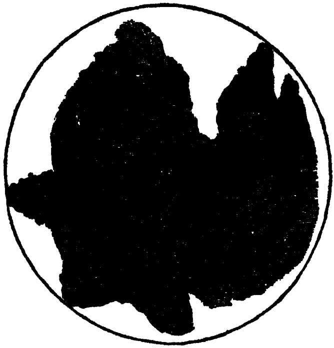
Magnified view of Muscular fibre.

The whole theory was, therefore, clear. The blood was thrown out from the extreme vessels; the globules coagulated and attracted one another, so as to form fibres; and, that nothing might be wanting, MM. Prevost and Dumas passed an electric shock through fluid blood, by which its coagulation was much hurried, and this sinking together of the globules was declared analogous to the contraction of the muscle; while Dr. Wilson Philip seemed to wind up the demonstration, by showing that the nervous influence was similar to the electric fluid. But not content with discovering the mode of formation of a single fibre, Sir Everard went on to show how this same blood, when effused and coagulated, can become organized, intersected with blood-vessels, and capable of forming a living bond of union between two parts of the body that had been separated by a cut or wound. We know the first effect of a cut is to cause an effusion of blood, which generally continues until some of it coagulates in the wound, and thus stops up the ends of the bleeding vessels. If the wound be then covered up and kept quiet, it will rapidly heal; if the opposite sides of it be not quite in contact, they will appear united through the medium of the *lymph* or *fibrin* of the effused blood, and the whole will be covered over by a new skin. The *lymph*, on examination, appears intersected with blood-vessels; it is henceforth a living solid, and partakes of the nutrition of the parts. How has this occurred?

In making observations on the growth of certain plants, M. Bauer observed, that occasionally a little bubble appeared on the side of the young root, surrounded by a viscid slimy substance; the bubble would then burst with force, so as to extend the slimy matter to the length required for a little fibril or rootlet; the gas had passed through the centre of it, so as to make a tube, and the slimy matter instantly coagulated round this. It struck Sir E. Home that the vessels in the newly thrown out lymph might be formed in the same way. This gas M. Bauer ascertained to be carbonic acid; and Dr. Maude had shown that the same was given out by blood when coagulating. Could it then be applied to the same use? Sir Everard set to work. He punctured his arm with a lancet, so as to draw a drop of blood, which was received into a watch-glass in a fluid state, and placed in the field of the microscope. The eye was then kept constantly fixed on it, to note the changes that might take place. The first thing that happened was the formation of a film on the surface, that part beginning to coagulate sooner than the rest. In about five minutes something was seen, to be distinguished in different parts of the coagulum, beginning to show itself where the greatest number of globules was collected, and from thence passing in every direction, with considerable rapidity, through the serum, but not at all interfering with the globules themselves, which had all discharged their colouring matter. Wherever this extricated matter was carried, a net-work immediately formed through every part of the coagulum.

The annexed plate gives the exact representation of the appearance the drop of blood put on, when coagulated, as seen in the field of the microscope.

All this net-work here represented was made by the carbonic acid extricating itself during coagulation. It presents,



therefore, so many ready-formed tubes, fit for the reception of any blood that might be poured out near them, and, therefore, prepared to carry on the circulation of this newly-organized part.

We have gone through these speculations of Sir E. Home, because they are ingenious and connected, and will serve to give our readers an idea of the usual style of such investigations. It is clear, however, without going into a formal refutation, that he has scarcely got beyond a bare probability. Almost every one of his facts have been denied or questioned by men equally accurate, and equally able. Dr. Young, supported by the late observations of Dr. Hodgkin and Mr. Lister, assures us that the globules are no globules at all, but little flat rounded cakes, with a depression in the centre. They also deny that they are composed of a nucleus and envelope. This central depression, the Abbé Torre magnified into a perforation, and concluded that they were neither globules, nor flattened circular bodies, but rings. He made his observations with little sphericles of glass, formed by dropping melted glass into water, and it was the peculiar form of his instruments that led to the error in his observations. Many authors have conjectured that these globules alter in shape, narrowing themselves to enter the minute capillary vessels, and again resuming their rounded form when they reach the wider passages; while Haller and Spallanzani have not been able to distinguish anything but an uniform fluid in the capillaries, from which M. de Blainville draws the conclusion, that the globules terminate by being dissolved into a soft, viscid, plastic mass, before they are finally applied to the purposes of the formation of muscular fibres, or the repairing injured parts. This at once puts an end to the idea of muscular fibres being made up of globules, which idea is indeed equally refuted by the microscopic observations of Dr. Hodgkin and Mr. Lister. The size of the globules has been a point equally disputed, and they have been stated at almost every size from the $\frac{1}{1000}$th down to the $\frac{1}{10000}$th part of an inch. Sir Everard Home made two observations; in the first the globule appeared $\frac{1}{4000}$th part of an inch in diameter; in the second, $\frac{1}{6000}$th. Such a remarkable difference might appear sufficient cause for repeating or altering the observations, but Sir Everard took an easier way, and assuming $\frac{1}{5000}$th the mean of his *two* observations, made that the standard size for all the globules of the human blood.

The size of the globules varies in different animals, but this variation bears no relation to the size of the animals. The shape also varies, as we are told they are elliptical in fishes, reptiles, and birds. Dr. Young found them of an almond shape, and extremely large in the skate; Rudolphi found them more or less oval in the common fowl, and many amphibia; Hewson found them larger in the fœtus, than in the adult animal; and, what was very singular, Prevost and Dumas found those of the chicken to be circular until about the sixth day, when some elliptic globules first appear, and in a few days more not a single circular one can be found*.

The *colouring matter* of the blood has been much studied, and is little understood. It has been most usual to attribute it to certain salts of iron, which, dissolved in *serum* by the aid of an alkali, were said to produce the exact tint of the blood. This has been denied, and even the presence of iron in the blood doubted; but it seems fully established, by the experiments of Berzelius and Engelhart, that it does exist, and is connected, not with the *fibrin* or *serum*, but with *hæmatosine*. They conclude, therefore, that though in very small quantities,

[* The blood globules of mammals are considered to have the form of a circular lens, with the exception of those of ruminants, which M. Mandl states to be elliptical.]

not exceeding one-half per cent., it must be in some way connected with the colour of the blood, but in what way they could not decide. Dr. Stevens has since suggested that the colouring matter is a peculiar animal principle, containing a large proportion of carbon, to which we can only say, we think it very possible; perhaps in his future researches he would consider how far the bronchial glands, which we find constantly black with carbon, may contribute towards the formation of this principle. It is at any rate not an essential part of the blood, for many lower animals, such as insects, mollusca, and crustacea, are very well nourished by a blood that has no colour. Parts also of the human body are supplied by vessels so small, that they convey nothing more than the plastic lymph of the blood, rejecting the coloured particles; such are the serous membranes, and certain coats of the eye. It is only in cases of inflammation that these vessels become dilated, so as to admit red particles. Every one knows this to occur in a *blood-shot* eye.

The *serum* is the remaining part of the blood after the *fibrin* and *colouring matter* are removed in a clot. It is a thin fluid like whey, with a slight yellowish or greenish tint, unctuous or slippery between the fingers, and containing a certain proportion of salts. When exposed to a heat of 150° (Fahrenheit), it soon becomes opaque in consequence of the albumen which it contains being coagulated. This albumen differs in little from the *lymph* or *fibrin*, except in being fluid. Their chemical constitution is almost the same, and they are applied to the same uses, the nourishing of the body. The albumen or white of egg, is in fact the earliest nutriment of the chick, and the same principle is also found in the seeds of plants, affording the earliest materials for their growth before the root has established a connexion with the earth, or the leaves with the air. It may be discovered with a microscope in the serum, under the appearance of little unformed flakes; these have been observed to form slowly into colourless globules, and even have been found, towards the close of exhausting hæmorrhages, to coagulate spontaneously, and forming a clot at the mouth of the vessels, to terminate the bleeding. This interesting fact, first noticed by Dr. Macartney, fully confirms the view started by Berzelius, that albumen and fibrin are merely modifications of the same substance, less perfect in the former, more perfect in the latter.

There is still another constituent in the blood, termed *serosity*. This is procured by pressing the albumen that has coagulated, when a certain portion of a thin watery fluid, holding in solution animal matter and a little salts, exudes. It is well known under the name of gravy, and is seen to run out on cutting meat that has been dressed. We thus see that the blood in the higher orders of animals, is a very complicated principle, complicated in proportion to the number of different organs it has to maintain, and the different secretions for which it must supply matter. Its importance to the whole frame is well known; it penetrates every tissue, affords them the materials necessary for their growth, and the stimulus that enables them to act. Without it the nerve could neither feel nor convey the commands of the will. When, in sitting, we press on the nerves of the thigh, so as to impede the passage of the blood into them, the leg and foot lose all sensation and motion, they become what is commonly termed *asleep*. When we rise or shift our situation, so as to take off the pressure, the blood commences to flow again, and our first perception of its return, as our earliest perception of life, or the first sensation of a man recovering from drowning, is accompanied by pain. There is a disagreeable, unpleasant, pricking feel, commonly known as "pins and needles," which is produced by the blood re-entering the minute vessels. If this impediment to the flow of blood be continued, the part dies. On this principle surgeons act when they remove certain excrescences, by what is termed "ligature." They tie a string tightly round the neck of the excrescence, so as to strangle the vessels going into it from the body; the excrescence, no longer supplied with blood, dies; and as dead matter cannot attach to living, it *sloughs*, and is cast off. So true is it that "the life of all flesh is the blood thereof." The quantity of this fluid contained in the body of an adult has been very variously estimated. Allen makes it scarcely more than eight pints; Harvey, nine; Borelli, twenty; Haller, thirty; Riolan, forty; Hamberger, eighty; Keill, a hundred! The former, Blumenbach says, are evidently much nearer the truth. It is evident, however, that any arbitrary statement of the quantity of a fluid, which probably varies after every meal, must be incorrect, and merely allowed as an approximation. The fluids of the body are generally considered as forming five-sixths of its whole weight, and the solids only one-sixth; perhaps, indeed, the proportion of fluids may be fairly set down as still greater. Sir Joseph Banks had sent him a perfectly dry mummy of a Guanche, from the island of Teneriffe, which, though perfect, and containing all the intestines, weighed but seven pounds and a half. The bodies of persons overwhelmed by the sands in the Arabian desert are also occasionally found, which, from the parching nature of the soil, have been dried up so suddenly as to allow no time for putrefaction, and these are said to weigh generally ten to twelve pounds. When containing all their fluids, they probably did not fall short of a hundred or a hundred and twenty. Now all these fluids either were blood, were intended to be such, or had been such; that is, existed in the state of *chyle*, or matters taken in by the absorbents, and which were on their way to enter the circulating fluid; or having entered it through the veins, and undergone the action of the heart and lungs, appeared as perfect blood in the arteries; or, finally, being conveyed by those arteries to the several secretory organs, had been separated in the form of secretions, such as the bile, urine, &c. But as we do not know the proportion which the first and third of these classes bear to the second, we cannot from this deduce anything respecting the quantity of blood in the circulation. The usual estimate is from fifteen to twenty pints; we have no means of giving a more accurate valuation.

Variations in the quantity of the blood are productive of many and serious diseases. When it is not formed in sufficient abundance, as may arise from derangement of some part of the digestive organs, we see emaciation and debility come on; or the sudden withdrawal of a portion of it, by the operation of bleeding, will cause fainting and temporary weakness. A superfluity of blood is equally dangerous. This is termed *plethora**, and most usually occurs at the period of life when, the body being completely formed and knit, there is no further demand for the supplies which a powerful digestive system still continues to furnish in the same abundance as before. If these are not worked off by active exertion, or diminished by a moderate and temperate diet, the blood becomes too rich and copious, and Nature attempts often to relieve herself by discharging a portion of it. These discharges more commonly take place from the nose, or from the extremity of the intestinal canal, under the form of bleeding piles, and are most usual in persons of about forty or fifty, who use little exercise, and indulge freely in the pleasures of the table. Should the discharge, however, take place from the small vessels of the brain, the effused blood will press on the brain, and cause those preliminary apoplectic attacks that often occur about this period. The tendency to these is much increased by the use of stimulating liquors, by fits of passion, or by wearing tight neckcloths, which, pressing on the jugular veins, prevent the free return of the blood from the head, while the arteries lying deeper, are not affected by the same pressure, and continue to supply the head in the usual quantity.

Another mode in which the superfluous blood is got rid of, is by being employed in the deposition of fat. It was the old idea, that fat was secreted by certain glands destined for that purpose, but as no such glands can be discovered, it is now allowed that it is formed in the circulation, and deposited from the sides of the vessels, more particularly the veins. It exists in a great variety of forms, as oil, marrow, fat, spermaceti, and suet, which all contain the same principles, and only differ in

* πληθώρα; from πλήθω, to fill, to inundate.

solidity. These principles M. Chevreul, who has particularly investigated this subject, has termed *elaïne** and ***stearine***†; the predominance of the former renders the compound more fluid,—of the latter, more solid. That it is deposited from the sides of veins, we can, in some measure, satisfy ourselves, by examining at any butcher's stall, the caul of a lamb, which is generally spread over it as an ornament. We observe the fat here not uniformly laid over the entire surface, but deposited in stripes, or ribands, taking different directions, meeting together, and again parting, so as sometimes to approach the appearance of lace. In the centre of each of these ribands we shall find a vein running, and the deposition first takes place round its circumference, from which it gradually spreads out. This deposition, also, is most abundant in those animals in whom the venous blood bears a large proportion to the arterial, such as the whale-kind, where we always find an immense quantity of blubber underneath the skin, and in the *cachalot*, or spermaceti whale, a collection amounting sometimes to eighteen or twenty tons of the fluid fatty matter, from which it derives its name, and which occupies two large caverns on the upper surface of its head. In the high-flying birds, in whom, on the contrary, the arterial blood is more abundant, fat is rarely deposited. It increases in those which nestle on or near the ground, and make less distant excursions; such are the partridge, the barn-door fowl, and many small birds. In water-fowl the quantity of venous blood again predominates, as the darkness of their flesh would indicate, and we well know the quantity of rich, rancid fat, often found in their bodies. When to this natural dispo-

* From ελαιον, oil; as remaining liquid at ordinary temperatures.

† From στεαρ, suet; which, in such circumstances, is solid. Advantage has been taken of this to separate those two principles. If common oil be exposed to a low temperature, its *stearine* congeals, while the *elaine* remains liquid, and may be separated from it by pressing between folds of bibulous paper. In this pure form it is used in greasing the wheels of watches and other delicate machinery, which, when the oil was used entire, were often clogged and stopped by the congelation of the stearine, consequent on the first winter cold. This is one reason why watches are more liable to stop at night, when laid on a table, than during the day, when they are worn about the person.

sition we superadd a state of perfect rest, when we bind an unfortunate goose in a hot close situation, debar it all motion, put out its eyes to prevent the entrance of any excitement from without, and then cram it with food, under these unnatural circumstances the liver becomes diseased, it swells, a rich oily fat is deposited around and in its substance, and it forms that delicacy so highly esteemed by the gourmand, but which should be abhorred by every man of humane feeling, the far-famed "foie gras de Strasbourg."

Fat is also formed abundantly in such animals as remain torpid during the cold weather. A little before the approach of winter they feed voraciously, and the fat collects in enormous quantities, chiefly about the intestines and mesentery, from which it is easily absorbed, and carried off for the nutriment of the system during the long sleep, when no sustenance can be supplied from without. That such is its use, is evident from the fact, that however fat and plump they may have retired to their dormitories, they always re-appear thin and emaciated. Persons employed in hunting the bear for the sake of his grease, know that this is always collected in most abundance towards the close of autumn. The fur, a more important object, is also in perfection at the same time, or perhaps a little later, when the autumnal moulting is over, and he is completely furnished with his new winter-coat. Irregular accumulations of fat in different parts of the body occur in several animals. Of this nature are the humps on the back of the camel and dromedary, which, like the internal collections in animals that lie torpid, become much diminished when no food has been taken for some time; this would seem an additional provision to fit the camel for traversing "the *barren*" as well as "the dry land." The hunch on the shoulder of the bison is nearly of the same description, mixed with much gristly matter, and is esteemed by the American Indians a high dainty. A very savoury description of the mode in which it is dressed, along with an animated account of a bison-hunt, occurs in one of Cooper's tales; and it is pleasant thus to find a fictitious scene based on the reality of nature,—the colours of fancy adorning the ground-work of observation.

The Cape sheep, it is well known, have tails of such enormous size, as to require to be supported on little carriages, which they trail after them; the Bosjesman women, inhabiting nearly the same country, have similar fatty depositions on their buttocks, of which the person exhibited under the name of the Hottentot Venus afforded a well-known example. She died in Paris in 1815, and M. Cuvier, who had the opportunity of examining, reports that the enormous protuberance consisted altogether of an elastic tremulous fat. It is singular that the same is found in certain of the monkey-tribe, as for instance the mandrils, inhabiting Guinea; and it would appear that in neither case does this collection commence until the female has become a mother, or at least arrived at the age of puberty. General obesity is more frequently met with in the female than in the male sex. This may, in part, be attributed to their more sedentary habits, but must also be influenced by the greater quantity of cellular structure in their bodies, which we know to be the most usual place for its deposition. They would appear, also, to have a greater proportion of venous blood, and this, in such persons, is found loaded with a rich oily matter, that requires only to be poured from the sides of the vessels to harden into fat. De Blainville, who has adopted this idea of the origin of fat, mentions a singular fact in support of it. He was engaged in dissecting an elephant that had died at the Jardin des Plantes. The animal had been long domesticated, highly fed, and, in consequence, had died of apoplexy. He was making some examination by the side of the jugular vein, which he chanced to cut slightly; returning the next day, he found that a certain quantity of blood had flowed along the neck. But what struck him most was, that the liquid had deposited to the right and left along its whole course a quantity of fine, white, greasy-looking matter, which he analyzed with great care, and found to be perfectly-formed fat. This he looks on as conclusive, that fat is not formed by glands, but in the circulation, and exuded then from the sides of the vessels.

Remarkable cases of corpulence have, from time to time been recorded. A man who was shown at the Palais Royal, weighed five hundred pounds, and was almost as broad as long. Mr. Bright, of Maldon, in Essex, died in the 30th year of his age, and had then arrived at the enormous weight of forty-four stone, or six hundred and sixteen pounds. He was five feet nine inches and a half high, measured round the chest, just under the arms, five feet six inches, and round the belly six feet eleven inches. But the fattest person of whom we have authentic account was Daniel Lambert, of Leicestershire, who died at the age of forty, weighing seven hundred and thirty-nine pounds. Such men are seldom of extreme sensibility; the extremities of the nerves seem lost in the prodigious accumulation, their acuteness of sensation is blunted, and the mental feelings generally exhibit similar obtuseness. The disposition is often easy and contented, they have none of the stronger passions; they are not given to plotting or devising plans. Men of anxious mind and irritable temper seldom get fat. With what justice does Shakspeare make Cæsar say,

> Let me have men about me that are fat;
> Sleek-headed men, and such as sleep o' nights;
> Yond' Cassius has a lean and hungry look;
> He thinks too much: such men are dangerous.

The influence of rest in producing this deposition is curiously exemplified in insects, in many of whom we find an abundant quantity of fat, while in the state of larva, which disappears as soon as they have sprung from this dull, motionless, living sepulchre to "wing their way through fields of air." The use of malt liquor is another cause, and every one knows the fattening effect of *grains* given to cattle.

We have thus seen that *plethora* and fat are consequences of too great a quantity of blood in the system. *Hypertrophy* *, or an undue growth of certain parts of the body, may be men-

* From ὑπερ, over: and τρεφω, to nourish.

tioned as a third. This has been known to occur in the brain, heart, and kidney. When the substance of the heart is affected by it, a most painful, and often incurable disease is the consequence. Alterations in the quality of the blood are productive of equally serious affections. The blood in scurvy is more fluid, of a violet or grayish colour, and possesses a peculiar odour. It is probable that changes are produced in it by the effect of marshy exhalations, and perhaps the primary changes in some contagious disorders occur in this fluid, but observations are much wanting on this point. Dr. Stevens has not been by any means sufficiently accurate to satisfy the doubts which are proper on such a subject. His inquiries, too, have the misfortune of having been made to support a preconceived theory.

The colour of the blood is well known to vary in different parts of the circulating system; thus, if we examine it in the veins, or the right side of the heart, we shall find it of a dark red or purplish colour; but after it has passed through the lungs, and been there exposed to the action of the air, it becomes of a bright lively red, and is so found in the left side of the heart and the arteries. Aristotle first made the remark, which subsequent observations seem to have confirmed, that the blood of a negro is darker than our blood. The temperature of the blood varies in different classes of animals. In man it is about 98° Fahrenheit, in birds higher; in cold-blooded animals it is but little above that of the medium (whether air or water) in which they live. We shall have occasion, however, to speak more fully of these matters afterwards. After death the blood usually coagulates in the vessels, and the clot thus formed in the heart, from the organized appearance the fibrin puts on, has not unfrequently been mistaken for a diseased growth. In persons who die by hanging or drowning, the blood ordinarily remains fluid. The same occurs after death resulting from violent muscular exertion; from locked-jaw, which, in fact, is very similar to the former, being a general spasm, or forcible contraction of the muscles; from impressions on the nervous system, such as violent fits of passion; and, it is also said, from lightning. In all these cases the body sooner runs into putrefaction, as if the extinction of life had been more sudden and complete. In those cases, too, the body remains flaccid, and as the fibrin does not coagulate in the vessels, so neither do the fibres of the muscles assume their usual rigid contraction.

John Hunter was induced to believe that the blood was alive, and that coagulation was its last vital act. The idea of a fluid being alive is at first received with difficulty, but when we reflect on our total ignorance of the nature of life, we must confess that no reason can be shown why it should not be conferred on a fluid as well as a solid. Besides, out of this fluid solids are formed. We have shown, that when blood is poured out into a wound, and coagulates there, its solid part becomes penetrated with vessels, which, uniting with the vessels on either side, carry on the circulation through it, and it becomes, to all intents, a living organized mass. Why, it is said, allow it life, now that it is solid, and deny it before merely because it was fluid? An impregnated egg, it is well known, is alive. The principle of life in it prevents putrefaction taking place when the egg is placed, during incubation, in circumstances most favourable for its occurrence. It also enables it to resist cold; and eggs which have been once frozen are more readily frozen a second time, the first congelation having destroyed the vital principle. An addled egg will also freeze more readily than a fresh one. Now it is asserted that blood just drawn, and exposed to a freezing mixture, resists its influence longer than the same blood thawed and warmed to its original heat will. This would be a strong corroboration of the opinion, and we believe that we agree with the greater number of physiologists of the present day, in considering the blood as possessing at least a certain kind of vitality, in consequence of which, a mutual relation is established between it and the vessels in which it circulates.

The idea of transfusing blood, that is, transferring it from the vessels of one animal to circulate in those of another, was first put into execution by Dr. Lower. He found, that when an animal lay, after a copious bleeding, exhausted and almost lifeless, it was immediately restored by conveying into its veins a quantity of blood taken fresh from another animal. It was supposed that the application of this fact might be useful in medicine,—in short, that diseases were to be cured by supplying the patient with a quantity of fresh healthy blood. The first experiment, however, of the kind proved fatal, and some other accidents occurring, the practice fell into disrepute. Latterly, however, it has been revived in a more rational manner, chiefly owing to the exertions of Dr. Blundell, and in his hands it has succeeded in preserving the lives of many females who were reduced to the lowest state of exhaustion in consequence of profuse discharges of blood consequent on childbirth. It is evident, however, in these cases, that the only object was the maintaining in the body a sufficient *quantity* of blood. No change in its *quality* was aimed at.

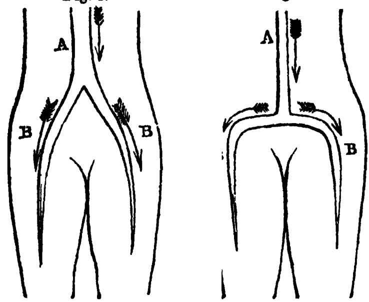
From the belief that certain diseases originate in the blood, it has been suggested to apply our remedies to the fountain head, by injecting them into the circulation. We regret that no decided success has been shown to attend this mode of treatment. It was pretty extensively tried during the late melancholy epidemic, and we do not believe it did much injury, except when pushed, as it occasionally was, to the extravagant length of throwing in whole gallons of fluid. For the rest we may say it had the fate of other remedies. It had its supporters and its opposers. It was brought to combat a disease, the progress of which was like the flight of the locust-tribes, "before them was a fertile paradise, behind them a desert waste;" a disease of which we know the sad results, while the causes are still hid from us; a disease against which it was justifiable to try every expedient, yet in which we fear that it might often with truth be said, He who did least, did most.

Chapter VIII.

THE CIRCULATION.

Now having gotten the blood, the fluid by which all parts of the body are nourished, and out of which all the secretions are made, the next question is, by what means is it to be conveyed to those parts, and how can we ensure the return of such portions of it as may not be required for those offices? Of course, the most obvious way is to lay down a system of tubes, or rather one large main-pipe, giving off branches as it passes along, and these again subdividing until they penetrate the minutest part. This is the principle on which a city is supplied with water. From the basin, or reservoir, sets out a great main-pipe, which at first, perhaps, gives off leading branches for three or four prominent districts; these branches, running along the principal streets, send off lesser conduits into each cross street; from these conduits still smaller tubes lead into every house, and perhaps a still further subdivision supplies every room. This supply is in the human body carried on through the great system of vessels termed the arteries. The central pipe is the *aorta*. Setting out from the chest, it first ascends a little, and forms a curve, from the uppermost surface of which it sends off the vessels that are to supply the head, neck, and upper extremities. Having thus provided for those parts it bends downwards, and lying close on the back-bone, rather on its left side, commences its course along the trunk, sending out at each side a branch to supply the muscles between each pair of ribs; these branches are called *intercostal*, from *inter*, between, and *costa*, a rib. Having got out of the chest and through the *diaphragm*, which, as we have said, separates the chest from the abdomen, like a shelf placed between them, it gives out from its front part a short thick trunk, which, after a course of about half an inch, breaks suddenly into three divisions, the one on the right going to the liver, the one in the centre to the stomach, and the one on the left to the spleen. These three organs, it will be remembered, lie nearly in the same level, so that a good engineer would take advantage of this to supply them through a common duct. But there is also another organ lying in the same line further back, the pancreas. This is a long narrow gland, compared in form to a dog's tongue, lying across the back-bone, with its thin end towards the left, in contact with the spleen, and its thick end, called the head of the pancreas, placed towards the right, surrounded by the turns of the duodenum, and consequently in the immediate neighbourhood of the liver. Now as it is thus close to parts abundantly supplied, there would be no use in sending a particular pipe to itself, but short pipes are laid into it from the arteries of the spleen on the left, and from those of the stomach and liver on the centre and right. Having thus supplied the upper stage of the abdomen by one great trunk, the aorta continues its course down along the back-bone. It soon arrives at the mesentery, which, as we have explained, is the fold of serous membrane binding the intestines to the spine. Of this fold it takes advantage to send a large branch to the intestines, and this branch supplies all the small intestines and the first half of the large, that is, the cœcum and a large part of the arch of the colon. Lower down, a second branch finishes what is necessary for the intestines, by supplying the remaining part of the colon and the rectum; while, between those, two branches are sent off, one on each side, to supply the kidneys. The organs contained in the abdomen being now furnished, the parts below are next to be considered, and, as the body soon begins to divide into the two legs, it is clear that the one central pipe will no longer be sufficient. But there is nothing an engineer guards more against in dividing his pipes than having any sudden or sharp turns where they can be avoided, as such increase the friction, and diminish the quantity of liquid he can supply. To avoid this, therefore, the aorta commences dividing itself high up in the loins, that the alteration in the direction of the current may be as gradual as possible. This will be rendered evident from the accompanying diagram, in which A is the aorta, B B the vessels into which it divides. In fig. 1, we see the natural course; in fig. 2, the much greater impediment

Fig. 1. Fig. 2.



the current would receive, were the division not made till absolutely necessary. The arrows show the direction of the current.

Now these two divisions of the aorta are called the *iliac* arteries, from *ilia* the flank; and before long they each subdivide into two branches, the internal and external. The internal branch dives deep into the pelvis, where it supplies the bladder, the lower part of the rectum, and other parts varying with the sex, and penetrating backwards, conveys the nutritive fluid to all that great mass of muscle which forms the buttocks. In the mean time the external runs forward to the front of the thigh, where it takes the name of *femoral* (*femur*, the thigh), sends off branches to nourish the muscles here, winds itself towards the inside of the thigh, and getting on the back of it, can be felt in the hollow of the ham behind the knee. Its presence here is also evinced by the well-known experiment of a person, when sitting, throwing one of his legs across the other; the suspended leg is observed to vibrate, and the vibrations take place at the same moment as the pulsations, being, in fact, caused by the fresh wave of blood attempting to straighten the arterial tube, where it is curved at the knee. The artery is here called *poplitæal* (*poples-itis*, the ham), and divides itself further into two principal branches, the one running along the front and outer part of the leg, the other along the back and inner part. These branches throw out small twigs to all the muscles, and other parts, in their way, and finish by supplying the feet and toes. This is a general outline of the great system of tubes by which the blood is conveyed to the remotest parts. They terminate by being subdivided in the substance of each organ into vessels of extreme minuteness, termed *capillary*, from *capillus*, a hair. It is in these that nutrition and secretion are performed, but the knowledge of the course and distribution of the vessels no more enables us to understand these operations carried on at their extremities, than a perfect map of all his pipes and tubes enables the engineer to comprehend to what uses the tradesmen and manufacturers, inhabiting the several houses, may turn the water with which he supplies them. But to pursue our system of pipes. The engineer suffers the waste water to run off through the sewers, as it would be of no use to him to bring it back again to his reservoir. A different plan, however, is to be pursued in the body, for the blood, when brought back, mixed with some fresh chyle poured into it by the thoracic duct, and exposed to the action of the air, becomes fit to be again employed in the same service; as also the water of the sewers would be if properly filtered and purified. For this purpose, therefore, another system of vessels, termed veins, is laid down; and the arteries communicate with the veins through the medium of the capillaries, or rather the capillaries are the extremely fine terminations of the arteries, and the equally fine commencement of the veins, running into one another in a mode that eludes our observation. As the veins get more distant from their origin, they unite more and more, until at length they all terminaie in two large trunks, the one bringing back all the blood that had been sent to the head and upper extremities; the other, that which had nourished the body and lower extremities; and these two vessels are called *venæ cavæ*, superior and inferior.

Vessels have now been provided sufficient for a perfect *circulation*, that is, for the return of the fluid to the point from which it set out. One thing is yet wanting; the power that is to set this fluid in motion.

Now for this purpose the engineer uses forcing-pumps, which, being worked by the power of animals, or water, or steam, drive the water into all the pipes, and so supply all parts of the city. But in the body we have neither animals, nor steam, nor water, to drive the nutritious fluid, but in their place muscle, which is the true productive or originating cause of motion in the animal frame. Suppose, then, that to the origin of the arterial system, we append a reservoir, and surround this with strong muscular fibres, the shortening of which would diminish its capacity so as to cause it to expel its contents into the arteries, we should then have the first and simplest form of heart; in short, just such a heart as we find actually present in the *crustacea*, as, for instance, the crab or cray-fish.

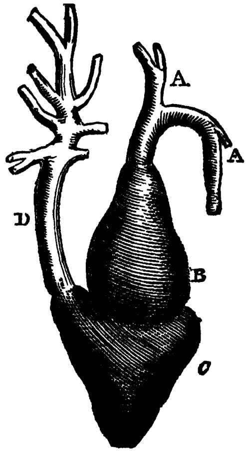
Such a heart answers sufficiently well for this class of animals; but when we rise a little higher, and find a more perfect circulation, and the whole vessels constantly full, we soon observe something further than this one cavity to be wanting. For the vessels being, as we have said, full, it is clear than when this cavity contracts, so as to throw a fresh quantity into the arteries, an equal quantity must be discharged from their extremities into the veins, and the veins in turn must seek to unload themselves into this cavity of which we speak. But the cavity, being just at that moment in a state of contraction, is not prepared to receive this wave which is thrown towards it, consequently, it becomes necessary that there should be a sort of ante-chamber, or receptacle to hold the blood until this cavity can relax to receive it.

This provision, which we have argued out as proper and necessary, actually occurs in the frog*, in several of the *mol-*

* The frog is now said to have two auricles. Of course this makes no difference, as they both discharge themselves into the same ventricle. It is only a double reservoir in place of a single.

lusca, &c. The receptacle is called *auricle*, from its bearing in the human subject some resemblance to a dog's ear (*auricula*); the other, or forcing part, is called *ventricle*, from its likeness to a little stomach (*ventriculus*).

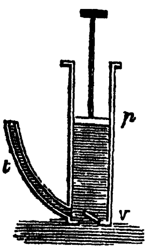
The auricle is surrounded by muscular fibres as well as the ventricle; they are, however, much weaker, as they have merely to propel the blood into an adjoining cavity. The contractions of these cavities take place alternately in this manner. The *venæ cavæ* empty themselves into the auricle; this be-



A A the *venæ cavæ*. C the ventricle.
B the auricle. D the great artery of the body.

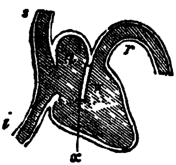
coming filled with blood, is stimulated to contract, and so commences discharging its contents into the ventricle, which, in turn, when fully distended, contracts, and forces the blood into the artery; its retrograde motion into the auricle being prevented by the action of a valve, opening only in one direction. While the ventricle is contracting, the auricle again is dilating and receiving the blood which the venæ cavæ are bringing it, and so the action is continued.

This valve is a perfectly mechanical contrivance, and is exactly what the engineer uses in his forcing-pump, of which, in its simplest state, this sketch will give an idea.



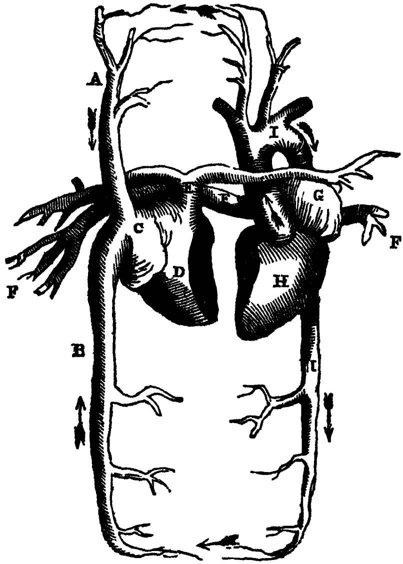
When the piston *p* is drawn up, any liquid below the valve *v* will instantly, in consequence of the atmospheric pressure, rush in; but when *p* is pushed back towards *v*, the liquid, now above *v*, will forcibly hold it down, so as completely to shut the aperture through which it had entered, and, being compressed by *p*, no means of escape remain for it but through the tube *t*, from which it will spout with great force.

Now this diagram will represent the application of the same principle in the heart. When the ventricle *v* dilates, the effect is the same as when *p* is drawn up from *v* in the forcing-pump, that is, there is an increased capacity; and if the atmosphere pressed on *a*, its contents would be discharged into *v*.



But as the heart is situated deep in the chest, and out of the immediate reach of atmospheric pressure, the want of this is supplied by the action of the muscles by which *a*, the auricle, is surrounded, and which, contracting, pour the blood into *v*, the valve *x* offering no opposition in this direction, but naturally falling inwards. When, however, *v* commences to contract, the capacity is first diminished, as when in the forcing-pump *p* is driven towards *v*; in consequence the blood rushes back, catches the valve *x*, the more readily that it is of a concave shape inwards, forces it against the opening into the auricle, so as completely to stop it, and thus leaves itself no other mode of exit than through the aorta *r*, into which, therefore, it is driven. In this cut we have only represented the situation and action of the valve; of its form we shall speak when examining the human heart. The *venæ cavæ*, superior and inferior, returning the blood into the auricle, are represented as *s* and *i*.

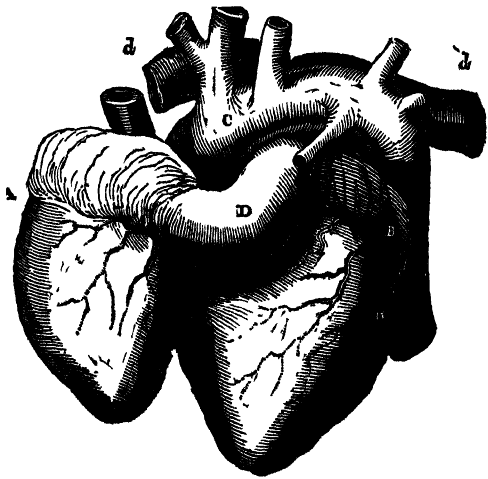
So much for a simple circulation. But the blood, in its course through the body, is constantly depositing its nutritiou particles, and taking up those which, having formed part of the body, are now, as it were, exhausted. It must, therefore, when returning through the veins, be unfit to go a second time through the body, without some renovation and purification. Now the renovation is effected by the pouring in of fresh matter in the chyle; the purification, by exposure to air in the substance of the lungs. This is particularly necessary in all the higher and warm-blooded animals; and for the purpose of this new course of the blood a new heart is added. It would be more accurate to say that new parts are added to the heart we have now described, the auricle being placed to the right, and supplied with a new ventricle, while the ventricle is placed to the left, and supplied with a new auricle. We have thus four cavities, the two former of which are distinguished as the right, or venous cavities of the heart; the two latter as the left, or arterial. The blood poured into the right auricle C, by the veins A B, is dark in colour, and unfit to nourish the body. The right auricle, being merely a reservoir, sends it into the right ventricle D, from which arises a large vessel F, called the *pulmonary* artery (from πυλμων, the lungs), which immediately divides into two branches, for each lung. Through this the right ventricle impels the blood into the lungs, where penetrating into extremely minute vessels, it is exposed to the air which we are constantly taking in by the action of drawing our breaths, and which produces a most marked and instantaneous change on it, the nature of which we shall examine when speaking of Respiration. By this change the blood seems to have lost all its impurities; from a dark red it becomes instantly a bright scarlet colour, and is found to have acquired its proper stimulating and nutritious qualities. It is now, therefore, sent by the pulmonary veins F F, into the left auricle G, thence into the left ventricle H, to be distributed by it through the aorta I, to all parts of the body, from which it returns by the veins black and impure, again to undergo the same process in the lungs, and again to be sen out for the nourishment of the body. This, then, is the per fect or double circulation, as we find it to exist in all warm-blooded animals, including birds, quadrupeds, the whale-kind and man.



Right and Left sides of Heart, with Veins and Arteries.

It does not necessarily follow that these two parts should be united together; and it will materially assist the understanding them, if, with Sir Charles Bell, we first depict them separate.

Now this form of heart is almost exactly what Sir E. Home found in the dugong, a warm-blooded animal of the whale-tribe, brought to him from the Straits of Malacca. The ventricles were quite distinct in the greater part of their length, and only connected above by some cellular structure, which, with the usual twist of the aorta over the pulmonary artery, formed almost the sole connexion between the two sides. As it is interesting to see every step in the advance of this organ towards the perfect state in which it occurs in man, we represent this, which may be considered as one of the earliest forms of the double heart.

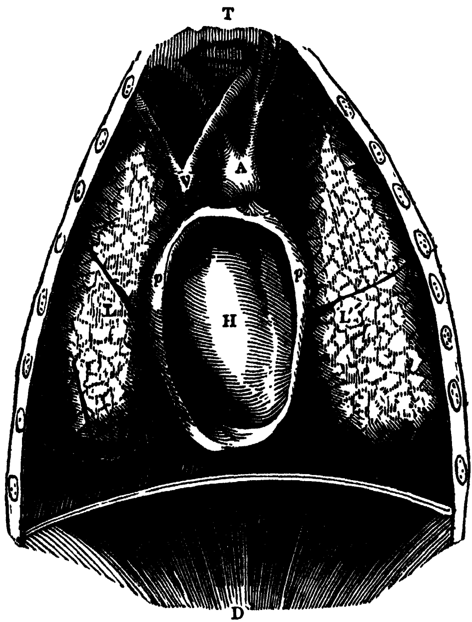


Heart of Dugong.

A right auricle and ventricle.
B B left auricle and ventricle.
D pulmonary artery, arising from right ventricle, and dividing into *d d'* a branch for each lung.
C aorta, or great artery of the body.

We may now advance to the human heart, in which these parts are finally joined together, yet not so invariably that traces of their separation may not be found. Bartholin relates, that in opening the body of a malefactor he found the heart bifid at its extremity, the right ventricle being clearly divided from the left. Most usually, however, they are closely united, and the epithets right and left are scarcely applicable any longer, as that part which in animals lay towards the right, now appears rather in front, the left being attached to its posterior surface. In consequence it has been proposed to change the names to anterior and posterior, or, from a consideration of their nature and offices, to call the right the venous heart, or heart of the lungs; and the left the arterial heart, or heart of the body.

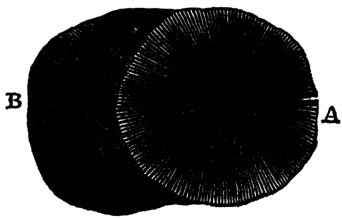
Thus composed, the heart is situated nearly in the centre of the chest, but more to the left side. It rests on the diaphragm by its lower part, and lies rather obliquely from right towards left, its point being in the latter direction. It is enclosed in a



Heart *in situ*: Pericardium cut open, Lungs and Diaphragm marked.

T the trachea, or windpipe; L L′ the lungs; V the superior *vena cava*; H the heart; A the aorta; *p p pericardium*, or heart-case, cut open; D the diaphragm.

peculiar sac or bag of its own, termed *pericardium* (from *περι*, *about*, and *καρδια*, *the heart*), which we have represented as cut open. The *pericardium*, however, naturally, is closed like other serous sacs, and its internal surface, when it is in contact with the heart, is constantly lubricated by a fine exhalation, which must facilitate the heart's motions and prevent adhesion. A person looking at a heart for the first time would find some difficulty in saying which was the right side, and which the left; the chief difference he would perceive would be, that one side looked weaker than the other, had fallen in flat when emptied of its blood, while the other, from the thickness and strength of its muscular sides, had preserved its full and rounded form. It would occur to him, then, that this latter side, being evidently the strongest, must be the left side, that which was employed in sending the blood to the whole body; while the other, having only to send the blood through the lungs, did not require equal power. If he proceeded to make a section across the ventricles, he would be still further confirmed that he had judged rightly, by finding something of this appearance.

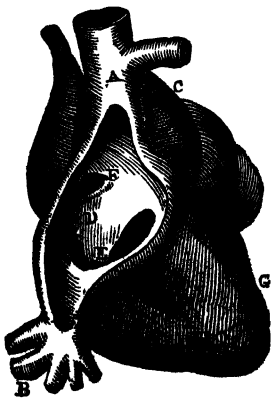


Section of Heart across both Ventricles.

A, the left ventricle, the thick muscular sides of which enable it to keep its shape; while B, the right ventricle, is flattened and collapsed.

If, however, any part of the blood-vessels were left attached to the heart, this would finally decide him, for he could not fail to recognise the two venæ cavæ discharging themselves into the right auricle, or the aorta, with its great arch, arising out of the left ventricle. If he wished then to examine the heart, say that he had got a bullock's heart, in which all the parts are quite perfect, he would, as the best method, wish to follow the course of the blood. His first step, then, would be to slit up the two venæ cavæ, which bring all the blood into the heart, and lay open the right auricle, which looks like a dilatation of them at the point where they meet.

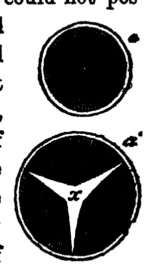
We have represented this done, in the human heart, in the annexed cut: where A and B represent the two *venæ cavæ*, the former returning the blood from the head and upper extremities, the latter from the trunk and lower extremities, and both uniting to form D, the right auricle, which is seen cut open from behind: E is the opening into G, the right ventricle; F the remains of the obliterated *foramen ovale;* and C is the commencement of the arch of the aorta.



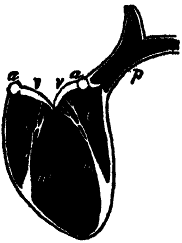
Right side of Heart laid open.

While the child lay in its mother's womb there was no opportunity for respiration, therefore there would have been no use in sending the blood to the lungs, which, indeed, are at that time so collapsed, that the blood could not circulate through them. Accordingly at this period a direct opening exists between the right and left auricle through their common partition, so that the blood, when returned from the veins, passes from the right into the left auricle, from that into the left ventricle, and thence out again to the body. The opening through which this communication takes place, is termed, from its shape, the *foramen ovale;* it closes up as soon as the child is born, for then the circulation through the lungs instantly sets in. A slight thickening and depression, however, mark its place, which may be noticed at F. In the adult, therefore, no opening remains but that into the ventricle, the valves of which we must now proceed to consider. In speaking before of their action, we represented a simple valve acting mechanically. Such a valve would do very well for a forcing-pump, the sides of which were immoveable, and when it could be made of any desired thickness; but in a living contracting organ it would want both strength and adaptation. The mode in which both these are provided for, is admirably explained by Sir Charles Bell, to whose works we have often been indebted.

The valve is composed of three membranes, the bases of which are attached round the edges of the opening, while their points are in some measure free and floating, and when laid together are sufficient completely to stop up the orifice. Now, as the size of the valves cannot change, it is necessary that the size of the orifice should not change, else they could not possibly fill it up. Thus, if the circle *a* should enlarge itself to *a'*, it is clear the valves would be so drawn at the base, that they could not meet, and so a large space *x* would be left, through which the ventricle would return half its blood, in place of sending it all on to the lungs. This is provided for, by making the circle *a* a firm tendinous ring; and we may fairly assume it as an indubitable evidence of design, that this part alone of the heart should be incapable of motion, where alone motion would be injurious. But simple membranes would not be sufficient either, for though capable

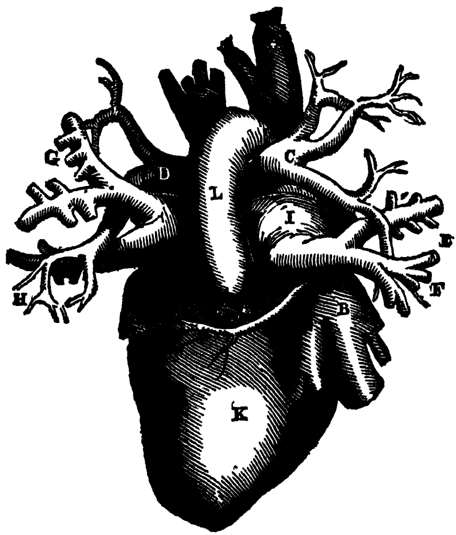


of filling the orifice, they could not resist the strength of the ventricle pressing on them from below; and so they would be driven up into the auricle, and the passage forced. Now, let us see how this is prevented.



If we suppose this to be a section of the right ventricle, we have, as it were, a profile view of two of the valves: *a a* the cut extremities of the tendinous circle, opening from the auricle into the ventricle; *v v* the valves made of a thin membrane, with their concave side looking downwards, so that the blood immediately catches them, on attempting to return, and throws them up against the opening. Now come into play *c c*, which are beautiful thin tendinous cords, attached, as we see, to the edges of the valves, and running from them to the sides of the ventricle. These are not extensible, and their length permits the valves just to reach the orifice, but perfectly prevents their being carried up any further. Thus is their strength provided for. But further adaptation is still requisite, because when the ventricle commenced to contract, its sides would approach more nearly to the opening, therefore the tendons being relaxed, would suffer the valves to float up. This, too, has been foreseen, and guarded against; the ends of the tendons have been inserted, not directly into the sides of the ventricle, but into small muscular pillars, called *columnæ carneæ*, which we observe at *m m*. These share in the general inclination to contract; and the more the sides approach the orifice, the more tightly do they pull at the tendons, so that the valve is never suffered to quit its place until all the blood is driven into the pulmonary artery *p*. When this has taken place, the sides relax, the ventricle dilates, the valves fall down, and everything is again in a state to be filled from the auricle, which now commences work in its turn. The blood is now in the pulmonary artery. This, as we have represented it, opens from the *top* of the ventricle;

the reason is obvious. Fill a bladder with water, insert a pipe into its neck, compress the bladder, and the water will spout to a considerable distance. But, if you first invert the bladder, so that half of its contents may run out, and then compress it, you will scarcely drive the water beyond the pipe. Now, this would be the condition of the ventricle if the artery were inserted into its lower part. The blood as it entered would, by its gravity, descend into the artery, the ventricle, not filled, would want its proper stimulus to contract, or, if it did contract, could scarcely use any force on its contents. The artery is, therefore, placed at top. We have seen the complicated structure of the valves of the heart, and we have seen the necessity for such complication; but look at the valves of the artery, they are nothing but simple folds of membrane; yet they are quite sufficient. Tendons to strengthen them would be useless, because the artery can exert nothing like the



Back View of the Heart.

muscular power of the heart to force them; fleshy pillars would be useless, because the dilatations and contractions of the artery are too slight to require any adaptation, they are, therefore, omitted, for Nature does nothing in vain.

The blood, in the mean time, has gone on; the pulmonary artery soon divides into branches, C D, one for each lung, and these subdivide, in the substance of the lung, into innumerable minute twigs, through the delicate coats of which the blood is aërated. It begins to collect again in the pulmonary veins, which finally uniting into four trunks, E F G H, enter the left auricle I, filling it with red, perfect, arterial blood. This is discharged by it into the left ventricle K, and from that through the aorta L, to supply the whole body.

The mechanism is so exactly similar to what we find on the right side, that there is no necessity for going over it. The opening between the right auricle and ventricle being large, the valve, as we have seen, had three principal divisions, and is called *tricuspid*, or three-pointed; that in the left side being smaller, the valve has but two divisions, and, from some fancied resemblance to a bishop's mitre, is called *mitral*. The valves of the aorta are similar to those of the pulmonary artery; there is yet a little bit of contrivance about them which remains to be noticed. If they lay completely back against the sides of the artery, it is possible that the blood might glide back over their smooth surface without catching

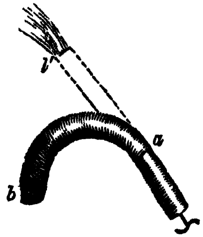
in them. To prevent this, the aorta is dilated immediately behind them, so that they cannot reach it. There is, therefore, always a little space into which the blood, when returning, must flow, and so shut down the valves, and put an end to the retrograde motion.

The texture of the heart generally is muscular, with tendinous or cartilaginous bands around its four openings, that is, those between auricle and ventricle, and ventricle and artery. Internally it is lined with a smooth membrane, which is found continued through the whole course of both arteries and veins; and externally the serous part of the pericardium is reflected over it, while the fibrous coat of the pericardium forms a strong covering over all. The heart is still further protected by the bony sides of the chest, and the muscles with which they are clothed, so that, next to the brain, it may be considered the best defended, as it is the most important organ in the body. The size of the heart is variable, and it is said to be largest in those animals that are endowed with most courage. We can understand that the more freely the blood is sent to all parts, the more perfect will be their vitality, and the greater the exertion of which they are capable. The consciousness of increased power, thus obtained, may give a greater disposition to use it; and thus animal courage may be the consequence of physical organization: and Sancho Panza may not have been altogether wrong, when he argued that it was as natural for one man to be a coward, as for another to be subject to bile. Common modes of expression indicate the generality of this feeling; thus we speak of a faint heart, a stout heart, lion-hearted, &c. We are not philologists enough to decide whether "showing pluck" is to be referred here, though we are aware that in Scotland the *heart* and lungs attached to the head of a dead sheep are technically called "the *pluck*."

The cause of the pulsation of the heart, felt between the fifth and sixth ribs at the left side, has been disputed. On opening an animal, the contractions of the several parts of the heart are observed to take place in this order.

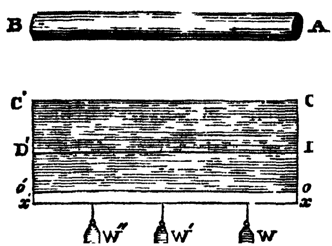
1. The venæ cavæ fill the right auricle, at the same time the pulmonary veins fill the left; 2. Both auricles contract, and fill both ventricles; 3. Both ventricles contract, and fill, the right the pulmonary artery, and the left the aorta; 4. The arteries act on the blood.

Now the first and third of these actions happen together, as do also the second and fourth, and it is chiefly by the third that the stroke of the heart seems produced. If you inject water into a curved flexible tube, *a b*, the first effect of the current will be to straighten the tube to $a\,b'$, from the extremity of which it will be discharged. But if b be made a fixed



point, and in place of a syringe a moveable ventricle be attached to the tube, it is evident that the attempt at straightening the tube must all be exerted on v, which, therefore, will be thrown up towards v', and striking against any thing that opposes its progress, as in the present case against the interval between the fifth and sixth ribs, would cause a sensible pulsation. Dr. Corrigan a short time since attempted to show that the pulsation did not depend on this, but was caused by the gush of blood into the ventricles from the auricles. He made some experiments to prove this, and argued, that as the curve of the aorta was towards the left, any attempt to straighten it would throw the heart up to the right, where, consequently, the pulsation should be felt. But he forgot that the aorta, when leaving the ventricle, first goes towards the right, and also has an inclination backwards towards the spine, before it makes its great arch to the left, consequently the straightening of these two first inclinations would throw it forward and to the left. He also left out of account the straightening of the pulmonary artery, which takes place at the same moment, and which, as the artery curves almost directly backwards, must have the effect of throwing the heart directly forwards. Neither has he adverted to the fact, that the heart's motion is much more constrained towards the right by the entrance of the veins, and the situation of the *mediastinum*, a membranous partition running across the chest from the spine to the breast-bone, than it is towards the left, where, in fact, its point is quite free. In short, he only took into account one force, where the combination of many was to be considered. We must, therefore, adhere to the other opinion. It is probable the dilatation of the auricles which takes place at the same time, may assist; for Haller found the heart in a dead body give a stroke at the breast when he distended the left auricle with air, and Senac reports the same result from filling the right. The heart is elastic as well as contractile, and owes this property to a quantity of cellular membrane, with which its muscular fibres are enveloped. The opening out of its cavities, therefore, is to be considered as much its proper action as their contraction. It is not that they merely dilate by the blood poured into them; they open to receive the blood, and the suction-power thus exerted, has been much insisted on by Drs. Barry and Carson, amongst the causes of the motion of the blood in the veins. How far they are right, we shall consider afterwards; the fact can be demonstrated by taking out the heart of a fish, emptying it of all blood, and laying it on a table, where it will be observed to contract and dilate itself regularly, often for some hours.

The arteries come next to be considered, and the share which they take in propelling the blood. When examined after death, they are found to consist of, first, an outer coat of strong elastic substance; second, a middle coat of a yellowish colour, showing well-marked circular fibres, by which alone it seems to differ from the *yellow elastic ligament*, which we before mentioned as used to support the head in the horse, cow, &c.; and third, an inner coat of smooth lining membrane. This last is the most important, as it is found to exist in every kind of vessel; it is, therefore, called the proper vascular tissue. The middle is peculiar to arteries, and the question, whether its fibres are, or are not, muscular, has been the cause of one of the longest and most violent of physiological disputes. Yet, like many other disputes, the difference is rather about names than facts. If we compare these circular fibres with the fibres of the *voluntary** muscles, they most certainly are not the same. They differ in appearance, in taste, in chemical composition, in mode of action, in the effects consequent on the application of certain stimuli. But though they are not moved to act in the same way as the fibres of the voluntary muscles, yet they as certainly contract and dilate in a manner more suited to the parts they belong to, and these motions of contraction and dilatation are under the direction of a vital principle. Hunter endeavoured to prove this directly, by experiment. An animal was bled to death, by which the arteries are brought into their greatest state of contraction, the artery always endeavouring to embrace firmly its diminished contents. A portion, AB, of such an artery was taken, slit open, as we see at CD, and



weights w w′ w″ appended. When these had stretched it as far as $x\,x'$, they were removed, and the artery again contracted, not to its original dimensions, but only as far as $o\,o'$. On this experiment he argued thus. Two powers produced the full contraction of the artery AB; the one *elasticity*, which we know to be possessed by dead matter; the other vital contractility, which belongs only to living. Now when the artery was cut out of the animal, this latter power was destroyed; consequently, when extended to $x\,x'$, and the weights removed,

* Muscles under the immediate direction of the will,—which we can at any time call into action, or cause to cease from action;—such are the muscles of the arm, leg, &c.,—we may say generally all muscles, except those of the heart and intestinal canal.

it did not retract to its original dimensions C D. The elasticity shortened it from *x* to *o*, but the vital contractility was gone, which should have taken it from *o* to D. D *o*, therefore, might in some measure represent the extent of the vital contractility, and *o x* of the elasticity. But vital contractility exists in no part of the body that we are acquainted with except the muscles; therefore these circular fibres of the middle coat of the artery must be muscular.

We do not propose leading our readers into the endless arguments adduced on each side. They will perceive that the two parties have forgot to decide what should constitute a muscle, and thus, each taking different standards, have succeeded in proving their own opinions without disproving those of their adversaries. We shall, therefore, avoid using the term *muscular*, as applied to this coat, and shall term it, from its appearance, the *yellow fibrous coat*, or perhaps the *contractile* coat, and shall mention a few facts to justify its claim to this latter name. It may be well to say that we use the term *contractility*, to express a quality of living bodies, in contradistinction from *elasticity*, which they possess in common with dead matter. Dr. Parry, having exactly ascertained the circumference of an artery in an animal, killed the animal, and again measured the artery. After an interval of several hours he repeated the measurement, and found, as the invariable result of many experiments of this kind, that immediately after death the artery was contracted; but on the third examination had increased again. Now the artery does not die exactly at the same moment as the animal, but, continuing for a little time to act, discharges all the blood sent into by the last contraction of the heart. On this account the artery is always found empty after death, and its *contraction* is evidently the result of a *vital* power. But after some hours the artery is dead as well as the rest of the body, and then he always found it relaxed. This is a clear proof that the artery possesses a vital contractility, and not merely an elasticity.

Every surgeon knows that when he has opened a small artery, the readiest way to stop its bleeding is to cut it through. The artery contracts so readily and strongly, as often to arrest the jet of blood at once.

If we make the stimulus more powerful than a simple cut, it will produce a contraction sufficiently strong to stop the flow of blood, even from very large vessels. M. Amussat, a French surgeon, has, in several operations, arrested the bleeding by catching the end of the artery in a pincers, and giving it a twist. The *fibrous* coat has contracted so powerfully as to shut up the mouth of the vessel. It was not the mere twist did this, for if you twist a dead artery, and then with a syringe inject into it, even very gently, some water, you will perceive it undo the twist, and flow from the open mouth of the vessel.

Arteries, when exposed in operation, have contracted before the operator had touched them with his knife. The testimonies of this are so numerous and respectable that it is impossible to doubt it.

We may, therefore, fairly conclude that arteries are endowed with a peculiar vital power of contracting on their contents, and that such power belongs to the central fibrous coat is evident, from its being deficient in the veins, where this coat is not to be found. Thus they are possessed of one quality, which we have also seen in the heart; its other power, that of active dilatation, seems equally to belong to them. The arteries of the cheek enlarge under the feeling of shame or modesty, and, according to the measure of their increase, we have the gentle suffusion, or the burning crimson glow. If increased action be going on in any part, or a copious supply of blood be required for a sudden growth, the arteries supplying the part enlarge themselves, and furnish in abundance the nutritive fluid.

The growth of the stag's horn is a beautiful example of this kind. The stag usually sheds his horns in spring; the place from which they had fallen is soon covered over with a thin skin, and the first sign of the new antler is a little tubercle rising up in this place like a bud, and covered with a fine, soft, velvety skin. In this skin run the vessels that are to form the future antler, and they penetrate, in great numbers, the little tuberculous swelling, which is still soft, and like gristle. It grows with remarkable rapidity, still covered by the skin, and the vessels deposit in it white bony matter, until the whole is quite hard and full-grown. The next step is to rid it of its soft and very sensible covering, which, as long as it remained, would completely unfit it for the uses to which it is to be applied. And this is said to be performed by a very beautiful contrivance, noticed by Mr. Hunter, and his original preparation to explain which is still in the Museum that bears his name. Around the bottom of the antler, where it springs from the skull, is observed a burr, or bony rim, which surrounds the vessels as they pass up. This, growing along with the rest of the part, becomes, by degrees, so firm and dense, that it presses on the vessels supplying the soft velvety integument, which, thus deprived of its supply of blood, withers, dies, remains for a short time in a ragged state attached to the antlers, and is finally got rid of by rubbing against the trees. At the same time the *carotid* arteries, from which these vessels sprung, resume their original size, having been much enlarged during the continuance of this process, a process, as Blumenbach observes, exhibiting, in a striking manner, the rapidity with which growth can take place in warm-blooded animals, as a horn of a stag, which may weigh a quarter of a hundred weight, is thus completely formed in ten weeks.

We thus see arteries endowed with the two powers we have noticed as existing in the heart; a power of dilating, and a power of contracting. These powers are only similar in kind; they are by no means equal in degree. As to the effect of ordinary stimuli, also, it is doubtful how far either heart or arteries are sensible to it. Harvey mentions that a young nobleman had the side of his chest laid open, in consequence of a large abscess, so that the heart plainly appeared within the opening. By the commands of the king, Harvey examined this case, and found that the heart might be touched or handled without causing the least sensation to the young mán; in fact, so completely insensible was it, that when he shut his eyes, he could not tell whether it was touched or not. Now though in many cases the arteries, on being mechanically irritated, have contracted, and this result occurred in fifteen out of twenty experiments made by Verschuir; yet other persons have been by no means so successful, and have stated to us that they could often perceive no difference at all, and at other times an absolute dilatation. Nor is this to be wondered at. The heart and arteries receive their nerves from a far different source than that which supplies the voluntary muscles. Their mode of perception is, therefore, different, and requires to be excited by proper and peculiar stimuli. The sensibility of each part is suited to the function it has to perform, and the danger against which it is to guard. Now the voluntary muscles are for moving the body, and they are excited to action by mechanical stimuli, such as pricking, wounding, &c., because it is useful, that on the application of such they should immediately contract, to remove the body from the influence of those agents, which, if continued, would be injurious. But this kind of sensibility is much more obscure in the heart and arteries, because, before such agents could reach them, the skin and muscles must first have been penetrated, and so sufficient notice given to withdraw. The proper and peculiar stimulus of these parts, then, is the blood, with the sensation of being full; as their proper office is, under such circumstances, to react and impel forward the vital current.

It is an equally wise and prudent provision, that parts, the constant and uninterrupted action of which is necessary to life, should have been withdrawn from the immediate direction of the will; else would a slight inattention or forgetfulness be attended by death, and sleep, so necessary to the refreshment of our powers, would be certainly fatal. But now, requiring nothing from our forethought or watchfulness, supplied constantly with its appropriate stimulus, this system continues to act night and day, when we sleep and when we wake, often for a long succession of years without let or hinderance, so that we are at a loss whether most to admire the infinite wisdom which could devise so admirable a machinery, or bless the infinite goodness that could make it to us the source of so many blessings, of health, of strength, of life. "Eunt homines," says St. Austin, "mirari alta montium, ingentes fluctus maris, altissimos lapsus fluminum, oceani ambitum, et gyros siderum ;—seipsos relinquunt nec mirantur."

Though the circulating system is thus free from the general direction of the will, yet it is well known to share in every powerful or sudden emotion. Joy will send the blood in gushing current to the cheek, or chilling fear will cause its revulsion to the heart, which no longer beats with sufficient force to drive it out to the extremities. Its throbs can no longer be felt, it seems to retire deep into the breast, whence we speak of the "sinking of the heart," or "the heart dying away within us," as expressive of the effects of fear.

As the arteries diminish in size, we find their peculiar vital power becoming stronger, and the circular fibres more numerous, and this disposition is supposed to reach its utmost height in the capillaries. Whether it ceases suddenly here, or diminishes gradually from any given point, we are unable, from their minuteness, to decide; but in the smallest veins we examine, this power seems quite gone, and along with it the central coat of circular fibres, of which we have said so much. The veins, then, are merely passive in the circulation, or can be considered as endowed with no power beyond that of elasticity. This resides in their external coat, which, as the same coat of the arteries, is merely condensed cellular membrane. The internal coat is the smooth lining membrane which, as we have said, is the essential part of the whole vascular system, and in these we find it constantly thrown up in folds forming valves, sometimes single, sometimes two or three together, but invariably opening towards the heart, and suffering the blood to move only in that direction.

The contraction of the heart is evidently the first of the causes that move the blood, and for some time it was considered as the only cause. In consequence of this, attempts were made to calculate the force with which it must contract to overcome all the effects of friction, angular turns, gravity, &c.; many results were obtained which, by their extraordinary discrepancy, showed that some gross error must have pervaded the reasonings employed.

Borelli, proceeding on the supposition that the power of a muscle is in proportion to its weight, estimated the force of the heart at 180,000lbs. Keill, considering this as very extravagant, adopted a different line of argument, and, partly by experiment, partly by assumption, and partly by reasoning, reduced the power of the heart to about five ounces and a half! Hales's experiments are by far the most accurate made on the subject. He inserted tubes into the arteries of living animals close to the heart, and observed the blood to rise in them to the height of about ten feet above the level of the heart, and then to continue rising and falling a few inches at each pulsation. Now Dr. Arnott explains that a tube an inch square, and about two feet high, will contain a pound of water, and its base will sustain this pressure; therefore the pressure of blood standing at the height of ten feet will be (10 divided by 2 or) five pounds on the square inch, or even a little more, seeing that blood is of a greater specific gravity than water. But the surface of the left ventricle of the heart is about fifteen square inches, on each of which this pressure of five pounds would be exerted; on this calculation, therefore, the total force exerted by the left ventricle, at each contraction, is able to overcome a resistance of more than seventy-five pounds, as is seen by the blood rising in the tube*.

Men, however, soon perceived that the heart was not alone in maintaining the circulation. Worms have no heart, and in

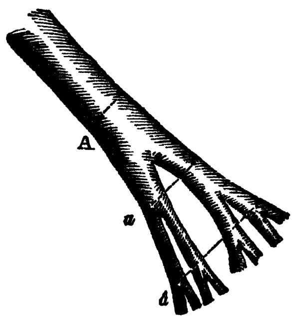
* We have not exactly given Hales's calculation here, but rather an outline of the principle. He supposes that had his pipes been inserted in the human artery, the blood would not have risen so high, in consequence of which he makes some diminution, and concludes the power of the left ventricle to be about fifty-one and a half pounds.

them the blood is moved by the vessels, assisted probably by the general muscular contractions. There is no heart in insects, yet it appears, from late discoveries, highly probable that they may have a circulation. Some facts, tending to support this opinion, had been put forward by Professor Carus, but lately a complete description of the whole process has been given by Mr. Bowerbank in the third number of the *Entomological Magazine*. This fact was announced, we believe, on the same authority, in the supplemental matter of Griffiths's edition of the *Règne Animal*. Other facts, tending to show the influence of the vessels on the circulation, independently of the heart, have also been adduced. If you tie an artery, the part of it beyond the ligature empties itself by its own action and that of the capillaries, evidently without any assistance from the heart. Monstrous children have been born without a heart, yet evincing, by their growth, that circulation had gone on tolerably well. Dr. Wilson Philip once saw the blood moving through the capillaries of a rabbit for an hour and a half after he had cut out its heart. Mr. Allan Burns mentions a singular case, in which both the ventricles were completely converted into bone, so as to be quite incapable of contracting, yet the circulation was maintained without much inconvenience, as long as the patient was in a state of tranquillity*. The arteries going to a diseased part, also increase in size, and it is even said in rapidity of pulsation. Richerand says, that the radial artery going to a hand on which was a whitlow, beat twenty or thirty in a minute more than the similar artery supplying the other hand. From such facts as these Sir Charles Bell was induced, in a little work which he wrote expressly

* This argument, taken from a diseased state, cannot, however, be allowed much weight. The auricles were considerably enlarged and strengthened, so as to be enabled to perform the office of the ventricles; besides we frequently see the sides of the arteries rendered hard and bony for a good length, without the circulation being impeded by their loss of contractility. The danger in such cases is, that the artery, becoming brittle, shall be ruptured by the force of the heart. It is evident, that if the circulation be carried on without much assistance from the heart in one of these cases, it has equally little from the arteries in the other.

on the subject of the powers that move the blood, to diminish very much the estimate usually formed of the value of the heart's action, which he considers more intimately allied to the respiratory organs, and only exercising a general regulating power over the circulation of the body. As the artery always embraces closely its contents, it is equally full before as after the gush from the heart; nor does it appear to dilate when it receives this new quantity. Bichat, Parry, and others, examined arteries most accurately during the pulse, and even with the aid of microscopes could never perceive the slightest dilatation or contraction. At each stroke, however, they become stiff and rigid, as if their fibrous coat had contracted almost at the same moment with the ventricle. By this way Dr. Arnott supposes that their natural elasticity is counteracted, and the heart enabled to produce its effect through them, almost as it would through tubes of metal. On such a supposition the full force of the heart would be transmitted to the capillaries, as much blood being discharged from the extremities of the arteries as is injected into their commencement. It would appear, however, that some slight yielding of the sides of the vessels must take place, otherwise the pulse would be instantaneous all over the body, the blood being moved by each stroke of the heart, exactly as a row of billiard-balls are put in motion by striking the first. That this is not *altogether* the case, any person may satisfy himself by placing his right hand on his heart, and his left on an artery, which he will find close behind the inner ankle of his right leg. If he now attend, and that the action of the heart be not flurried, he will find that the stroke at the ankle is distinctly, yet at a very short distance, after that at the breast. But this could only be produced by a slight yielding of the vessels, and their subsequent reaction on their contents. It is only on the same supposition that we can account for the fact that the stream of blood in the small arteries is nearly uniform, the jet that takes place in the large arteries being in a manner lost and diffused through the elasticity of the sides, as we see the wave caused by throwing a stone into water, extending itself in widening but less perceptible circles, till it finally disappears. As the blood gets further from the heart, its forward motion is diminished, as well in consequence of this slight yielding, as by friction, the effect of curves, the angles at which the small vessels go off, &c. Two provisions are made to ensure its advance, first, the channel is widened, and, second, the circular fibres of the arteries, and, consequently, their contractile power, is increased.

Dr. Arnott seems to think it impossible that the arteries should exert anything like a propulsive power on the blood, *because* they have no vermicular or progressive contraction. Now, it appears to us, that this is not requisite, on the simple principle that if a fluid be pressed or resisted on all sides but one, it will make its escape through that one; thus, the arteries pressing the blood, as the hand would grasp a bottle of Indian rubber, and return being rendered impossible by the valves at the commencement of the aorta, the blood must clearly pass the only way left open to it, that is, through the capillaries into the veins. That the channel widens, is not, at first sight, so evident; for we know that the aorta, as it passes along, divide into branches, these again into smaller branches, and so on; but what we mean is, that the capacity of all these branches taken together, is, for any given space, greater than that of the trunk from which they were derived. Thus, that the section of the two branches at *a* is greater than that of the trunk at A, and that the section of the four branches at *a′*, again exceeds that of the two at *a*. This is sometimes expressed by saying that the arterial system is represented by a cone, the point of which is at the heart, and



its base at the surface of the body. A more accurate representation *as to form* will be had, by considering it as a tree, which is rooted in the heart, the trunk is the aorta, and the boughs, branches, twigs, and leaf-stalks will be represented by the divisions and subdivisions of the vessels to their minutest ramifications. Now, as the section of the head of a tree at any place would show a more extended surface than a section of the trunk, so a section of the smaller arterial tubes will show an increased capacity as compared with the aorta: such, at least, was the result of John Hunter's experiments on this subject.

The motion of the blood being facilitated and continued by these means, it arrives at the capillaries almost with the force it had when leaving the heart. Were the capillaries, therefore, open tubes, this would be sufficient to carry the blood through them, and return it by the veins to the heart, without any further assistance. But this is not the sole object, *nutrition* and *secretion* are to be performed; these take place in the capillaries, they are vital actions; therefore the capillaries are endowed with vital powers. In consequence they are able either to close themselves against the arterial current, or to dilate, so as to receive a greater share, or to delay the blood in their channels, or, finally, to return it by the veins. It is true that we attribute to them these powers, more from reasoning than from observation, for their extreme minuteness places them almost beyond observation. But when the saliva flows into the mouth, as soon as a sapid substance has entered it, is it not that the capillaries supplying the salivary glands dilate, so as to bring them an unusual quantity of fluid? It is not the heart that acts more vigorously, for then every other part of the body would have its supply increased at the same time; it is not the large arteries, for then the face would be flushed, and the temples throb when we eat; nor is it in the gland itself that the action commences, for the gland can no more make saliva without blood, than a carpenter could make a table without wood. Where, then, can the action be, but in the extreme vessels? Or, when the tear starts unbidden to the eye at a tale of pity, or a sight of woe, do we not see that the capillaries of the lachrymal gland have received their appropriate stimulus, have enlarged themselves, and increased the supply with a suddenness, that at once indicates the vivacity of their own powers, and shows the perfect justice and beauty of the poetic epithet

Sic fatur . . . *obortis lachrymis?*

As to the mode in which their aetion takes place, Dr. Arnott reasons thus: "A muscular capillary tube, strong enough to shut itself against the arterial current from the heart, is also strong enough to propel the blood to the heart again through the veins, even if the resistance on that side were as great as the force on the other. For, if we suppose the first circular fibre of the tube to close itself completely, it would, of course, be exerting the same repellent force on both sides, or, as regarded both the artery and vein. If, then, the series of ring-fibres, forming the tube, were to contract in succession towards the vein, as the fibres of the intestinal canal contract in propelling the food, it is evident that all the blood in the capillary would thereby be pressed into the vein towards the heart. If, after this, the capillary relaxed on the side towards the artery, so as to admit more blood, and again contracted towards the vein as before, it might produce a forward motion of the blood in the vein, independently of the heart. We, of course, merely state this as a possibility, for the intimate nature of capillary action is not visible, and has not been positively ascertained."

The capillaries of the absorbent system, which we have described in their proper place, opening upon the intestines, exhibit an active power in selecting and taking up the parts of the food, which being changed into chyle, afford them their proper stimulus; in the same way the capillaries of the sanguineous system exhibit an active power in taking the blood up from the arteries and conveying it into the veins. As they continue to live for some time after the life of the body has ceased, this action of theirs empties the arteries, and causes the blood to be collected in the veins and at the right side of the heart. It was this that for so many years prevented men from discovering the circulation; for finding these vessels empty in the dead subject, they concluded them to be equally so in the living, and accordingly made them vehicles for "animal spirits," and other subtile and powerful agents, which never had existence, save in the brains of their inventors, and so they termed these vessels *arteries*, or *air-tubes*, a name which they retain to this day. There are some instances, however, in which the death being instantaneous, as from lightning, the capillaries lose all vital power at the same time as the rest of the body, and, in such cases, the arteries are found filled with a fluid blood. The same is said to occur in deaths from the action of certain poisons, inducing general relaxation of the muscular system; and this has been adduced as a further proof of the similarity of the fibrous coat of the arteries to muscular substance.

The blood has now reached the veins, and, as we have seen, with a force not much diminished from that with which it set out. Its impetuous gush, however, is modified into a more equable, gentle flow, but still, as it appears, sufficiently strong to convey it back to the heart. This is necessary, as the veins, possessing no quality but simple elasticity, are unable to add anything to the impulse. Their valves, however, afford a mechanical aid, by dividing the whole column into a number of lesser columns, and as the veins lie much in the neighbourhood of muscles, every time these contract they press on the veins, and so cause a portion of their contents to advance towards the heart, retrograde motion being prevented by the valves. We sometimes have an unpleasant proof of the use of these valves, for, should they fail to perform their office, as sometimes occurs in the lower part of the leg, the whole column of blood is allowed to press on the inferior parts of the veins, these become distended, tortuous, swell beneath the skin, and require the support of bandages, or a laced stocking, to prevent them bursting, and a bad ulceration coming on.

This affection is usually known under the name of *varicose veins*, and may be produced by ligatures round the leg, impeding the return of the blood. Tight garters ought, on this account, to be avoided, particularly on young children, in whom the parts are still tender and yielding.

We have now gone through almost all the powers that move the blood, and have marked the effect and mode of action of each. There remains one, to which we before alluded, and which has been much spoken of, in consequence of the ingenious experiments and observations of Drs. Barry and Carson. This is what is called the *suction* power of the heart, and is supposed to have as great influence in drawing up the blood through the veins, as its contractile power had in driving out the blood through the arteries. To understand what they mean by this, we must observe how the heart is situated within the bony walls of the chest, which save it from the effects of atmospheric pressure. We must also remember that the cavities of the heart have an active power of enlarging themselves. Now, during inspiration, the chest is enlarged, the ribs are drawn upwards and outwards by the action of their muscles, and thus freer space is left for the heart to dilate itself*. Under these circumstances, the auricle, having discharged its load into the ventricle, opens itself out, so as to form a vacuum at the head of the veins, which it is argued must suck up the blood from them, or, to speak more correctly, allow it to be forced up by the effects of atmospheric pressure, operating on the veins in all other parts of the body, but taken off them here in the manner shown.

There is no question but that something must be allowed for such a power, though its influence has been exceedingly overrated. If we make a wound in the sides of the chest, air will rush in during inspiration, and be expelled during expiration; or, if we insert a tube into the opening, and place the

* It might be supposed that the atmospheric air rushing into the lungs would press on the heart, which lies immediately adjoining them, but the resiliency or clasticity of the lungs, which cnables them to resist part of this pressure, saves the heart, in so far, from its effects.

other end of it in a coloured fluid, we shall see the fluid ı in the tube during inspiration, and fall during expiration.] Barry inserted a tube into the jugular vein of a horse, a laying the other end of it in coloured fluid, observed exac the same result as we have mentioned. This showed the t dency of the heart to form a vacuum during inspiration; l there is quite force enough to return the blood without a such assistance, which scarcely can be regarded in any otl light, than as a consequence of the heart being placed in t same cavity with the lungs. For, if the vena cava inferior tied near the heart, it will quickly be swollen with blood, aı if opened below the ligature, all the blood from the lower e tremities will be discharged from it, though the vacuum ca have no influence here. Hales inserted an open tube into tl vein of an animal, and found the blood stand in it six inch higher than the heart; there was little necessity, then, for vacuum, or a suction power to draw it up to the heart. you press on a swollen vein in the hand, the part above wheı you press will not be emptied, as it should if the suction weı powerful. But, beyond all these is the fact, that no suctioı however powerful, could raise a fluid to any distance throug soft yielding tubes, such as the veins, as any one may convinc himself, by inserting a syringe into a gut filled with wateı and trying to draw it out of it; for as soon as he had raised little of the water nearest the syringe, the atmospheric pres sure, being equal in every direction, will cause the sides of th gut to fall together, and so to make an end to his experiment.

The atmospheric pressure, however, must exercise an in fluence over the circulation in the head, for this being an air-tight cavity, and its vessels, therefore, perfectly relieved from this pressure, it is evident that as long as there is any blood sent out from the heart, a due proportion will be certainly retained here for the sustenance of the very important organ it contains. Mr. Kellie, having in some experiments bled animals to death, observed, that though all the other parts were perfectly blanched and bloodless, the brain contained a larger quantity of blood than usual, from which he was led to the singular conclusion, that an animal, under such circumstances, dies of *apoplexy*. It is probable that he was deceived as to the quantity being increased, by comparing the appearance of the brain with that of the rest of the body; but it is certain that the vessels of the brain would be kept in their ordinary state of fulness, by the atmosphere pressing on the *jugular* veins, so as to prevent the return of the blood, while the *carotid* arteries, in consequence of their deeper situation and stronger sides, remained open for its transmission.

The quantity of blood sent to the brain is very great, in proportion to its size. Haller states it as one-fifth of the whole supply of the body; and though Monro reduces the estimate to one-tenth, still we must consider this as a very large proportion sent to a part, which, in weight, is not one-fortieth of the whole. Although such a copious supply is thus provided, yet every one knows the danger of a sudden gush of blood to the head, and, accordingly, this has been guarded against with the most scrupulous care. In animals that hang the head in feeding, such as the ox, sheep, &c., this danger would be greatest. Therefore in them we find the most beautiful provision against it; for no sooner have the large arteries arrived at the head, than they divide into a number of small branches, which, after forming a net-work, assemble themselves again into a trunk, proceed towards the brain, and then a second time subdivide for its supply. The only object, then, of the first subdivision, is to break the force of the jet of blood coming from the heart, and ensure a more steady and even flow in the vessels of the brain. It would be wrong, however, to consider such an effect as merely mechanical; by it the extent of the arteries is increased, of course the amount of their vital contractility is increased with it, and they obtain, as it were, an independent regulating power. In the instance given, this power was used for lessening or moderating the flow of the blood; but it can also be used for increasing or strengthening it, as Sir Charles Bell has taken some pains to point out.

If a tumour commences growing on any part of the body, the arteries supplying that part, though before straight and even in their course, will become enlarged and tortuous, carrying more blood, and delivering it with more power. The surgeon knows that when called on to remove the tumour, should he cut one of those tortuous vessels, the blood spouts from it with much more force than when the vessel was straight. The artery going to the breast in a woman is naturally straight, but when she commences to give suck, and so an increased supply is required, the artery immediately becomes tortuous. The arteries supplying the womb become extremely tortuous during the period of gestation. The temporal artery in man, which conveys blood to the top of the head, and may easily be felt beating at the temples, is well known to be tortuous, yet the object here must be an increase of power to urge the blood up against the resistance of gravity; the arteries supplying the lower extremities are all quite straight. It is, therefore, evident that the mechanical obstacle produced by the various directions given to the current can be more than compensated by the additional extent of contractile power acquired, and that the object of the subdivision in the one case, or the tortuosity in the other, is to give the arteries a greater control over the supply.

In the human brain there is not the provision, described in the ox or sheep, for saving it from the effects of the heart's action, which we may, in passing, notice as an argument, if argument be necessary, against the absurd opinion, that man was ever intended to walk on all-fours, with his head hanging down. The matter is sufficiently provided for by the effects of gravity, and the bending of the arteries at abrupt curves, just before and immediately after entering the skull. It is also worthy of notice, that they divide immediately into a great number of minute vessels for the supply of the brain, no trunk of such a size entering its substance, as could, by its pulsation, cause any disturbance. The return of the blood from the brain is provided for, not in the ordinary way of veins uniting to form trunks, these still larger trunks, and so on; but the small veins all discharge themselves into certain cavities, termed *sinuses*, generally formed on one side by a groove in the bones of the skull, and, on the others by reflections of the firm fibrous membrane, which forms the general envelope of the brain. By these means they are constantly kept open, so that the blood flows into them with much ease; and they also resist dilatation, the effect of which would be to produce pressure on the brain. No valves are to be found in them, as they are not in the neighbourhood of muscles that might compress them, neither are they subject to the weight of the atmosphere, nor yet does the current rise against the power of gravity. They prevent the bad effect of a reflux, which may take place during any temporary obstruction to the entrance of the blood into the chest, by dividing its action amongst all the little veins entering them, so that the shock which would rupture one, is rendered harmless amongst many.

The pulse is a phænomenon familiar to every one, yet the cause of its occurrence is not perfectly known. We have seen that the heart at each contraction sends into the arteries a jet of blood, and almost at the instant this occurs, a finger placed on the wrist, or in any other situation where an artery can be compressed, will be sensible of a stroke. It was, therefore, thought that a dilatation of the artery, caused by the increase in its contents, was the cause of this stroke. But it appears that the dilatation alone is not sufficient to account for the pulse, inasmuch as Dr. Parry could not, in the most careful examination, observe any dilatation in the artery; and Dr. Barry, having thrust his arm into the chest of a living horse, and laid hold of the aorta, found that it gave no pulsation, unless he compressed it. There can be no doubt, however, of there being a certain degree of dilatation, for, as the blood is incompressible, there is no other way of accounting for its smooth equable motion through the capillaries. The sudden stiffening of the artery to aid in the transmission of the blood, must also be a cause. Between the jets the artery is flexible and yielding, therefore the finger presses it without difficulty; but when the jet comes, the contractile coat of the artery suddenly acts, and converts it into a rigid tube under the finger. Another cause may be a slight change of place that occurs in such arteries as are bent or tortuous; the gush of fluid will, as we have before explained, attempt to straighten the curves, and the effect will be the throwing up of the artery from its bed. The sort of vibration conveyed along the whole fluid must also assist, as we can convince ourselves, by filling any elastic tube with fluid, and exciting a motion in it, by tapping at one end; it will quickly be conveyed to a considerable distance. We see, thus, that the pulse cannot be referred to any single cause, but that several must be considered in attempting to account for it.

It now only remains that we should say a few words of the causes that led to the discovery of the circulation, and the arguments by which it is proved. This important fact was discovered by the celebrated Harvey about the year 1620, and, we may say, resulted from adherence to the principle, which in physical inquiries should never be lost sight of, that Nature does nothing in vain. Harvey, in the course of his anatomical researches, observed the fact, that the valves of the veins all opened towards the heart, but shut back so closely, as to resist the return of fluid, or even air, the other way; he at once decided that so remarkable a contrivance must have some use, that that use was to admit the flow of the blood in one direction, but resist it in the other, and, consequently, that the blood did not ebb and flow in the veins "like the tides of the Euripus," as had been the old opinion. Some channel was now requisite to take the blood out to the body, the veins being only calculated to return it, and what channel so proper as the arteries? To put the matter to the test, he opened an artery in the living body and out gushed the blood. So far was satisfactory; the artery contained blood, but what course was it taking? He tied an artery, and it swelled at the side next to the heart, therefore its blood was coming to it from the heart. He tied a vein and it swelled at the side remote from the heart, therefore its blood was returning towards the heart. He cut across an artery, the jet of blood took place from the heart-side; he cut a vein, the blood poured from the body-side. He showed that an animal would bleed to death, either from an artery or a vein, which clearly showed their communication. Finally, he opened a cold-blooded animal, and observed the whole process that he had thus beautifully argued out; the veins filled the auricle, the auricle passed the blood to the ventricle, the ventricle contracted, and sent its load through the whole body, whence it was again to return streaming through the veins. The proof was now complete, and entitles him to the glory of having worked out one of the most important discoveries ever made, by reasoning alone, without any mixture of accident. Little, we may say nothing, has been added to his demonstration; in fact it needs nothing. Malpighi, Leeuwenhoeck, and other microscopical observers, have seen the circulation going on in the wing of a bat, the tail of a fish, the web of a frog's foot, the mesentery, and other transparent parts; but this, of itself, would have been insufficient to prove the exact progress of the blood, and, indeed, without the previous proofs, would have given us very imperfect notions. The discovery is peculiarly Harvey's, in it he was both original and complete. The passage of the blood through the lungs had been imagined by Servetus, a Spanish physician, and the mixture of the blood and air in them, supposed to give birth to a vital principle. His description occurs in his work, called *Christianismi Restitutio;* but can no more be said to have led to the discovery of the general circulation, than the celebrated passage in Seneca to the discovery of the new world.

With the humility of a Christian, joined to the spirit of a philosopher, Harvey continued his investigations into the animal body; his researches were crowned with success, but it does not lie within our present scope to notice them further. We may be allowed to express our regret that we have been deprived of the results of many of these by the ruthlessness of civil war. Harvey was loyal, as well as pious. He had shared the prosperity of his royal master, and with equal readiness accompanied him in flight and in adversity. His museum was plundered, and his preparations destroyed, by the parliament party, yet sufficient remained to enable him to give the world his *Exercitationes de Generatione Animalium*, which illustrated in a new and striking manner the declaration of Holy Writ: "Wonderful are the works of the Lord; *sought out of all them that have pleasure therein.*" Harvey lived to see his doctrines triumph over all opposition, and died full of years and honour, A.D. 1658.

[If it could be given us to trace the paths of an individual mind which lived before the appearance of literature and science in the world, and if we should observe that it had taken the right course towards truths which some after traveller has laid down with acknowledged accuracy, and which still bears his name on the great chart of human discovery, we might hesitate whether we ought to yield entirely to the last the envied *εὕρηκα* of research. This is no imaginary dilemma. There are few positions that so betray the weakness of partial opinions, and the illogical ground on which they seem to rest, than the discussions, as fatal to right feeling as to all true philosophy, that invariably follow every great discovery, and which have not left even revelation intact. No sooner had Harvey, in 1628, published the *facts* of the circulation of the blood, than men discovered that in the writings of Solomon, Hippocrates, Plato, Aristotle, and Galen, they could read of the same facts and the same discovery. And undoubtedly they could do so to a certain extent; but they forgot to add that it was by the lamp of Harvey's genius alone by which they were enabled to see in the loose analogies of the ancients the positive relations which he first unveiled. More than 2000 years had elapsed since the works of Hippocrates had been given to the world, yet no one had found in his observations, or in those of any other author, the clue to this more than Cretan labyrinth, till Harvey published his *Exercitatio Anatomica de Motu Cor-*

dis et Sanguinis in Animalibus; and, were it possible to extinguish the light which he sheds upon the past, the shadows of truth that are now seen to chequer the pages of ancient literature would once more be hidden from us, for all would become equally obscure. But happily this cannot be; like the photographs of Daguerre and Talbot, genius transfixes for ever shadows that pass over the minds of many, though none else have power to arrest them.

Before we pass to the quotations which at one time formed the *texts* of many a bitter diatribe, let us once more assure the reader that their authors were quite unconscious of that fulness of meaning which later facts have given to their words. The following is the first step of error:—In an ancient work we find *words* which express our own familiar *ideas* of some later discovery, and we at once assume that the impressions of the writer were the same as those of the reader; but words, which are vague, are the only medium and test of this relation; and, amidst the multitude of metaphors necessarily used before inductive science taught realities, is it to be wondered at, that a few, when taken apart from the context, correspond to the form of expression of the facts themselves, since discovered? We shall find this to be the case in the present instance. Solomon, writing nearly 3000 years ago, compares the heart to a fountain, the liver to a cistern, and the circulation of the blood to a water-wheel; and Hippocrates, 500 years later, compares the circulation of the blood to the course of rivers, to the ebbing and flowing of the sea, to the revolutions of the planets; now, is it philosophical to pick out these metaphors, unsupported as they are by a single fact recorded in the works from whence they are taken, and affirm that the ancients knew the circulation of the blood as we know it, and as Harvey first taught it? The ancients knew that the blood moved, but all beyond that fact was metaphor. The anatomists of the Alexandrian school of medicine, so late as the time of Galen, taught that the arteries were filled with air, and the very name of *artery* means *I hold air.* The following are the quotations in chronological order.

1. "Or ever the silver cord be loosed, or the golden bowl be broken, or the pitcher be broken at the fountain, or the wheel broken at the cistern. Then shall the dust return to the earth as it was; and the spirit shall return unto God who gave it."—*Ecclesiastes*, xii. 6, 7.

The silver cord is the spinal marrow; the golden bowl, the skull-cap; the pitcher, the heart; the wheel, the metaphorical circulation of the blood; and the cistern, is the liver.

2. "The veins extended throughout the body exhibit life, and flux, and motion: many branches spring from one, but whence that one arises, and where it terminates, I know not; for a circle being described, the beginning is not to be found."—*Hippocrates.*

3. "The heart is the source of the veins and the fount of the blood, which circulates (περιφερομενον) through the whole body with some degree of force."—*Plato.*

4. "The blood flows through the veins, and these vessels receive it from the arteries."—*An ancient scholiast of Euripides.*]

Chapter IX.

RESPIRATION.

Respiration is that function by which the blood, exposed to the action of air, is rendered fit for the nutrition of the body, and the stimulation of its several organs. This exposure takes place in different modes in the different classes of animals. In man the lungs serve for this purpose; in fishes, gills; in some singular animals, as the proteus and siren, both lungs and gills occur; insects have neither lungs nor gills, but the body is penetrated with tubes conveying air into all its parts, while lower still all these provisions are wanting, and respiration seems carried on by the skin alone. This is an illustration of the law lately announced by M. Straus Durckheim, "that in following any organ through the scale of animals, we observe it undergo a regular degradation before it totally disappears." The function, however, is necessary in one mode or other, to every animal, a fact so well known as to have become a proverb, "necessary as the air we breathe." Spallanzani made numerous experiments on small animals, which he introduced under the bell of the air-pump, and found that they invariably died soon after he had exhausted it of air. Or if he placed them in circumstances that prevented the renewal of the air, death also followed in longer or shorter time, proportioned to the quantity of air in which they were enclosed. In these cases the air was always found vitiated. One of its principles (oxygen) was gone, and in its place was substituted carbonic acid gas, which is fatal to life.

Hales found that the same laws held respecting vegetables: they too died when the air was withdrawn, or vitiated the air with which they were enclosed. It appears, therefore, to be an universal law, that *air is necessary to life*. We must, therefore, commence with a short account of air, its composition and properties; next, consider the mechanism by which its action on the animal frame is ensured; this will lead us to a review of the respiratory organs in the different classes of animals, and their beautiful adaptation to each; we shall afterwards consider the changes that have taken place, both in the blood and the air, consequent on their being brought into apposition; and conclude with some remarks on voice, speech, and certain other phænomena, such as laughing, sighing, &c., connected with our subject.

The air is that invisible elastic fluid by which we are every where surrounded. It encompasses the earth like a shell *, probably to the height of about forty-five miles. Its *gravity*, that is, its attraction towards the centre of the earth, which it shares in common with all other bodies, fluid or solid, pre-

* The weight of this shell of air as computed by Dr. Thomson, in his system of chemistry, is 1,911,163,227,258,191,818 pounds avoirdupois.

vents it from flying away or yielding to the attraction of the sun; while its *elasticity*, or the tendency of its particles to remove themselves from one another, saves it from falling down altogether to the earth's surface, and condensing itself into probably a liquid, or solid crust around it. The consideration of these properties of the air belongs more peculiarly to the science termed *Pneumatics*, but their utility is evident in ensuring us an atmosphere proper for breathing. We are at present, however, most concerned with the composition of the atmosphere. By the ancients we know it was looked on as a simple body, and counted as one of their *elements*, out of which they supposed all other bodies to be formed.

A series of beautiful experiments, however, have now demonstrated the fallacy of this opinion, and the names of our own countrymen, Boyle, Priestley, Cavendish, and Black, rank high amongst those by whom the true nature and composition of the atmosphere has been disclosed. It essentially consists of two gases, oxygen and nitrogen, in the proportion of twenty-one measures of the former to seventy-nine of the latter, in every one hundred measures of atmospheric air. It matters not whether the air examined be brought from the highest mountains, or the deepest valleys, this proportion continues unvaried. There must, therefore, be a reason for this, and the reason is, that as far as the researches of pneumatic chemistry have gone, and no science has been cultivated more diligently or successfully, there is no other gas, no other composition of gases, which could, consistently with health and life, continue to be breathed for any length of time. In addition to these two gases we find less than ·01 of carbonic acid in every hundred parts of atmospheric air, yet so constantly found as to be looked on as a necessary ingredient. It would appear that this is not useless either, as the experiments of Saussure seem to show that the presence of a certain quantity of carbonic acid promotes the growth of plants; and it merits observation, that at great heights the quantity of this gas is much diminished; in fact, M. Mongez, who accompanied La Perouse in his last unfortunate voyage, could detect none of it in the air on the summit of the Peak of Teneriffe; but here we know vegetation is at an end. In addition to these, the atmosphere generally contains watery vapour, exhalations of various kinds, occasionally odours, emanations from animal and vegetable bodies, and *miasmata*, or contagious effluvia, which, though so generally allowed to be the causes of certain diseases, have as yet defied all attempts to investigate their nature, or demonstrate their existence, otherwise than through the baneful effects attributed to them. These, however, as they vary in different parts, are considered as being only accidentally present in the atmosphere, which essentially consists, as we have said, of one-fifth oxygen and four-fifths nitrogen. Now should a man attempt to breathe nitrogen alone, he is quickly suffocated; the nitrogen itself is not injurious, but causes death merely by preventing the entrance of oxygen. This property has induced the French chemists to give it the appropriate name of *azote**. If, on the contrary, a person breathes pure oxygen, he seems under the influence of a too powerful stimulus. His pulse increases in strength and rapidity: his breathing is accelerated: his face becomes flushed; he exhibits symptoms of high inflammation, which would supervene were the experiment continued. It is evident, then, that dilution is required, and it is an object that this dilution should be made with some gas, not in itself injurious to life. Of such gases there are but two, nitrogen and hydrogen. But a mixture of hydrogen and oxygen is so violently explosive, that were the atmosphere composed of this, the first accidental spark, the first attempt to light a fire, would have blown it all up, and destroyed all the animals on the surface of the globe. Nitrogen, therefore, is alone proper; nitrogen, therefore, has alone been employed. Whether it may not have some further use in the atmosphere than a mere diluent, will be considered when we come to speak of the changes produced in the air by respiration. But another question now arises; one hundred cubic inches of oxygen

* From α, privative, and ζωη, life.

weigh about thirty-three grains, while the same quantity of nitrogen weighs but twenty-nine. Why then, it may be asked, does not the oxygen fall to the bottom, or occur in greatest quantity towards the earth, while the nitrogen should mount up, and be found most abundant in the upper regions of the air? That this does not occur we have already stated, and we are assured of the fact by the analyses made of air brought by Gay-Lussac from a height of 21,735 feet, to which he had ascended in a balloon, and also of some brought by Humboldt from the top of the Andes. This uniform mixture of the component parts was at first attributed to the constant agitation produced by the winds, but this was very unsatisfactory. The effect of the winds reaches only to certain heights; during calms of long continuance no alteration is experienced in the composition of the air; and if air be confined in a tall glass tube, and kept perfectly at rest for several months, the upper part will still be found to contain as much oxygen as the lower.

Dr. Dalton applied himself to the consideration of this question, and the conclusions at which he has arrived seem to us quite satisfactory. He observed that, if he caused two vessels to communicate by a tube, the one of which contained oxygen and the other nitrogen, a mixture of the gases soon took place, and that it seemed indifferent whether the heavier gas were placed above or below. He proceeded to generalize this fact, and found it to hold good for all gases, the lighter invariably descending through the heavier, while the heavier rose through the lighter. This was an apparent contradiction of the laws of gravity, but the contradiction was only apparent. It will be remembered we mentioned another quality of gaseous or aëriform bodies—elasticity. This is the tendency which the particles of a body have to recede from one another in consequence of a repulsive power which they seem to exercise amongst themselves. It occurred then to Dr. Dalton, that though they thus repelled one another, yet that they exerted no such power on the particles of any other body; and this simple supposition resolves the whole difficulty. For suppose that, first, the world were surrounded by an atmosphere altogether of nitrogen, it is evident this would expand itself into space in the same manner as our present atmosphere, that is, until its further expansion were checked by such causes as cold or gravity. Now between the particles of this atmosphere of nitrogen, there would exist spaces which the mutual repulsion of the particles prevented them from occupying. If, now, a quantity of oxygen were let loose at the surface of the earth, it would rise into all those spaces, inasmuch as its particles would suffer no repulsion from the particles of the nitrogen, and would proceed to diffuse themselves almost as if no nitrogen were present. The relative proportions, therefore, of these gases at any given height, would always be the same, being the result of a common law, that the expansion of gases is measured by the diminution of pressure.

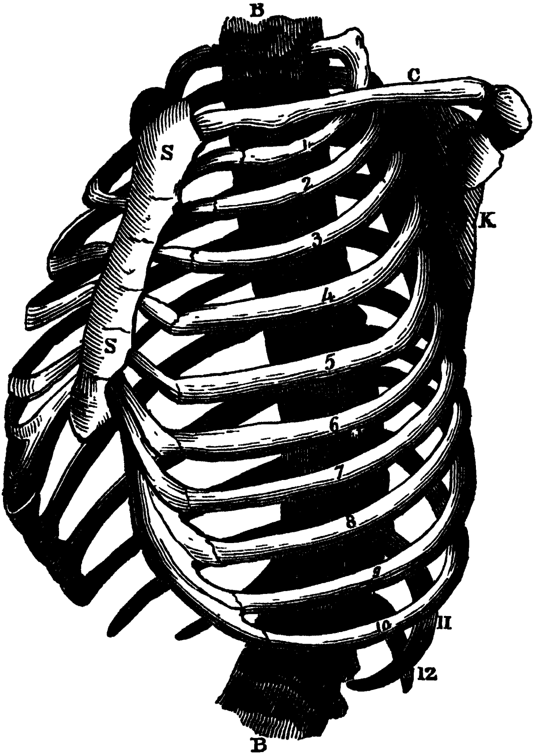
Dr. Dalton's theory is, therefore, pretty generally received; but whatever may be thought of this, the fact is undoubted, that the composition of the air is uniform at all heights from which as yet it has been brought, and that this composition is in the best proportions for the support of animal and vegetable life. In confirmation of this last assertion, we may add that the same elements, viz., oxygen and nitrogen, in different proportions, produce *nitrous oxide,* that singular gas the inhalation of which for a few moments will produce temporary intoxication; or, if the oxygen be still further increased, even *nitrous* or *nitric* acids, which rank amongst the strongest corrosive substances we know, and would be instantly fatal if admitted either into the lungs or stomach.

We shall notice but one more of these aërial harmonics or adaptations of the air to our necessities. It is this, that its component parts are so loosely combined that any body which possesses an attraction for oxygen removes it as easily as though it were in a state of purity. Thus, iron exposed quickly *rusts,* that is, combines with the oxygen of the air, rust being merely an *oxide* of iron. The same may be said of the other metals that rust, corrode, or tarnish by exposure;

these words express nothing more than the combination of such metals with oxygen. Oxygen is also required to combine with, or in some manner act on the blood so as to change it from venous to arterial, but were the oxygen strongly attracted, or held, by the nitrogen, we could not expect it to be separated during the short period it is allowed to act on the blood in the lungs. We are able to illustrate this by what actually occurs to fish. They breathe, not water, as is commonly supposed, but a quantity of atmospheric air which is constantly held in solution in water. If we exhaust the water of this air by placing the vessel containing it under the receiver of an air-pump, a fish placed in such water under such circumstances would die; *the fish would be drowned.* Yet there is plenty of oxygen around it, for water is composed of oxygen and hydrogen, but they are in a state of such intimate combination that the fish's gills cannot decompose them so as to apply the oxygen to the arterialization of its blood. How many provisions necessary before we could make a single available respiration!

Now, to consider the organs by which this air is made useful to our existence; for as solid and liquid nutriments are taken into the stomach, certain parts of them employed for the support of the body, and the remainder which is useless, cast out; so, gaseous food, that is, the air we breathe, is taken into the lungs at each inspiration, undergoes certain changes there, and when returned by expiration is found deprived of a portion of its constituents which have been applied to the uses of the system.

In man and the higher order of animals, such as quadrupeds, the lungs are always contained within a cavity called *thorax* or *chest.* This we consider as extending from the bottom of the neck to the top of the abdomen. It contains the lungs and heart, organs of the highest importance. It is, therefore, fenced round and defended with much care and foresight, having behind, the back-bone; in front, the breast-bone; and, round the sides, the ribs, which run from one of these to the other; being of a rounded or bowed form, which allows free space for the expansion of the lungs, and is the cause of the general shape and outline of the chest. It will be necessary to say a few words of the structure and mechanism of each of these parts. The term back-bone, which we have hitherto used with a view to being understood by general readers, is really incorrect, inasmuch as the part so designated, consists of twenty-four distinct bones, to which the name *vertebræ* is given. Between each pair of these a plate of elastic cartilage is inserted, and the whole structure thus built up possesses two qualities which no single bone could have had; it is flexible, so as to accomodate itself to all the motions of the body in twisting, turning, stooping, &c.; and it is springy, that is, it is capable of yielding a little at each joint and again recovering itself, so that any jar caused by leaping from a height on the heels becomes divided and diminished in its passage along the spine, and is thus prevented reaching the brain, where it might do injury. Of these twenty-four vertebræ, seven belong to the neck, and are named *cervical;* twelve to the chest, and from being situated at its *back* part, are called *dorsal;* the remaining five are in the loins, and thence termed *lumbar*. To each of the twelve dorsal vertebræ corresponds a rib which fits on it by means of a round head resting in a shallow cartilaginous cup placed on the side of the vertebra; or rather between it and the one immediately above it. The rib thus is connected with the spine by a regular joint allowing motion, and we have the never-failing accompaniment of such a structure, the *synovial* membrane secreting joint-oil. Setting out, then, from this point, the rib is curved round the side so as to gain the front of the body; but beside this curve forward, it has also an inclination downwards, the consequence of which is, that any force tending to draw it upwards draws it at the same time outwards, and so enlarges the capacity of the chest. The seven upper ribs passing round are directly connected with the breast-bone by means of pieces of cartilage continuing them into little sockets along its sides; while the five lower have no such connexion, but run their cartilages each to the rib above them, forming a retiring margin which any one may feel in himself, sloping away from the bottom of the breast-bone, round the sides of the belly, towards the back. These five ribs are called false. Perhaps, as we write for persons who may not have an opportunity of examining a skeleton, it may not be unnecessary to say, that the number of ribs at



Profile view of thorax; distinguishing Rib from Cartilage.

B B is the back-bone; S S the *sternum*, or breast-bone; C the *clavicle*, or collar-bone; and K the *scapula*, or blade bone. The ribs are numbered from above downwards.

each side is always the same. The well-known popular error of believing that a man has one rib more at his right side than his left, has arisen from a hasty misconception of the circumstances attending the creation of woman. It is evident that the assumption is quite gratuitous, for we know that a man who has had a leg removed, for instance, may afterwards have a child born with the usual proportion of members; most horses have their tails docked, yet we never saw a foal born in this condition.

Such are the bony walls of the chest: in the intervals between the ribs, and connecting them together, are placed the muscles called *intercostal*. The contraction of these will evidently tend to draw the ribs towards one another, and as the first rib is the most fixed, the motion is made in that direction. Above, there is no distinct partition between the chest and the neck, but it is usual to say, the former begins and the latter ends at the first rib. Below, however, the chest is clearly and perfectly divided from the abdomen, by the muscular partition before alluded to, and known by the name of midriff or diaphragm*. This singular muscle passes like an arch over the contents of the abdomen, descending, however, much further behind than before. Its convexity is directed upwards into the chest, so that its contraction tending to draw it downwards and more nearly to a plane surface, must evidently enlarge the capacity of the chest and diminish that of the abdomen. Any person may obtain a good idea of this muscle, by fancying to himself a vaulted partition stretching completely across his body, attached in front where he can feel the termination of his breast-bone, from that, along the sides, to the margin of the ribs, and behind to the spine as low down as the top of the loins. From the knowledge he has already obtained, (supposing him to have read through our previous chapters,) it will also strike him that this partition must have some openings in it to give passage to parts that run from the chest to the abdomen,

* Diaphragm, a partition between; from δια, between, and φρασσω, to shut up.

or *vice versâ*. And he would be perfectly right. The gullet runs from the mouth along the back part of the chest to the stomach, which is in the abdomen; it therefore penetrates the partition, and a distinct hole is left for its passage. The aorta also, carrying blood to the abdomen and lower extremities, must pass through this partition, and a second opening is left for it: of this opening the thoracic duct takes advantage to pass up, conveying the chyle to the vein which is to pour it into the heart. But a third aperture is necessary, for the vena cava must bring back to the heart the blood which the aorta took out. This third aperture accordingly exists:—in short, reason never evinces a want for which examination does not produce a corresponding structure; and this it is, that makes the argument taken from the evidences of design so perfect and irresistible.

The diaphragm, by its contraction, enlarges the chest; the consequence of this is, that a quantity of fresh air rushes in from without to fill up the space thus left. We must, of course, next examine the passage through which it enters. This is the wind-pipe which we can feel distinctly running along the centre-line of the neck, and placed in front of the gullet. It is a round tube, having at intervals little cartilaginous hoops, the object of which is to keep it constantly open. At its summit, is placed the *larynx*, which we shall describe more particularly when speaking of the organs of voice. At present, we are considering it merely as the pipe or tube through which air passes to the lungs. Arrived at the bottom of the neck it divides into two branches, one going to each lung, and, before long, these further subdivide, the one going to the right lung into three, because the right lung has three lobes; the one going to the left into two, because the left lung has but two lobes. The cause of this difference is supposed to be that the heart, lying at the left side of the chest, occupies the space which at the right side is filled by the third lobe.

After this, the divisions and subdivisions of these *bronchial tubes*, as they are called, become exceedingly numerous, and after they have attained a great degree of fineness, they terminate in little rounded sacs, something like bunches of currants at the end of the stalks. The number of these terminating sacs, or cells, has been computed by Keill at 1,744,000,000 in each lung; and Lieberkühn, with equal exaggeration, makes their surface equal to 1500 square feet. But without attempting to settle this point, let us rather consider the structure of these tubes and cells. The hoop-like cartilages of which we have spoken do not pass quite round the windpipe, but form about two-thirds of the circle, their extremities being connected by muscular fibres. By means of these fibres we are enabled to contract the tube, which is of use in bringing up phlegm, as the air expelled from the lungs by coughing or hemming must pass with more force in proportion as the passage is narrower.

Their situation, also, is an evidence of foresight:—they are placed behind where the windpipe is in contact with the gullet, and where, therefore, cartilaginous rings would be an impediment to swallowing; while these latter occupy the front and sides of the windpipe, where they support it against atmospheric pressure, and enable it to resist the tendency to collapse.

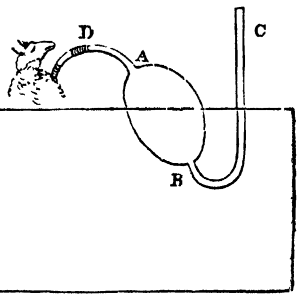
The cartilages become less evident as the bronchial tubes become smaller, and at last entirely disappear; their place being, it is said, occupied altogether by muscular fibres. The lining membrane of these tubes is of the same description, and furnished in the same manner as the lining membrane of the alimentary canal. The skin, turned in, as we have seen, over the lips, alters its qualities, becomes a *mucous* membrane, furnished with glands, and moistened with a constant secretion; it enters the throat, one division passing down the gullet to the stomach, while the other lines the windpipe and goes on to the lungs. It is this membrane which finally forms the minute air-cells in which these tubes terminate. Around these tubes wind the capillary branches of the pulmonary artery, bringing black blood from the right side of the heart, the air taken into the cells readily acts on it through their delicate membranous sides, the blood is reddened or arterialized, and so passed on to the left auricle:—this is the pulmonary circulation.

The lungs themselves are two spongy, light, expanding bodies, composed of a number of these minute cells connected together by cellular membrane, and surrounded by ramifications of blood-vessels, constantly in close apposition with the sides of the chest, and only separated from them by the *pleura*, serous sacs, which by one surface invest the lungs while, by the other, they line the inside of the ribs. From this description, it will appear that the air-cells have no direct communication amongst themselves, nor with the cellular structure by which they are surrounded; their only opening is into the bronchial tubes. Such a communication may, however, be made unnaturally, and is generally the result of violent straining or exertion, made when the air-cells are full. Under these circumstances, a rupture of their sides may occur, and the air which they contain will be diffused in the cellular membrane pressing on the air-cells in the neighbourhood. Now since this air may increase at each inspiration, while from its irregular situation it cannot be so easily expelled during expiration, we see that the pressure on the air-cells may at length be so great, as to shut them up and render that part of the lung useless. This is a form of disease not very uncommon, and it occasionally results from long playing on wind instruments, such as the trumpet, which require much air to be kept in the chest. When it occurs in horses it generally results from their being run too hard, and the animal is said to be broken-winded. The possibility of such rupture taking place should always be carefully kept in mind when attempting to resuscitate a person after drowning. Forcing in air too fast, and with too much violence, will inevitably break up these fine cells and the vessels that surround them, and so render revival impossible.

The lightness of the lung results from the quantity of air contained in its substance, and this is so great, that the lung of a person who has once breathed, will not sink in water. In the fœtus, however, in which respiration has never taken place, the lung is a thick fleshy body, with its little cells closed up, so that it readily sinks. This, in the case of inquests held on dead infants, whose bodies bore no mark of violence, has enabled the medical witness to testify whether or not they had been still-born. It is necessary, however, in such cases, to ascertain that putrefaction has not set in, as this, by the disengagement of gases, might cause the lung to swim, though the child had never breathed.

Let us suppose an empty bladder placed inside a bellows, with its neck fitted tightly around the inner opening of the pipe. If now we lift the upper side of the bellows, closing the aperture, which is in the under-leaf, air will rush in through the pipe, and fill the bladder. But if we let go, the upper lid will gradually descend, forcing the air out of the bladder until it is empty as it was before. This almost describes the mechanism of respiration. The lungs are not a bladder, but a collection of many bladders (the air-cells), each communicating through the bronchial tubes with the wind-pipe. The sides of the bellows are the diaphragm, and the ribs with their intercostal muscles. When they act, the capacity of the chest is increased, the diaphragm sinking down into the abdomen, and the intercostal muscles raising and drawing outwards the ribs and breast-bone. To fill this enlarged space air rushes in through the wind-pipe and distends all the little bladders: this is inspiration. The muscles then cease to act; they let go, and the elasticity of the lungs coming into play, causes them to expel the air that had been taken in; the diaphragm, following the lungs as they shrink, retires again into the chest; the ribs fall inwards to their old situation: this is expiration. The elasticity of the lungs is not, however, totally unassisted in expelling the air; we must allow something for the elasticity of the cartilages, by which the ribs are joined to the breast-bone, and which, having been unduly thrown up during inspiration, will, of course, react and press on the lungs in expiration. We thus see that there is more active exertion in inspiration, which depends for its performance on muscles, while expiration, like the closing of the bellows, is, in a great measure, passive.

If a part of the walls of the chest be cut away, so as to leave the lungs exposed to a certain extent, respiration can no longer go on at that side; for now the air admitted to press on the surface of the lung, counterbalances that which endeavours to find its way through the wind-pipe, and dilate the lung, therefore these powers being equal, the elasticity of the lung remains without any antagonist, and therefore causes the lung to collapse and shrink against the back of the chest. This collapse is more complete, if the lung be opened during life, than after death, whence some have conceived that, in the former case, the elasticity must be assisted by certain very minute muscular fibres, which they suppose to surround the air-cells. This opinion was maintained at some length by Dr. Willis, in opposition to Etmuller, and he even went so far as to say that their existence was demonstrable by the assistance of a microscope. His eyes, however, must have been sharper, or his glasses better, than those of the present generation. Reisseisen, who has, in our days, supported this opinion in a most admirable essay on the structure of the lungs, endeavours to make it good, rather by argument than an appeal to the senses; and he principally supports himself by the fact we have mentioned, of the more evident collapse during life, and by Varnier's experiments, in which a notable contraction occurred on the injection of stimulating fluids. These we cannot consider satisfactory proofs: the muscles of the bronchial tubes would contract when irritated and draw down the lung with them, and, as to the different extent of collapse before and after death, even Sir Charles Bell, the great advocate of muscular fibres, whenever they can be "seen, felt, or understood," admits this difference between living and dead elasticity, that in the former the resistance is perfect, while in the latter it is incomplete; and he happily exemplifies his opinion by referring to the *living* elastic ligament in the neck of a horse, which, however often strained, always resumes its original dimensions, and, on the other hand, to the *dead* elastic string of a harp, which, on being stretched, yields, and requires to be screwed up afresh to bring it to its proper tone. The amount of this elasticity, or the force by which the lungs themselves assist in expiration, and antagonize the efforts of the diaphragm, has been investigated by Dr. Carson, with his usual ingenuity, in a paper read before the Royal Society in 1820, and to be found in their *Transactions* for that year. His apparatus was extremely simple.

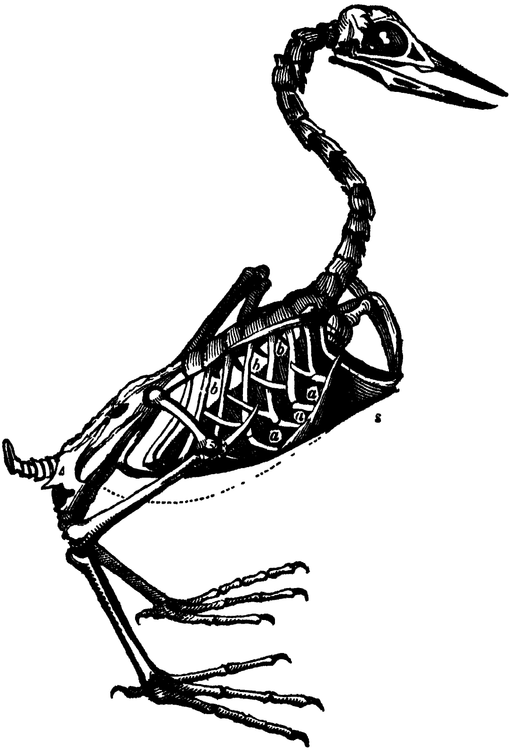


An oblong glass globe, containing nearly two quarts, had tubular openings at each end A and B. A glass tube, nearly three feet in length, and bent at one end, was joined by the blow-pipe to the opening at B, and is represented by B C. To the other opening at A, a shorter tube was joined in the same manner, and in the form A D. A free passage was established from D to C, where the tubes were both open. To D a piece of the dried gut of some animal was bound, of a few inches in length. The other end of the gut was fixed to a cylindrical tube of bone, metal, or wood, also of a few inches in length, and of a diameter corresponding with the diameter of the wind-pipe of the animal which was to be the subject of the experiment. The wind-pipe of an animal, which had been recently killed, was divided across near the throat, the cylindrical tube of bone was inserted, and tied so tightly, that no air could pass between the external surface of the tube and the internal surface of the wind-pipe. An open and secure passage was thus established between the glass apparatus and the wind-pipe, and, of course, the lungs of the animal. Water was then poured into the apparatus at C, until it stood in the upright tube C B, at a certain height above the level of the water in the glass globe. The apparatus was now prepared for use. Some of his earlier experiments failed, either in consequence of the lungs being rounded, or the globe too small, or the tube not sufficiently high, particularly when the larger animals were examined. Having taken much care to obviate all these accidents, he at length succeeded fully in the following experiment. On the 31st of October, 1817, the apparatus was applied to the trachea of a dog, which had been hanged on the preceding day. Water was poured in until it stood in the upright tube, at the height of six inches above its level in the globe. By incisions made at both sides air was cautiously admitted to the surface of the lungs. The water *ascended* instantly about an inch in the upright tube, and the lungs were found to have receded from the openings. Now the atmospheric pressure on the surface of the lungs exactly counterbalanced that on the surface of the water in the tube B C. These powers may, therefore, be taken away, and there will remain the weight of the column of water in B C, above the level of the water in A B, tending to press the air in the upper part of A B into the lungs, and, on the other hand, the elasticity of the lungs tending to drive back the air which they contain into A B, depress the water in it, and consequently *raise* that in B C. This, as we have seen, occurred in the present experiment. The conclusion, therefore, was that the elasticity of the lungs of a dog was able to overcome the pressure of a column of water, six inches in height. Water was now added, until its level in the tube above that in the globe stood at the height of ten inches. This degree of pressure seemed equal to the elasticity; the water in the tube continued steadily at the same height, and the lungs continued fully dilated. "The appearance which the lungs exhibited in this situation was novel and interesting, and was, no doubt, the same which they would have exhibited in the living body, had it been possible to bring them into view. Their surface was smooth and polished, and their edges rounded, without any of those corrugations and sharp angles which they usually exhibit. Their colour was red, and life-like. They felt firm to the touch. The heart appeared like a bird nearly covered by its nest."

From this, and a number of similar experiments, Dr. Carson has shown that in calves, sheep, and in large dogs, the elasticity of the lungs was balanced by a column of water, varying in height from one foot to a foot and a half; and in rabbits and cats by a column of water, varying in height from six to ten inches. From a defect in the apparatus, the extent of the power in question could not be ascertained in the lungs of oxen and animals of their size, but it was proved to exceed, considerably, the force necessary to support a column of water a foot and a half in height above its level.

In all this, it will be observed, there is nothing said of muscular fibres, elasticity appearing quite sufficient for everything that is to be done. It is a good general rule in physiology, to believe what your senses prove to you; and as no one has ever seen these fibres, so neither do we see the necessity for them: we must, therefore, allow their existence to remain (as far as we are concerned) in doubt.

The general shape of the lungs in man, and the other mammalia, is adapted to that of the cavity which contains them. It may, therefore, be described as conical, the smaller extremity situated towards the neck, the base large and concave, to adapt itself to the diaphragm, while the intermediate surface is full and rounded, to fill the hollow space comprised within the ribs. In birds, however, it is far otherwise. The lungs are small, oblong, fleshy bodies, situated close up against the spine, where it is quite immoveable. Such bodies, it is evident, would never answer for the abundant respiration required by animals so rapid, impetuous, and incessant in motion. They are, therefore, connected with large thin sacs made of a very fine transparent membrane, which penetrating, not only into the chest and abdomen, but beneath the skin into the cavities of the bones, and even into the tubes of the feathers, at once serve to render the animal light and buoyant, and afford most extensive surfaces upon which the blood may be exposed to the influence of the air. It is evident that a diaphragm could not have the same effect in filling these cells with air, as it exercises over the lungs of mammalia. The consequence is, that as it could not be of use, it does not exist. Perhaps it will be more proper to say that a thin membranous partition, occupying its place, is to be found over the lungs of birds, but in general it has so few muscular fibres, that it can scarcely be considered as having any power of contraction, or exercising any influence over respiration. In the ostrich, however, and the cassowary, birds that never fly, these fibres become distinct muscles, attached along the ribs, and ascending towards the lungs, the inferior surface of which they border by a large firm membrane, in which they terminate, and which forms a continuous vaulted connexion, approaching so nearly the nature and appearance of a diaphragm, as to form an evident link between the respiratory systems of aerial and terrestrial creatures. This fact, for which we are principally indebted to the researches of the old Parisian dissectors, is exactly what sound reasoning would have led us to conclude respecting animals, which by structure belong to one of these classes, while by habit they are more allied to the other. Birds being thus deprived of the diaphragm, at least as an efficient organ of inspiration, we must consider how its place is supplied. And in examining the bony walls of the chest of birds, we perceive that the separate vertebræ of the spine, which in our backs are so pliant and flexible, readily yielding to every motion, no longer retain this property, but are bound together by firm lateral ligaments, so as to be perfectly stiff and immoveable; sometimes even the spinous processes growing completely together in the form of a ridge, so as to convert the vertebræ into a single bone. Now, as muscles are only given for motion, they would be of no use here, and every one knows how completely bare of *flesh* is the back of a bird. The reason of this inflexibility is next to be sought, and it readily occurs, that as motion, to be effectual, must be made from a resisting point, and as the motions of the wings in flight are extremely powerful, it was necessary that the spine which is placed between them should possess this quality. Were any confirmation of this idea requisite, it is to be found in such birds as do not fly, in whom the spine still continues moveable.



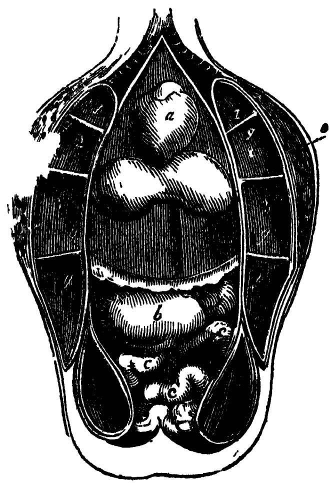
Skeleton of Bird.

The right wing has been cut away, in order that the direction and joining of the ribs may be seen.

Equally remarkable changes are to be found in the ribs, which the preceding sketch will assist us in understanding more clearly. We have already mentioned that the ribs in our chest do not pass completely round from the spine to the breast-bone, but are connected in front with the latter by means of elastic slips of cartilage, and we have had occasion to remark some of the advantages derived from this elasticity. But did the same provision exist in the eagle, which cleaves its way through the air with such rapidity as to disappear from our view, in a clear atmosphere, in less than three minutes, or darts from the cliff with the rapidity of lightning to seize its prey that our eye can scarce distinguish beneath; would there not be ar[illegible] [illegible] langer that the air removed with such immense velocit[illegible] would exert [illegible] a force as to press in the breast-bone, and [illegible] yielding cartilages on which it rested, and so impede or interrupt the function of respiration? To guard against the possibility of this, the cartilages are taken away, and their place supplied by solid bone. These bones, *a*, proceeding from the sternum, go to meet the ribs, *b*, arising from the spine, but not directly; they meet, as may be observed, at an angle, and at this angle is formed a joint. The openings of these angles all look towards the head. Between the bones pass, as in us, the intercostal muscles, and as their fixed point is above where the *furciform* bone (commonly known as the merrythought) and the large processes from the blade-bones run to join the breast-bone, s, it is evident the action of these muscles will be to draw the ribs forward. This will necessarily enlarge the angle at their joinings, in consequence of which their extremities must become more apart; therefore the interval between the breast-bone and spine will be increased, which, as the latter is immoveable, can only be done by thrusting down the former to the line indicated. But the breast-bone lies just around those large air-sacs which we have described as situated in the chest and abdomen, therefore, when it is depressed, pressure is taken off these, room is given, and fresh air must rush in to fill it. In doing this it passes through the lungs, which are the only channel of communication between the wind-pipe and these cells.

Such is the mechanism of inspiration in birds. Expiration is still more simply performed, depending chiefly on the muscles of the belly, which being attached to the lower extremity of the breast-bone draw it up again towards the vertebral column, the intercostal muscles, at the same time, ceasing to act. Some slight assistance may also be derived from the elasticity of the lungs. The view given by the French dissectors, though now a century old, is one of the most accurate we have of these peculiarities of the respiratory vstem · birds.

John Hunter was of opinion that th· rincipal use of ·he air-cells was to serve as reserv·irs of ai· ·de that there should be the less frequent necessity for respiration during · flight, when it might well be supposed to be accompanied ·me difficulty. He also though it might be the means ·· ·tting such vast continuance f song as birds can pour



Lungs and Air-Cells of Ostrich.

t, the wind-pipe; e e, the fleshy lungs; 1, 2, 3, the large air-cells, into which the air passes through the holes, g g g; a, the heart; b, the stomach; c, the intestines; all enclosed in, or surrounded by, air-cells.

out without an interval for breathing. The same structure is to be found in reptiles, and in them certainly respiration is very rare and unfrequent. The idea also of its giving lightness, in consequence of the air in these cells being rarefied by the heat of the body, has been suggested. The swimming-bladder of the fish is much more obviously for this purpose.

It would appear that birds have the power, by closing the glottis, of forcing air into those cells, and swelling out the parts in which they lie. This is more evident when the cells are placed immediately under the skin, and is generally a mark of passion, as appears clearly in the turkey-cock, the pouting pigeon, &c. It is extremely visible in the breast of a goose when she cackles. To show the universal communication of these cells, John Hunter succeeded in making birds breathe through an opening in the thigh-bone, the shoulder-bone, and the cells of the belly, after he had completely tied up the wind-pipe. These singular experiments will be found recorded in vol. LXIV. of the *Philosophical Transactions*.

Birds, we thus see, breathe principally by the assistance of their ribs; beasts by the diaphragm; but when we descend still further, and come to examine certain reptiles, of the frog and tortoise kind, we find that they have neither diaphragm nor ribs, or have the latter so short or so firmly fixed as to be of no use in enlarging the cavity of the chest: how then do they breathe? They *swallow* air.

A frog, when it wishes to make an inspiration, first shuts its mouth. It then, by the action of the muscles of its throat, causes a vacuum in this part, to fill which air immediately enters through the nostrils. Having gotten the air thus far, holding its mouth still closed, it proceeds to prevent its return through the nostrils by means of a valve, as Cuvier says, or, as this valve has never been clearly made out, by the back of its tongue, as Cloquet suggests. At the same time it contracts the muscles around the passage of the stomach, and then presses on the air, which is necessarily driven down to the lungs through the wind-pipe, the only course now open to it.

These lungs are composed of a number of large air-cells, and run down into the belly of the animal, by the muscles of which they can be completely emptied of air. It has been said this power is of use to frogs when they dive, as it enables them to diminish their bulk, and increase their specific gravity. The action of the abdominal muscles on the lungs is at once evident, when we open a living frog, by removing these muscles, for then the air-cells swell up, and remain permanently dilated, the animal having no longer the power to empty them. This also shows that the elasticity of the lungs in frogs is very weak. From the mode of inspiration above described, it is evident that, to smother a frog, nothing more is necessary than to keep its mouth constantly open.

In the other orders of reptiles, the lizard and serpent kind, respiration approaches more to that of birds, being chiefly performed by the ribs and muscles of the belly. In lizards particularly, the ribs are composed of two parts, united at an angle, exactly as occurs in birds, and it is by the opening of this angle that the chest is enlarged. Of this order is the chamæleon, the lungs of which are so extensive, that when they are filled, the body of the animal appears transparent. It was from this that the ancients fabled this animal to live on air: we now know that it is an expert insect-catcher, and has a tongue admirably adapted for the purpose. Its faculty of changing colour seems also connected with this organization, and we can readily conceive the variety of shades according as the animal is more or less inflated, sends its blood in greater or less quantity to the surface, or has that blood more or less perfectly coloured. For respiration in these animals is by no means so necessary, or so equally performed, as in birds and mammalia. They appear to have it more under the control of the will; they can abstain from it for a considerable time, which, however, seems to be influenced by external circumstances, such as temperature. The most remarkable instance of this is the torpidity, or *hybernation* as it is called, of these animals during the cold season of winter, when they may be seen to lie for an hour together, without making a single inspiration, their heart, meanwhile, scarcely beating, their senses all buried in deep sleep, and their state differing but little from death. No sooner, however, does spring with its genial warmth return, than they acknowledge its vivifying influence, and emerge from their holes and caverns till again warned to return by the chill autumnal blast.

Another remarkable fact connected with this class of animals is, that some of them undergo *metamorphoses*, representing, at the commencement of their lives, animals inferior to themselves in the scale, and appearing only to arrive by degrees at their full and proper developement. Thus a frog, in its tadpole state, is an aquatic animal—a fish; and like fishes, it has a tail and breathes *by gills*. This species of respiration we shall explain below. After, however, passing some time in this state, its tail disappears, its gills are absorbed, lungs are developed, limbs spring from its formerly smooth body, it leaves the water and comes on land, it is no longer aquatic but terrestrial, no longer a fish but a reptile. During these transformations, corresponding changes are going on within, and it is a beautiful instance of prospective design, to observe how the little branches, apparently useless, that spring from the trunks going to the gills, gradually enlarging, draw off the blood more and more from the circumference towards the centre, till at last, when the gills have finally disappeared, all the blood which used to go to them is found to have passed into these new channels, which united together, constitute the great aorta, or trunk, for the nourishment of the whole body. The influence of external circumstances in retarding or accelerating this change is extremely curious. By a well-conducted set of experiments, M. Edwards showed that it was hastened by nourishment, heat, light, and the free access of atmospheric air; on the contrary, it was delayed by cold, as tadpoles, born late in summer, are not transformed until next summer or spring; also, tadpoles placed in a box, to which the water had free access, and sunk some feet in the Seine, never became frogs, but grew into gigantic tadpoles ; while others, taken at the same time, and placed in vessels supplied daily with the same water, had undergone their proper changes. The only wants, in the former case, were light and atmospheric air, the deprivation of which was, therefore, concluded to have produced such effects. Now the proteus, an animal of the frog kind, presents the strange anomaly of having both lungs and gills ; the former, however, so imperfectly developed, that it is obliged to continue an aquatic animal all its life. It inhabits the subterraneous waters of Carniola, and to this situation, where it must be scantily supplied with light and air, have many naturalists attributed its organization, which they look on to be the result of an imperfect metamorphosis, something after the manner of M. Edwards' tadpoles. Still more singular is the fact lately mentioned, that several poor wretches having sought an asylum in the *dark* and *close* vaults beneath the fortifications of Lisle, and having continued to reside there for some time, the number of deformed and defective children born to them, had become out of all proportion great. The attention of the Board of Public Health was drawn to it, and an order issued for the closing these receptacles, and for the future, preventing their being used as habitations.

In the two first classes of animals, all the blood that is sent to all parts of the body has previously been submitted to the action of air ; and for this purpose, as we have before shown, they are provided with a double heart, the one side charged with sending the blood through the lungs, the other with distributing the blood thus purified to the body. But in reptiles this is not the case. The aërated blood certainly enters a separate auricle from the blood which returns from the body, but both these auricles discharge themselves into a common ventricle, so that the two bloods are here mixed, and sent out in this state to the body. Now the degree of admixture is by no means the same through the whole class, which causes much greater difference between animals belonging to this class than can occur between animals belonging to the class Mamma-

[illegible]. The degree of mixture will evidently be measured by the size of the artery going to the lungs as compared with the common trunk. In frogs this is extremely small; it is larger respectively, in tortoises and lizards, which therefore rise above it in the animal scale. The labours of M. Geoffroy St. Hilaire have demonstrated that the crocodile, which ranks at the top of this class, and approaches nearest the Mammalia, has actually a double heart, with its ventricles perfect and distinct. No mixture, therefore, can take place here, but it is accomplished by means of a vessel which arises from the right ventricle close to the artery of the lungs, and bending over, unites itself with the great vessel from the left ventricle, so that the body is still supplied with a mixed stream. It is well worthy of observation, that before this union takes place, two vessels are sent off to supply the head and neck, so these parts alone receive *pure* arterial blood; to the rest of the body it is sent mixed.

In the attempts to trace an unbroken chain amongst animated beings, the crocodile clearly formed the link by which mammalia descend to reptiles. The proteus also afforded a sufficiently natural step from reptiles to fishes. In this class, lungs no longer exist; for, as they are destined to inhabit the great deep, they must be for a considerable part of their lives so circumstanced, as to render it impossible they should breathe by inspiration and expiration. As, however, it is necessary that their blood should be brought in contact with oxygen in a loose state of combination, atmospheric air is held, as it were, dissolved in the water in considerable quantities. The constant agitation from currents, tides, or storms, is amongst the means by which this mixture is effected; and thus we observe a reciprocal action between these two great *media*, in which animals live,—the air, agitating the water, is probably one of the means by which it is saved from growing corrupted, while the water, absorbing the air, is by it rendered fit for the habitation of aquatic animals. Well might the inspired writer say, "All things work together for good."

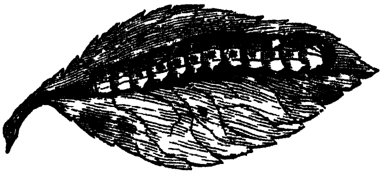
It would evidently be inconvenient, that a constant current of water should be passing in and out of the body; and to avoid the necessity for this, *the gills*, which in fishes perform the part of lungs, are placed externally. They may be described as consisting, in the bony fishes, such as cod, salmon, &c., of four arched bones, placed in succession close behind the mouth of the animal on each side, and covered by a lid called operculum. On these arched bones or branchial ribs, as they are called, from their appearance and office*, are spread out several fine laminæ, or thin membranous folds, in which the artery bringing the blood from the heart, spreads itself out into very numerous and beautiful ramifications of extreme minuteness. Situated on the neck, they communicate by their base with the mouth, of which, in fact, they may be said to form the posterior and lateral boundary. The operculum is moveable at pleasure by muscles which are attached to it. When, therefore, a fish wishes to respire, it takes a mouthful of water, and passing it to the back of its mouth, suffers it to remain there a moment in contact with its gills, through which, at the same time, the blood is freely passing. When the water, or rather the air which it contains, has acted properly on the blood, an action which, as we have before explained, is not prevented by the very fine moist membrane which divides them, the fish lifts its operculum and causes the water to be discharged backwards. The blood being thus aërated is again collected from very fine branches into trunks, which running from each of the branchial ribs, finally unite and form the aorta for conveying the blood to the whole body. From this, the blood is returned by the veins to a simple auricle, thence it passes into a single ventricle, which in turn drives it into the *branchial* artery, and so back to the gills again. The circulation, we thus see, is quite simple. From what we have said of the mode of respiration, it is clear that a trout, before it attempts to breathe, must turn its head up

* Because they support the *branchiæ* or gills proper.

against the stream. Were it to attempt this operation facing down the stream, it would in vain try to let out the water from its gills, for as soon as it had lifted its *operculum*, the current would pour in water from behind, in place of suffering it to discharge what was there. It therefore becomes part of the angler's art, to keep the head of the trout he has hooked down the stream, in which situation it cannot attempt to breathe, and is therefore the sooner exhausted.

There is found in many fishes a bladder filled with air, and placed in the upper part of the abdomen close against the spine, which has therefore been conceived to be in some manner subservient to the function of respiration. It seems, however, more probable, that it is rather destined to assist the animal's motions; and this idea is strengthened by the fact of the swimming-bladder being most considerable in such fishes as move with great velocity. It is wanting in flat-fish, where, however, the large lateral fins supply its place; also in the lamprey, which, in consequence, moves but slowly along the bottom of the water. Its situation in the upper part of the back, is exactly on the same principle that a bird's muscles are placed on the breast, to prevent the animal overturning, as it would do, were a heavier part above. The air contained in this bladder is generally found rich in nitrogen; in sea-fish Blumenbach says it contains carbonic acid. It is, in both cases, secreted, and there is generally a vascular and glandular body situated in the cavity, which is probably the secreting organ. The bladder sometimes communicates with the stomach, sometimes with the gullet, but is, also, at times, quite closed and isolated.

In the aquatic *mollusca*, as the oyster; and the *crustacea*, such as the crab, lobster, &c., respiration takes place by gills. In terrestrial *mollusca*, the snail, there is a cavity, the sides of which are a thin moist membrane, upon which the vessels ramify; and in this manner their blood is exposed to the air. Insects have their bodies penetrated in all directions by *tracheæ*, or air-tubes, which convey air into the most internal parts. The two principal tubes lie one on each side, running the whole length of the body, and are supplied from small external openings, termed *stigmata*, nine in number, which may readily be seen, as figured on the sides of the common caterpillar.



Still lower in the zoophytes, or radiated animals, almost all distinction of organs seems lost. They breathe as well as digest by the common integument, which outside is a skin and inside a stomach.

We have thus run through the scale of animals, very imperfectly, we admit, and observed various mechanisms and contrivances, by which the blood is brought under the action of atmospheric air. We are now to consider the results of this approximation; in other words, the changes that it produces in the air and the blood. And first, as being the easiest investigated, of the air.

The quantity of air taken in at each inspiration, as also the total quantity which the lungs can contain, have been stated in such various manners, as to show there is little certainty yet arrived at. The former has been estimated at all intermediate numbers from ten to twelve up to fifty cubic inches; on the latter, opinions and experiments have been equally discordant. Without attempting, then, the hopeless task of reconciling or accounting for these differences, we shall, with Dr. Bostock, adopt that founded on the very intelligible experiments of Menzies. He breathed into a bladder, of which he had previously ascertained the capacity, until it was filled, and found that aach expiration was somewhat more than forty cubic inches: he confirmed this result, by attaching his tube to a second bladder filled with air, from which he inspired, and found, in like manner, that the amount of each inspiration corresponded nearly with his previous estimate of a single expiration. He then immersed a man over his chest in a vessel of warm water, and measuring the rise and fall of the water, had the satisfaction to find that it corresponded with his former experiments, and those of Jurin, affording for each natural inspiration an average bulk of forty inches. As we can, after a natural expiration, force out a further quantity of air by voluntary exertion, this was next measured, and calculated at about 170 cubic inches; but still the lungs are far from empty, for they can never fully collapse, unless the sides of the chest were opened, and the weight of the atmosphere allowed to act on their surface. By this means about 120 cubic inches more might be obtained. The whole contents of the lungs in a tranquil state will, therefore, amount to 290 cubic inches, to which forty being added at each inspiration, will give 330 cubic inches as their contents in a moderate state of distension. The forty inches changed at each inspiration will, therefore, be about one-eighth of the air contained in the lungs, which, therefore, after eight respirations, would be entirely renewed. But about twenty respirations are made in a minute, so that in that time there passes through the lungs a volume of air equal to two and three quarters, or nearly three times their full contents. The quantity of air then consumed by an individual in twenty-four hours will amount to 1,152,000 cubic inches, or 666 cubic feet; a fact of the utmost importance to remember in building and furnishing with beds, hospitals, barracks, prisons, or other places, where many human beings are to assemble together. For the air which has once been respired is not again fit for that process, until it has been purified in the great laboratory of nature.

And the reason of this is, that a change has taken place in its composition; and if examined, after being once inspired, it will be found to contain more carbonic acid and less oxygen than before, the nitrogen remaining nearly, though not altogether, in its original quantity. Thus, of the forty cubic inches of air we take in, about thirty-one or thirty-two are nitrogen, and nine or eight oxygen. The quantity of carbonic acid is scarcely noticeable. But of the forty cubic inches that we expire, not more than six will be oxygen, the place of those which have disappeared being occupied by an equal quantity of carbonic acid, which now would, therefore, amount to two or three cubic inches. The air is thus rendered improper for respiration in two ways; by the removal of what was useful, oxygen; and the addition of what was deleterious, carbonic acid. Now, were this same air breathed over again, it is evident it would become still more deteriorated, and so on of a third and fourth respiration, till it became quite unfit to sustain life. This is what occurs in a diving-bell, when any accident happens to the tubes, by which a fresh supply of air is sent down. The people are found suffocated below, in consequence of having nothing to breathe but the air which they themselves had rendered impure; drowning is never the danger to be apprehended, as long as the sides of the vessel are of sufficient strength*.

Whether the quantity of carbonic acid produced, exactly equalled that of oxygen consumed, was long a debated question. Experiments, made apparently with the greatest accuracy, gave opposite results; and while M. Lavoisier, Seguin, and Sir Humphry Davy maintained that more oxygen was consumed than carbonic acid formed, the surplus being, as they supposed, absorbed into the system, or used in making watery vapour, Messrs. Allen and Pepys, Mr. Ellis, Magendie, and other chemists and physiologists believed that the quantities of each exactly corresponded. It was reserved for M. Edwards to reconcile this apparent discrepancy, which he did most satisfactorily, by showing that the proportions varied according to the species of animal experimented on, the season of the

[* Dr. Ure says that an average-sized man exhales 1632 cubic inches of carbonic acid gas per hour; and, that 800 cubic inches of the same gas is generated by the combustion of a single wax candle during the same period.]

year, time of day, and other external circumstances, which had been neglected as non-essential. Attending to these matters, he was able to show that considerable fluctuations took place in the quantity of oxygen consumed, there being at times even one-third more than the volume of carbonic acid formed, while at other times the surplus was scarcely observable.

Differences have also existed as to the use of the nitrogen, which occurs so abundantly in atmospheric air. Formerly it was considered merely as a harmless means of diluting the oxygen, which, if pure, would be too stimulating to be long respired. It is now, however, allowed to have not only this negative, but a direct positive use, as M. Edwards has shown it to be absorbed into the circulation, and again exhaled from it. The relative proportions in which it is absorbed and exhaled vary with the seasons, in consequence of which respiration is found to increase the quantity of nitrogen during spring and summer, but to diminish it in autumn and winter.

But air which has undergone the process of respiration, is also found to contain a certain quantity of watery vapour, the existence of which is rendered particularly evident in frosty weather, when the external cold condenses this moisture, so as to make it visible. A considerable portion of this water comes, not from the lungs, but from the mouth, top of the throat, &c.; for Magendie observes, that in an individual who had an opening in the upper part of the wind-pipe, the air which was expired through this opening, contained scarcely any vapour. By the older physiologists, however, it was all considered as coming from the lungs, and connecting this with the fact above mentioned, that in general more oxygen is consumed than carbonic acid produced, they framed a very ingenious theory how that the blood in the lungs got rid of two principles, carbon and hydrogen, which meeting with the oxygen of the atmospheric air, immediately formed two new compounds, the carbon forming carbonic acid, and the hydrogen forming water, which consequently were to be found in the air after expiration.

But before proceeding to consider this theory, we must speak of the changes which the blood does undergo in passing through the lungs. These, though they have attracted much attention, and caused much dispute, are, we regret to say, but imperfectly known. If we open an animal alive, we perceive the blood, at the right side of the heart, of a dark-red colour, while that at the left is a bright scarlet. The former is the venous blood, just returned from the body, and mixed with chyle; the latter is the arterial blood, preparing to set out again on its course. But in passing from the right to the left side of the heart, the blood has merely gone through the lungs. It is, therefore, in them that the change has occurred. If, however, we now prevent the entrance of air into the lungs, the change no longer takes place; the blood pours into the left side as dark as it was in the right, and soon ceases to move. The samė alteration of colour can be produced out of the body, by exposing the blood to atmospheric air, whence we conclude that it depends on this as its cause; and as oxygen produces the change in a still higher degree, and no other gas will produce it at all, the inference seems fair that the oxygen of the atmosphere is the cause of the scarlet colour of arterial blood. Dr. Stevens's experiments would seem to show that the presence of some saline matter was necessary to enable the oxygen to act; he has, however, totally failed in proving that the saline matter is, of itself, capable of producing the change of colour, and subsequent experiments by Dr. William Gregory have fully disproved the possibility of such an occurrence.

The other differences are stated to be, that more fibrin occurs in arterial blood, which, therefore, coagulates more quickly than venous. The latter is richer in carbon; but this is rather inferred from its giving off carbon or carbonic acid in the lungs, than from actual analysis. In like manner it is said to contain more water,—more albumen, to have a greater specific gravity, a less capacity for caloric, and less actual heat, as shown by the thermometer.

It will at once appear, that these few and unimportant differences are totally inadequate to account for the remarkable variety, in physiological character, that these two fluids present. Nor does a little more or a little less carbon, a shade in colour, a degree in temperature, a trifle in weight, assist us in accounting for the fact, that one of these fluids, sent to the brain, nourishes, stimulates, strengthens, and enables it to direct the whole system; while the afflux of the other would produce delirium, torpor, death. Is it not clear that there is some influential power that eludes all our researches, that defies alike the chemical investigator and the microscopic observer; in short, *a vital principle*, with which we can only become acquainted by observing its effects?

We have thus the principal *facts* of respiration before us; and to account for these, two theories have been imagined. The first, which is only a modification of Priestley's, and which we mentioned before, supposes a direct combination to take place in the lungs between the oxygen of the atmospheric air, and hydrogen and carbon thrown off from the venous blood. This has the merit of being extremely simple, and of showing at once how the carbonic acid and watery vapour might be formed; but, unfortunately, it is deficient in facts, there being no proof that hydrogen and carbon are secreted or given off in the lungs from the blood; and further, it is irreconcileable with the experiments of Messrs. Allen and Pepys, in which the whole oxygen was not more than sufficient for the carbonic acid produced, yet the watery vapour continued to be formed as usual. The second was originally proposed by La Grange, and supported by Hassenfratz, but owes its principal celebrity and authority to the experiments of M. Edwards. According to it, the carbonic acid is formed gradually through the whole course of the circulation, and given off by the venous blood in the lungs; at the same time the blood absorbs oxygen, becomes red and stimulating, properties which it gradually loses as it gets into the smaller arteries, until at last, in the fine capillary vessels, no distinction can be made between the fluid in the last arterial and first venous tubes. This theory is the more probable of the two, and is at present most generally adopted; yet it would not be difficult to raise objections, as, for instance, How can it be reconciled with the result of Mr. Brande's and Sir Charles Scudamore's experiments, which seem to show an equal quantity of carbonic acid in arterial as in venous blood?

Connected with this, is the interesting question of the generation of Animal Heat.

Living bodies are endowed with a faculty, by means of which they are enabled to resist changes of temperature. The term, animal heat, as applied to the result of this property, is evidently erroneous, 1st., because the power is common to all living beings, plants as well as animals: 2nd., because it seems to operate, at times, rather as a principle of coolness than of heat; for instance, when Dr. Fordyce, in air of 140° Fahrenheit, found his body still at the usual temperature of 98° to 100°. On this, however, we shall not insist, as the experiments of M. de la Roche would lead to the conclusion, that the transpiration from the lungs and perspiration from the skin are, in such cases, so abundant as to account for the lower temperature at which the body remains. We shall rather consider the more usual exercise of this property, in maintaining the body at a temperature above that of the atmosphere. Of all animals, birds are the best provided in this respect, their heat varying from 105° to 110° Fahrenheit; next come quadrupeds, at about 100° or 101°; and after them men, averaging 96° to 98°. As all these degrees are considerably above the ordinary temperature of our climate, these animals have been classed together under the name of *warm-blooded* animals. If, on the contrary, we examine the body of a reptile, of a fish, and of most of the invertebrate tribes, we shall find their temperature very nearly that of the external air, or only exceeding it by about two degrees. Thus Broussonet remarks, that the temperature of a fish is about three-quarters to one-half a degree (Réaumur) higher than the medium in which it is immersed; Despretz found a carp 53° when the water was 51°.4 Fahrenheit; and every one knows the proverbial coldness of a frog. These, therefore, as contradistinguished from the others, form the second great class, or the *cold-blooded* animals. Physiologists were not long in observing, as connected with this difference of temperature, a corresponding difference in the perfection and energy with which the function of respiration was carried on. We have already described the very extensive apparatus provided for this purpose in birds, who breathe with so much rapidity that Lavoisier found two sparrows to consume as much air as a Guinea-pig. But something more is necessary, for heat has a tendency, wherever generated, to diffuse itself amongst surrounding objects until an equilibrium is established. The only means of preventing this, is by enveloping the source of heat with certain bodies which it is ascertained have a very imperfect power of conducting it. On this principle we cover our own bodies with blankets in winter, because they prevent the rapid communication of the heat generated within us, to the air or the objects around us; exactly on the same principle, in summer, we place blankets around our ice-houses, to prevent the external heat penetrating to them and thawing their contents. Now, amongst the most perfect non-conductors of heat that we know, are feathers and fur; with the former of which birds, with the latter of which the mammalia, are generally covered; we therefore see why they both exceed us in heat, and why we are obliged to imitate, by artificial clothing, a provision with which nature has already endowed them. In the case of birds, which soaring to such great heights are necessarily exposed to the most piercing cold, this provision is peculiarly admirable; and the use of it was practically illustrated by the falconers, who, when training a young hawk, always plucked the down from his breast, well knowing that, while thus exposed, he would never venture a flight to such an elevation as would be beyond their ken and call. In aquatic birds, which, spending their lives on the water, are thus constantly exposed to a medium most powerful in abstracting heat, how beautiful and close is the plumage, how soft and impenetrable the down, particularly on the breast and belly, the parts nearest the wave! So also the animals that inhabit the arctic regions: the ermine, the Siberian squirrel, the polar bear, present the finest, closest, and most valuable furs. But all these are means of keeping in heat, and not of generating it; they, therefore, infer that some such power as the latter exists in the bodies to which they belong: in all these bodies respiration is an energetic function; the question then was obvious—Does not animal heat depend on respiration?

And looking at another great division of animals (the cold-blooded), the conclusion would appear strengthened. In the reptiles respiration is incomplete, the structure of their lungs is less perfect, the number of inhalations less frequent, and only a portion of their blood is submitted to the action of the air. In fishes, the quantity of air to which the blood can be exposed is small, being merely that which is dissolved in the water. In both these the temperature is low, little exceeding that of the media in which they live. Cold, therefore, readily affects them, and this is particularly observable in the reptiles, which are scarcely to be found, few in number and diminutive in size, towards the arctic circle; while between the tropics they are of such size, abundance, and variety, as to afford a ready key to the old Egyptian fable, which supposed the crocodile to be engendered by the heat of the sun.

Insects, it is well known, die in these countries at the approach of winter, having first laid their eggs, which remain in the larva state till brought forward by the heat of the succeeding spring. It is, therefore, evident that for them the cold has the same terrors as for the reptiles, and in them also respiration is imperfectly performed*.

So far there seemed a fair connexion between the intensity of respiration and the generation of animal heat, so that, in direct contradiction to the old philosophers, who held that

* Insects, however, which live in society, such as bees, and ants, develope very considerable heat. A thermometer placed, during the winter, in a bee-hive, will constantly show from 96° to 99° Fahrenheit, and when we excite the insects, their respiration, it is said, becoming more rapid, the heat rises.

respiration was used to cool the blood, it was now decided that respiration was a means to heat it.

Dr. Black was one of the first who reduced these vague ideas to something of a definite theory, and his explanation, as modified by Crawford, is held by the chemical school of physiologists to this day. He found that when carbon was burned in air oxygen disappeared, carbonic acid was formed, and heat evolved. This is exactly what takes place in respiration. The conclusion is clear: respiration is a species of combustion; hence the more energetic the respiration, the greater the quantity of heat evolved. This was simple, at the same time so ingenious, that it readily was adopted by a great number of converts; an objection, however, was made to it, which even to Black himself appeared difficult to be got over. It was this; if the heat of the whole body be derived from the lungs as a focus, and caused by a sort of combustion taking place in them, their temperature must be superior to that of all other organs, in fact so high, that we cannot suppose their structure capable of bearing it. The reply to this objection, and the perfect elucidation of the theory, were reserved for Crawford; and even those who hesitate as to the accuracy of his facts, and do not admit his hypothesis, unanimously declare it to be a most beautiful and ingenious application of physical and chemical reasoning to explain a problem of the animal economy.

We shall endeavour to explain it to the general reader. If a piece of sponge and a piece of bread, of the same size, be each dipped into a cup containing water, the sponge will take up more water than the bread. In such case, we would say the sponge had a greater *capacity* for water than the bread. Let us say that the sponge took up an ounce, and the bread only half an ounce of water, and that, to the eye, they looked equally *wet*, the capacity of the sponge for water would then be pronounced to be double the capacity of bread.

Now if, by any possibility, the sponge could be changed into bread, it is evident that it would give out half an ounce of water, and look as wet as before; or if the bread were changed into sponge, it could take up an additional half-ounce without appearing to have increased in wetness.

As bodies are thus shown to have a different capacity for water, so also bodies may have a different capacity for heat; and in this case we measure, not by the eye, but by the thermometer. Thus, if a pint of mercury and a pint of water, in each of which a thermometer immersed will show 60°, are placed in a stove for a short time, and when withdrawn, the mercury raises the thermometer to 100°, while the water only raises it to 80°, it is evident that the same quantity of heat which raises mercury 40°, raises water only 20°, therefore mercury has a greater capacity for heat than water in the proportion of 40 to 20, that is, as 2 to 1. If, then, the water at 80° were suddenly converted into mercury, it is evident that it could give out 20° of heat, and still continue to show 80° on the thermometer, for by the terms of the experiment it received as much heat as would raise mercury 20° above 80°; while if the mercury at 100° were converted into water, it should either at once fall to 80°, or, if heat were in its vicinity, absorb a quantity sufficient to maintain it at its high temperature*.

Now this difference in the capacity for heat, Dr. Crawford showed by experiment to exist between arterial and venous blood, the former exceeding the latter, in that respect, in about the proportion of 114·5 to 100, or about 11½ to 10. When, therefore, venous blood was converted into arterial, which took place in the lungs, it was able to take up an additional quantity of heat without *appearing* hotter, as the bread, if converted into sponge, would take up an additional quantity of water without *appearing* wetter. And again, when the arterial blood became converted into venous, which takes place in the extreme vessels in all parts of the body, it gives out this heat in the same way that water would if converted into mercury, and thus maintains the temperature of the whole body. We

* In this explanation we have confined our attention to the quantities of heat employed in the experiment as being all that was necessary for our object. We should merely have perplexed the general reader, whom it is always our object to take along with us, had we entered more at length into the question of "specific caloric."

thus see how a great heat may be generated in the lungs without injuring their structure, because at the moment of its production it is absorbed and rendered latent in the arterial blood, and how this arterial blood conveys this heat to every part, and distributes it to all in their due proportion. There remains but one thing, which is to show that heat *is* generated in the lungs, and on this Dr. Crawford made numerous and satisfactory experiments. He showed that the quantity of heat evolved by an animal during the production of a certain quantity of carbonic acid by the process of respiration, was nearly the same as that gained during the production of an equal quantity by the direct combustion of carbon in oxygen. He showed that heat was evolved, not only during combustion, but during putrefaction, fermentation, germination, and all those processes by which carbonic acid is produced. It was then fairly inferred that heat must also be evolved in respiration. This heat is consumed in three ways: 1st. The cold air taken into the lungs must be warmed up to the temperature of the body; 2nd. the watery matter secreted in the air-passages must be converted into vapour, in which form it is exhaled; and 3rd. the increased capacity which the fresh-made arterial blood has for heat, must be saturated. The whole theory, then, would run thus. The dark venous blood is loaded with a quantity of carbon, which is thrown into it in its course by all parts of the body. Arrived at the lungs it exposes this carbon through the medium of a very fine membrane to the oxygen of the atmospheric air, and in consequence of the attraction subsisting between these bodies, they unite and form carbonic acid. The result is the giving out of heat, and its instant absorption by the arterial blood, which, with its carbon, has lost its dark colour, and, in consequence of the change, requires an additional supply of heat. The mode in which this heat is applied to use, we have explained above.

Chemists, and chemical physiologists, still use this theory, with a few modifications, chiefly suggested by the experiments of M. Edwards, on animals whom he caused for a time to breathe an air deprived of oxygen. He found that they still gave out carbonic acid, and in some cases the quantity given out exceeded the whole bulk of the animal, so that there was no possibility of attributing it to the oxygen of any air it might have carried into its lungs. It is evident, therefore, that carbonic acid, not carbon, is what the venous blood gives off in the lungs; and from other experiments of the same ingenious and talented gentleman, it is concluded that the air taken in respiration is absorbed into the blood, that in the minute vessels meeting with carbon, carbonic acid is formed, and thus heat generated at the point where it is wanted, not generated in the lungs and conveyed to that point; that this carbonic acid darkens the blood, a power which it can be shown to have by experiment, and finally, being conveyed to the lungs, is there thrown off, and a fresh supply of air imbibed. It is not so clearly ascertained what becomes of the nitrogen of the air, but it seems probable, that being taken into the blood it is applied to the uses of the system, while other nitrogen, which had been so applied, and is now unfit for longer stay in the system, is returned into the blood, and discharged by it from the lungs.

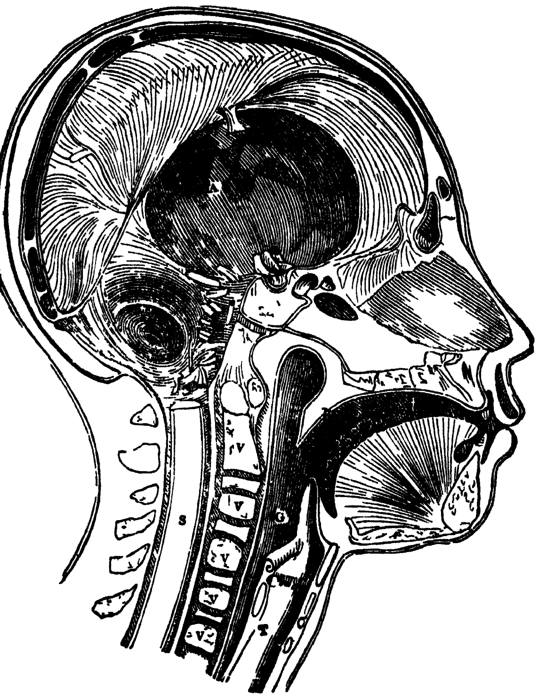
We have dwelt so much on this theory, which besides, with the modifications described, is adopted by such men as Bostock, Elliotson, and Turner, that we shall be more brief with the other opinions advanced.

Dr. John Davy endeavoured, by a well-conducted set of experiments, to be found in the *Philosophical Transactions* for 1814, to show that the difference in capacity for heat between venous and arterial blood, on which so much of Dr. Crawford's theory turned, had no real existence. In consequence of the subsequent views which we have stated, this question is now of no importance; for as it appears the carbonic acid is not formed in the lungs, of course the heat is not evolved there, consequently there is no necessity for increased capacity to carry it off. This would seem a confirmation, however, of the accuracy of Dr. Davy's experiments, as if the capacity were really greater, the temperature of the arterial blood should be lower than that of venous, which is not the case, the thermometer at the left side of the heart generally standing a degree or two higher than at the right.

By some curious experiments published in the *Philosophical Transactions* for 1811 and 1812, Sir Benjamin Brodie endeavoured to show that the whole theory was erroneous, and that animal heat was solely dependent on nervous influence, and had nothing whatever to do with respiration or arterialization. The action of certain poisons appears wholly exerted on the nervous system; of this kind are the woorara and prussic acid. If, while an animal is under their influence, respiration be artificially kept up, the blood will undergo its usual changes from venous to arterial, the air will be found loaded with carbonic acid, in short, all the *chemical* part of respiration will be gone through. Having killed, or rendered insensible, two rabbits by means of these poisons, Sir B. Brodie suffered one to lie untouched, while in the other he kept up respiration by means of an elastic gum-bottle, which alternately pumped air into the lungs and drew it out. This air, when examined, appeared to have undergone the usual changes, the blood had been reddened, the circulation continued, and carbonic acid formed, yet this rabbit had cooled down faster than the other. He repeated the experiment in different ways, sometimes destroying the nervous influence by dividing the spinal marrow, in place of by poison, but the results were always the same—the rabbit in which respiration was kept up, cooled faster than the rabbit which was let alone. The action of these poisons is temporary, and if life be thus artificially supported for some time, the brain seems gradually released from their influence, and the animal becomes as before. In such cases Sir Benjamin Brodie found that, exactly as the nervous influence became restored to the body, so did the heat return. Here, then, was an entirely new doctrine of Animal Heat. It was no longer connected with the generation of carbonic acid, but was directly under the government of the nervous system.

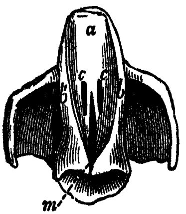
This, however, was not long suffered to pass undisputed. In addition to the arguments with which it was assailed by the chemists, followers of Crawford, it met more formidable opposition from the repetition of the same experiments with different results by Le Gallois in France, and Wilson Philip in England. They observed, what Sir Benjamin Brodie had neglected attending to, that during life respiration is always proportioned to the wants of the system by a sort of instinct; that, of course, this instinct being abolished, and the wants of the system much lessened by the low state of vitality to which the whole body was reduced by the temporary suspension of nervous power, the quantity of air introduced into the lungs should be considerably diminished, otherwise cold air was introduced into the interior of the animal, which it did not want, and which, therefore, did nothing but lower its temperature. When all these circumstances were duly allowed for, they found, in direct contradiction to Sir Benjamin Brodie, that the cooling of the body was actually delayed by the process of artificial inflation, though, in consequence of the diminished consumption of oxygen, it was not altogether prevented. M. le Gallois, therefore, reverted very nearly to the old chemical theory, considering the nerves as only acting indirectly, by producing a more perfect communication between the air and the blood; while Dr. Wilson Philip arrived at the conclusion that Animal Heat is a secretion. M. de Blainville sets it down as a simple result of nutrition, and Dr. Williams embraces very nearly the same views. All agree that it is, to a certain extent, influenced by the nervous system; but whether directly or indirectly is a point not yet decided. Dr. Marshall Hall found that, in hybernating animals, such as the bat, the temperature fell as the respiration became less frequent, and the carbonic acid formed less abundant; on the other hand, Sir B. Brodie, as we have seen, showed that as the nervous influence was restored, so exactly did the heat rise. For our parts, we find chemistry, electro-chemistry, and mechanics, alike unable to explain this phenomenon. We are contented to consider it as a property attached to life, more especially as it is to be noticed in plants and trees, where similar chemical changes do not occur, and similar nervous influence cannot be shown to exist. But in so doing we mean not to be considered as offering any explanation. When any one shows us what gravity is, otherwise than by an enumeration of its effects, we shall attempt to show what life is, in a similarly abstract manner. Meantime we must be content to describe it as the unknown cause of known properties. And perhaps that is nonsense, but we take the term from wiser men than we pretend to be.

But we must say something of the voice, that faculty by means of which we best express our feelings, affections, and sentiments; which, modified by the organs of speech, gives utterance to the hidden things of the heart, and alike enables the sage to communicate his wisdom and the fool to babble his folly. And here we have already made a distinction that will require to be attended to: the voice is one thing; it is common to us with beasts, whose cries will express pleasure, or pain, rage, sexual desire, or fondness; speech is another thing, and is the peculiar prerogative of man. It is true some animals, such as the jay, the parrot, &c., can articulate, but this is not to speak: speech is the expression of thought, and monkeys don't speak, says Lordat, because they have nothing to say. This simple observation, which is as philosophical as it is terse, might have saved a world of trouble to different anatomists, who spent much time in finding out, by peculiarities of structure in the organs of voice, why no animals spoke but man. Now anatomy is totally unable to resolve the question, inasmuch as several animals, who do not speak, can, nevertheless, articulate when taught to do so by man; it is evident, therefore, that their natural dumbness is not to be attributed to any organic cause. In fact, the organ of voice in man is extremely simple, being nothing more than a tube conveying air, near the top of which are placed two vibrating cords, the vibrations of which, communicated to the air, throw it into sonorous undulations, and thus voice is produced. Nor are the organs of speech very complicated, being chiefly the lips, teeth, tongue, and palate, all, it will be observed, situated beyond, or exterior to the place where the voice is produced, inasmuch as it is necessary to have voice before you can make words, as a carpenter must have timber before he can make a table. The relative situation and structure of those parts, will be easily understood by a reference to the subjoined plate copied from Sœmmering's *Icones*, in which T represents one side of the trachea or windpipe, bringing up the air from the lungs, here laid open



Vertical section of head and throat, from front to rear

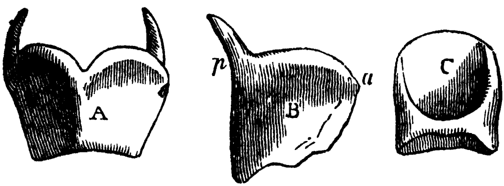
A, cavity for brain, S, spinal marrow, V, vertebræ or back bone, T, windpipe; G, gullet so as to display c, the fine cord or ligament stretched across near its upper extremity, and which, by its vibrations, produces voice, while beyond that are *p*, the palate, *t*, the tongue, with the teeth and lips, all, as we have said, engaged in the formation of speech. A more accurate idea of the situation of these vibrating cords, commonly called *chordæ vocales*, may be had from the following cut, in which they are represented as they would be seen by a person looking down the windpipe, from above, and able to descry their situation in the aperture.



In this cut *a* is the *epiglottis*, situated, as we have already learned, in front of the opening, and ready to shut down on it, so as to prevent the entrance of any foreign matter; from it we see two ligaments, *b b′*, prolonged backwards, so as to constitute, as it were, a sort of superior dilated orifice of the windpipe. The true opening of this we see deeper down, at *m*, and to this opening the name of *glottis* is given; while at either side of it are stretched *c c′*, the *chordæ vocales* or vibrating cords, on which the production of the voice depends; and above these we observe two little depressions or cavities, termed *ventricles of the larynx*, the object of which appears to be to leave room for the vibrating of the cords.

But we might be asked how we know that the voice is formed at the exact point which we term the *glottis*, and depends on the vibrations such as we have described. The questions are very fair, and we proceed to answer them. If an incision be made into any point of the windpipe, below that which we have indicated, the voice is immediately lost, but if the aperture be in any way stopped up, as by closing it with the hand, a pledget of lint, &c., the voice is restored. If, on the contrary, the incision is made above the *glottis*, the voice is in no way affected. This, we think, accurately determines the locality, inasmuch as, in the first experiment, the air is allowed to escape at a point lower down than the *glottis*, and no voice is produced; in the second, it is allowed to escape immediately after passing through the glottis, and then the voice is perfect. Of these facts we have ourselves been witness. For the second question we were satisfied with the general principles of the formation of sound, and the anatomical fitness of the parts to act in accordance with those principles; but M. Magendie has reduced the matter to an actual demonstration, for having made such an incision as the second we have described into the throat of a dog, he seized and drew forward to the mouth of the opening, the top of the windpipe, and, holding it there, was enabled to observe that, when the animal howled or cried, the production of sound was always accompanied by a tension of the glottis, while its edges (the cords of which we speak) vibrated in an evident manner. He further found, that he might cut the edges of the orifice of the windpipe, or even the tops of the small cartilages (the arytenoïd), by which it is supported at its hinder part, without sensibly affecting the power of producing sounds; but that as soon as he cut those ligaments the animal became mute, and the same effect was produced if he cut the nerves going to the small muscles by which these ligaments were moved.

From these experiments it seems beyond all doubt, that the voice is produced as we have described; but, not satisfied with knowing this much, physiologists insisted on knowing more, and, as they proceeded rather by the good old way of conjecture than the good new way of experiment, they soon became involved in a variety of conflicting opinions; some insisting that the human *larynx* was a wind instrument, like a flute, others that it was a stringed instrument, like a fiddle, and others, again, that it was a reed-instrument, like a flageolet or organ. For our parts, we think it is neither a flute, a fiddle, a flageolet, nor an organ, but a larynx; simply a larynx. But we must describe our larynx a little more perfectly to enable our readers to understand the cause of our opinion. The larynx, then, is placed like a box or case round the top part of the windpipe, to afford a firm, and in some measure resonant, fabric for the attachment of the parts immediately concerned in the production of voice. It is composed of three principal cartilages; the one like a ring, whence it is called *cricoïd**, surrounds the top of the windpipe, as if to give it a finish. This cartilage is much wider behind than before, or may be compared to a signet-ring, the seal part of which should be turned backwards. It forms the base of the larynx; and above it, in front, is placed the *thyroïd*† or shield-shaped cartilage, which is of considerable size, particularly in the neck of the adult male, where it is commonly known under the name of Adam's apple, and not only forms the front of the larynx but runs far back on the sides. This will be clearly understood from the following cut, in which A is a front view of the thyroïd cartilage, separated from all the rest; B a side view of same, in which *a* is the anterior and *p* the posterior extremity: C is the *cricoïd* or ring-shaped cartilage, with its deep part behind, while the thyroïd fits down upon the narrow part in front, in a way we shall presently describe.



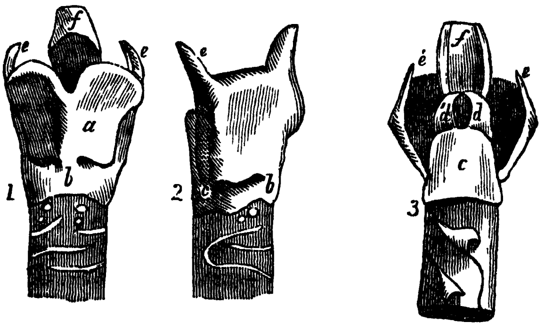
The third cartilage is the *arytenoïd*‡ or funnel-shaped cartilage, which we should rather describe as two distinct cartilages, one for each side, placed on the top of the elevated part of the *cricoïd* cartilage; and thus completing the back part of the larynx, which, when all its parts are put together presents the appearance represented in fig. 1, when viewed in front; in fig. 2, when viewed from the side; and in fig. 3, when viewed from behind; and in each of these figures, the same letters

* From κρικος, a ring, and ειδος, form or shape:—*ring-shaped*.

† From θυρεος, a shield, and ειδος, shape:—*shield-shaped*.

‡ From αρυταινοειδης, *funnel-shaped*.

represent the same parts, *a* being the thyroïd cartilage; *b* the anterior or narrow, and *c* the posterior or broad part of the cricoïd cartilage; *d d'* the arytenoïd cartilages, resting on the latter and meeting at the summits; *e e'* the horns of the thyroïd cartilage, and *f* the epiglottis.



Anterior, lateral, and posterior views of the Larynx.

These several cartilages are not fixed, but moveable upon one another by muscles: the chordæ vocales, also, are by no means to be considered as simply elastic ligaments, strained between their extreme points, and obliged to vibrate when blown with sufficient force, like the strings of an Æolian harp. They are, on the contrary, living ligaments, endowed not with a mechanical but a vital elasticity; and supplied with muscles, which regulate all their motions to the nicest degree, placing them in that state of tension and parallelism which the ingenious experiments of Dr. Willis (recorded in the *Cambridge Philosophical Transactions*, vol. iv.,) show to be necessary to the production of sound; and not only that, but moving them in every the slightest change of tone, so that we cannot doubt that every turn or trill on the human voice is produced by a succession of muscular contractions, as surely, though not so obviously, as a shake on the violin under the fingers of a Paganini. This is the reason why we say a larynx is not a flute, nor a fiddle, nor a flageolet, nor an organ, but a *larynx*, that is, a living instrument, which can give or withhold its sound, so long as no part of its *vital* apparatus is impaired, and whose vibrations depend not on any external impressing agent, but upon a power existing within itself. This it is that has rendered it a subject of such difficulty to mechanical philosophers, who have each been making their pipes, or their whistles, or their trumpets, and endeavouring, from the *mechanism* of these, to explain all the circumstances of the formation of the human voice. It is true that, in this way, rude imitations of certain sounds may be made. The vowel-sounds particularly, are said to have been imitated by Kratzenstein and Kempelen, in the last century, and we believe with still more success by Mr. Willis and Mr. Wheatstone in this. Nay, we are told by Rivarol, that the Abbé Mical made two colossal heads which could deliver entire sentences, but he unfortunately broke them, in consequence of not obtaining from the French government the reward which he thought his ingenuity merited; and as he left no record of the mechanism employed, we know nothing further than the anecdote we have mentioned. Kratzenstein, indeed, has left us full information as to the means he employed; which were simply pipes or tubes of different figures, with reeds of an ingenious construction inserted in them, which, on being blown through, sounded *a e o u i*. Figures of these different pipes may be seen in the plates to the first volume of Dr. Young's *Lectures on Natural Philosophy*, or in the *Transactions of the Petersburg Academy* for 1780, in which publication the essay first appeared. But what do all these experiments amount to further than that the art of man can, with infinite pains, and labour, and calculation, produce from inorganic or dead matter, very imperfect imitations of a very few out of the countless variety of sounds which, with a scarcely noticeable exertion, the living larynx can send forth. When mechanical philosophers, therefore, urge it as a serious objection against physiologists, that they attempt to study the voice by observing the organs of speech*, it would appear that physiologists might fairly retort upon those who seek to illustrate the phenomena of voice by instruments, deprived of the most important element in its production—life. The whole point, in short, seems to lie in two words: we study *voice*, they study *sound*†.

One objection may be urged against the theory, that voice is altogether vital, which is, that if you take the wind-pipe of a dead animal, and press towards each other the arytenoïd cartilages, so as to render tense the *chordæ vocales*, a current of air directed from the lips, or a bellows, through the wind-pipe will then produce a sound. But this is merely an apparent

* Mr. Willis's words are, "Kempelen's mistake, like that of *every other writer* on this subject, appears to lie in the tacit assumption that every illustration is to be sought for in the form and action of the organs of speech themselves, which, however paradoxical the assertion may appear, can never, I contend, lead to any accurate knowledge of the subject." If by "the subject," he means voice and speech, the assertion is sufficiently paradoxical, despite his subsequent explanation, which, by the way, refers all not to voice but to sound: but we find much more paradoxical his opening assertion, that Kempelen and every other writer had sought all their illustrations in the organs themselves, when he has just been occupying two pages of his essay in recounting the different tubes, pipes, speaking-machines, &c., of Friar Bacon, Albertus Magnus, Kircher, Bishop Wilkins, Mical, Kratzenstein, &c. &c., which were certainly at least intended to be "illustrations of the subject."

We cannot, however, suffer ourselves to disagree in one respect from Mr. Willis's opinions without acknowledging, generally, how much we admire his second truly excellent paper on the *Mechanism of the Larynx*, in which he enters into an examination of the structure and functions of its several parts in a manner deserving of all praise.

[† "Mr. Willis, of Cambridge, has recently adapted cylindrical tubes to a reed, whose length can be varied at pleasure by sliding joints. Upon drawing out the tube, while a column of air from the bellows of an organ is passing through it, the vowels are pronounced in the order, *i e a o u*. On extending the tube, they are repeated, after a certain interval, in the inverted order, *u o a e i*. After another interval they are again obtained in the direct order, and so on. When the pitch of the reed is very high, it is impossible to sound some of the vowels, which is in perfect correspondence with the human voice, female singers being unable to pronounce *u* and *o* in their high notes. From the singular discoveries of M. Savart on the nature of the human voice, and the investigations of Mr. Willis on the mechanism of the larynx, it may be presumed that ultimately the utterance or pronunciation of modern languages will be conveyed, not only to the eye, but also to the ear, of posterity. Had the ancients possessed the means of transmitting such definite sounds, the civilized world would still have responded in sympathetic notes at the distance of hundreds of ages."—*The Connection of the Physical Sciences*, by Mary Somerville, 2nd ed., p. 179.]

objection: it is, in fact, a real confirmation. True, you do produce a sound, but is this sound voice? You make a noise, and the mechanical philosophers can make as good a noise with their tubes, exactly because you are both acting on dead matter. But where are all the delicate inflexions, the modulations, the intonations, that gave expression, and sweetness, and power? They are gone,—gone with the *life;* and you can equally destroy them during the general life of the animal if you destroy the *relational* life of the part, as can be done by cutting the fine nerves by which it is supplied; cut those of one side, and the voice is weakened; of both sides, and the voice is gone.

The different tones of which the human voice is capable in singing or reciting, seem also to depend on these cords. Numerous theories were formed as to the mode in which they acted, some supposing with Ferrein that it was the greater or less tension of those cords that produced the acuter or graver sounds, just as the string of a violin will give a higher sound when screwed up, a lower when let down. Others thought that it was according as the glottis was more or less open that the tone varied; others thought that the raising or depressing the larynx, which any person may observe, by placing his hand on his own throat as he sings the gamut, afforded the true explanation. M. Magendie, however, put an end to guessing on this point also, and the experiment which he made for the purpose he thus describes.

"I laid bare the glottis of a noisy dog, by cutting between the thyroid cartilage and the hyoid bone; (this is immediately above the thyroid cartilage, so that he did not injure the chordæ vocales, or interfere with the passage of the air through them.) I then saw that when the sounds are grave, the ligaments of the glottis vibrate in their whole length, and the expired air passes out in the whole length of the glottis. In acute sounds the ligaments do not vibrate in their anterior part, but only in their posterior, and the air passes only in the part which vibrates; the opening is, therefore, diminished.

Lastly, when the sounds are very acute, the ligaments present vibrations at their arytenoid (posterior) extremity only, and the expired air passes only by this portion of the glottis. It appears that the extreme limit of acuteness in sounds happens when the glottis closes entirely, and air can no longer pass through the larynx*."

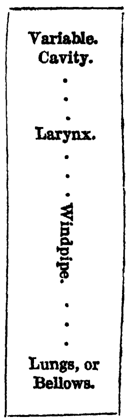
A circumstance, familiar to every one, strongly bears out these observations of M. Magendie, and that is the prominence of the thyroid cartilage (Adam's apple) in the neck of men, and not in those of women and boys. The explanation is this: the chordæ vocales, as our plates will show, are attached behind to the arytenoid, and before to the thyroid cartilages; consequently if these cartilages remove to a greater distance from each other, the cords must become longer. But this removal cannot take place by the retiring back of the arytenoid, for it is placed just against the gullet, and if it went further back, would interfere with our swallowing: it must, therefore, be accomplished by moving forward the thyroid, and this takes place in boys just at the age of puberty, when, as every one knows, the voice becomes of a deeper tone, in consequence of the lengthening of the cords, and is said to be *cracked;* the individual producing sometimes a high tone, sometimes a low, not having yet learned exactly to adapt the muscular contractions to the new state of his vocal cords. This change never takes place in women, consequently their voice at all times retains the high tone it had in childhood.

But there are certain modifying circumstances, which also require consideration: we have shown how a diversity of notes may be produced, but each of these notes may be stronger or weaker, *i. e.*, in accordance with the musical expressions *forte*

* With this latter conjecture we are not quite inclined to agree; it is well known that a person attempting to bring out an extremely high note will sometimes break down in the middle of it, the mouth continuing open and air passing, but no sound being heard. From the air passing, it would appear that the glottis was open, but the cause of the interruption of the voice is the inability to maintain the powerful muscular contraction necessary to the production of very acute tones. The complete occlusion of the glottis occurs when we make violent efforts, as we then always "hold in our breath."

and *piano*: there is, furthermore, what the French call *timbre*, which seems to answer to what we call *quality* of voice; thus, of two persons singing the same note, one may sing it in a melodious, another in a harsh, tone; one may have a mellow, the other a wiry, voice; whence, then, originate these differences?

With regard to the first, it would appear that the greater or less quantity of air forced out in a given time, is the chief means of increasing or diminishing loudness, by increasing or diminishing the extent of the vibrations. A certain adaptation of the parts, however, is here required, otherwise not only would the intensity be increased, but the tone would be raised. Every one who has listened to the wind blowing through a key-hole, knows that as long as the wind is gentle and moderate, there is only a low cooing, or murmuring sound produced; but when the strength of the wind is much increased, and it blows a storm, the cooing rises to a shrill whistling, or shrieking sound, many intervals more acute than it was heard before. Now the same should take place if our glottis were immoveable every time we attempted to shout or call out loud; that it does not take place, is the result of our larynx being a vital instrument. It seems more difficult to explain the difference of quality in different voices, and this is the less to be wondered at, when we find persons most skilled in acoustics and mechanics unable definitively to assign the cause of difference in quality of two violins, which they can take in their hands, measure, weigh, inspect, take to pieces, and examine in every possible manner. In both cases, however, it appears probable that the proportions and the quality of the material must be the most important elements, and setting out from this foundation, M. Geoffroy St. Hilaire endeavours to show how we may account for the weak and wailing voice of infancy, when the cartilages are still soft, spongy, and yielding; the more powerful and resonant voice of manhood, when all the parts have acquired their due proportions, hardness, and strength: the alterations produced in the voice by disease, when the lining membrane of the larynx becomes thickened and engorged by inflammation; and, finally, the disagreeable, broken, and cut voice of old age, when the parts have no longer an unimpeded freedom of motion, and are no longer of an uniform density, bony matter being then generally deposited in different parts of the cartilages. The influence of such causes we conceive to be undoubted; but we join M. Piorry in thinking that further modifications may be accounted for by varieties in the thickness, consistency, length, and structure of the chordæ vocales, as (to use ourselves a mechanical illustration) varieties in the quality of tone of a violin may be undoubtedly produced by altering the size and quality of its strings. The nature and form of the cavity through which the voice passes after being formed, must also be taken into account, and this includes the consideration of the pharynx, the mouth, the posterior nostrils, &c. &c.



Mr. Willis, indeed, insists on it that this latter consideration is alone sufficient, without any attention to the former, and he argues in this way. The vocal mechanism may be considered as consisting of *lungs* or *bellows*, capable of transmitting, by means of the connecting *windpipe*, a current of air through an apparatus contained in the upper part of the windpipe, termed the *larynx*. This apparatus is capable of producing various musical notes, which are heard after passing through a *variable cavity*, consisting of the pharynx, mouth, and nose.

Now, if this arrangement be artificially imitated, by combining together pipes and cavities, with bellows in a similar order, and substituting for the larynx an elastic lamina, capable of producing musical notes when vibrated by the stream of air, it is found that, by changing the form of the cavity above it, the various qualities which distinguish the continued notes of the human voice in speech, may be so nearly imparted to the sound which the imitative larynx is producing, as plainly to show that there is no necessity for seeking any power of altering the quality of the notes in the larynx itself. This, then, may be considered merely as an instrument for producing certain musical notes, which are afterwards to be converted into vowels, liquids, &c., by the proper changes of form in the superior cavity.

On reviewing this sentence, however, it will be found that Mr. Willis does not absolutely disagree with us, though his terms might lead to the supposition, for a little attention will show that he does not attach the same meaning as we do to the word *quality* of voice, but uses it to express that modification by which voice is formed into vowels, liquids, &c., in short, what we call articulation.

With respect to the quality of the voice, Vicq d'Azyr makes the interesting observation, that its fineness and excellence seem, in general, to be exactly proportioned to the simplicity of the organs by which it is produced. Thus, in man, the whole construction, as we have seen, is of extreme simplicity, a slit between two vibrating cords, supported by cartilages, and governed by muscles; while in the monkey tribe, it becomes complicated, with one or two membraneous sacs, or in some even with an irregular bony cavity, communicating by a horizontal passage with the larynx, immediately anterior to the *chordæ vocales*, while, at the same time, the voice has become altered and deteriorated, and the power of articulation is lost. In the digitated quadrupeds, such as the dog and cat, the larynx bears much resemblance to the human, except that in the latter, immediately below the chordæ vocales, are placed two very fine membranes, which vibrate when air is forced even into the dead wind-pipe, and produce a sound extremely similar to the *purring* of the animal when alive. In the pig the epiglottis is large and thick, the edges of the glottis are hard, cartilaginous, and pierced by a cleft, which allows the air to pass into two cavities occupying the place of the ventricles, from which the air is expelled, by means of the muscles which invest them, with a *grunt*. In the horse M. Hérissant described two small triangular membranes, situated at the extremities of the glottis, and which he supposed to be connected with *neighing*. This structure is wanting in the mule and ass, who, however, have one more singular in a little cavity hollowed out in the thyroid cartilages, across which is drawn a tight membrane, like the parchment over the head of a drum, but admitting air behind it, and producing very considerable, though, from the want of muscular fibres, unmodified vibrations. In the bat the *chordæ vocales* are extremely reduced in size, and in some species quite wanting, which will account for their muteness, or their feeble imperfect voice; another peculiarity of this order is, that they want the epiglottis, a character which is also to be observed in birds. Birds have no epiglottis, but its place is supplied by circular muscular fibres which run round the top of the windpipe and close it at will, so accurately as completely to prevent the entrance of any foreign body. The proper larynx, or organ of voice, appears to be situated in these animals low down in the neck, or just where the windpipe is dividing into its two principal branches, and the distinction before noticed is equally applicable here; in birds of sweet and melodious voice the organ is simple, as we see in the canary-bird and nightingale; in those with loud, harsh, or disagreeable tones, it is compound, furnished with additional membranes, or even having the windpipe twisted into convolutions, of which forms we have examples in the goose, the wild swan, &c. To these characters we must add, that in the singing-birds the lower or proper larynx is surrounded by abundant muscular fibres, whence its various intonations; but it appears membranous and devoid of muscle in the duck, the chicken, the bustard, that have only a *cluck*, a *quack*, or some other monotonous note. In reptiles the voice seems to reach its last term, and even to become extinct upon the total disappearance of the parts of the larynx. In front of the glottis of the frog are placed two long vibrating ligaments, perfectly detached from the surrounding parts, and incased in a cartilaginous frame of a lozenge-shape, the front extremity of which is in contact with the back of the tongue. These are the organs which give the long deep croak, so annoying to any one who has ever had occasion to attempt sleeping in the vicinity of a marsh inhabited by animals of the frog-kind. In serpents, the larynx and cords may be said to be quite gone; the windpipe opens behind the tongue in a long narrow slit, and the sound is reduced to the hissing of air rushing through a narrow passage.

We can say but a very few words respecting speech and articulation, and this is of the less consequence, as these matters are to be found treated of in numerous popular works already within the reach of every one. The vowels are simply voice modified by the shape of the cavity through which it passes, and it is those that mechanicians have been most successful in imitating. Any person may satisfy himself as to the mode of their formation, who will take the trouble to pronounce the five simple vowel sounds, *a* broad, as in call; *e* broad, as in fête; *i* as *ee* in tree; *o* as in grove; *u* as *oo* in food; and observe how they gradually proceed, as it were, from the back of the throat to the front of the lips, with corresponding modifications in the degrees to which the mouth is opened and elongated. Of course the vowel sounds may be as numerous as those modifications can be made appreciable. Dr. Arnott says about twenty of them are sufficiently distinguishable, but few languages comprehend more than twelve. Mr. Wheatstone, in an ingenious note inserted by Dr. Elliotson in his fourth edition of *Blumenbach's Physiology*, indicates a double series of vowels differing in their mode of formation, and diverging from *aw* (*căll*) as a central point. In the first series, he says, the external aperture remains open, and the internal cavity gradually diminishes by the successive alterations of the positions of the tongue: in the second series the positions of the tongue are successively the same as in the first series, but the aperture of the lips is diminished. We do not exactly understand the table which Mr. Wheatstone professes to have constructed upon this principle, and in which he adds to the two series, thus defined, a third, of which he gives no further definition than is contained in the brief note "lips nearly closed," which we think might very well be included in his second series, marked as "lips partially open*." We are inclined also to question his ideas of pronunciation, when he tells us the long sound of *aw* is to be found in *caught;* whereas, it appears to us evident, that in this word the *aw*, as soon as formed, must be closed by the *t*, or the speaker would be said to drawl, and, we believe, the difference usually made between the long and short sounds of a vowel is, that the former may be sustained. We must equally object to his making two distinct *vowel* sounds of the *o* in *coat*, and the *o* in *court*, as a moment's consideration here will show that the modification

* Having alluded to Mr. Wheatstone's views, and dissented from some of them, perhaps it is but fair that we should give his table in full, adding his own explanation:—"Each of these vowels may be long or short, according to the duration of its sound in a syllable."

TABLE OF VOWELS.

Each series formed by the gradual elevation of the tongue.

First Series. The lips fully open.			Second Series. The lips partially open.			Third Series. The lips nearly closed.		
	As pronounced.			As pronounced.			As Pronounced.	
	Long, in	Short, in		Long, in	Short.		Long, in	Short, in
1. *aw*	caught, fall	folly	6. *o*	coat	Not used.	11. *oo*	cool	full
2. *ah*	father, car	dull	7. *o*	court				
3. *ae*	nae (Scotch)	man	8. *eu*	bonheur (Fr.)				
4. *a*	fair	met	9. *eu*	affreux (Fr.)				
5. *e*	feet, the	fit	10.	Expressed in German by *ü*, in Danish and Swedish by *i*, in Dutch and French by *u*.				

The third *series* appears to be a series composed of an individual, which is rather a novelty. Other observations, in addition to those which we have made above, will, doubtless, occur to any person who peruses the table with attention. It is one of the latest constructed; but we must say it appears rather the work of a philologist than a physiologist.

depends altogether on the *consequent consonant;* and if this be considered sufficient ground for distinction, he should not have stopped at *two*, but given us distinct vowel sounds for almost every combination of which each vowel is capable: thus, in the present instance, he ought to have distinguished the *o* in c*o*bra, c*o*ve, c*oa*t, c*o*ne, c*o*le, c*ou*rt, c*o*ke, &c., because in each of them the vowel sound is interrupted by the consequent consonant in a different part of the mouth, which is the only distinction between the *o* in c*oa*t and the *o* in c*ou*rt. To exemplify this in the clearest manner, let the *oa* of the one, and the *ou* of the other be followed by the *same* consonant, and their sounds at once become identical: who can distinguish in pronunciation between c*oa*rse and c*ou*rse?

Of the consonants, perhaps the clearest account is that given by Dr. Arnott, who considers them as resulting from the interruption of the true, or vowel sounds, by the closure or approximation of the parts through which they are passing. Thus, let any one form the sound *a*, and suddenly stop it, by closing his lips tight, and he will plainly hear the syllable *ap:* if the closure have been effected softly, and without compressing the lips, the syllable will be *ab*. In this way we get *p* and *b*, two of the labial consonants, as the effect to the ear is quite the same, whether the consonant be pronounced before or after the vowel.

If now, in place of the lips, we stop the sound with the tongue, by causing it to strike the palate, just behind the teeth, we get the sounds *at* and *ad*, that is, *t* and *d*, according as the closure has been effected tightly or softly. But if we use not the tip, but the middle of the tongue, so that it may rise up against the palate deeper in the mouth, we have the sound *ak*, *ag;* and still further back, if the modification be made at the top of the throat with the very root of the tongue, we shall hear the *ch* of the German preposition *nach*, the same as the closing sound of the Scotch *loch*, or the Irish *lough*. This is a sound which Englishmen find some difficulty in forming. If now we go through the three positions already indicated, viz., the lips, the tip of the tongue, and middle of the tongue, allowing, at the same time, the sound which is stopped in the mouth to continue through the nose, we shall hear *am*, *an*, and *ang*, or the three *nasals*, *m*, *n*, and *ng* (as in *bang*), the last being the nasal sound so much used by the French, whose language requires in so great a measure to be spoken through the nose. There are various other modifications for pronouncing the other consonants, but all explicable on a similar principle; we shall only notice one more: viz., that made by closing the lower lip against the upper teeth, which, as like the positions already mentioned, it may be done in two ways, gives us two sounds *af* and *av*, or the consonants *f* and *v*. From principles such as these Dr. Arnott has been led to a consideration of the best mode of treating stuttering, lisping, and other deficiencies in the use of the vocal organs, and has laid down some rules equally philosophical and simple, by a proper attention to which, it seems more than probable that any intelligent person would be able to cure himself. "A lisping person, for instance, is cured at once, by being told that the tongue must not touch the teeth in pronouncing the letter *s*; and a Frenchman, who deems it impossible for him to pronounce the English sound of *th*, discovers that he cannot avoid doing so, if he rests his tongue softly against his teeth, when opened a little, and then forces breath or sound to pass between the tongue and teeth."

We promised a few words respecting sighing, coughing, yawning, &c.: they are all only different modes of respiration. When a person becomes occupied with some absorbing reflection, as when one sits overwhelmed with silent grief for the loss of a dearly-loved friend, the entire attention is devoted to the image with which the mind is occupied, the appeals made by the organs of sense to the brain are unnoticed, and foreign objects pass disregarded; even the vital functions seem to sympathize with the general concentration, and suffer their action, as it were, to flag, or be imperfectly performed. The lungs rise less frequently in respiration, because the intercostal muscles and diaphragm, which should expand the chest, suffer intervals to elapse between each performance of their office. In consequence the blood is less rapidly aërated, and less easily passed through the lungs: it begins to stagnate and collect in the right side of the heart, to which it is returned as usual from the body; the right auricle and ventricle are clogged and overladen, there is a feeling of heaviness and oppression, well termed "the sickness of the heart," which increases until the anxiety and distress become so painful as to attract attention; the vital system seems, then, to be sensible of what is wrong, a sigh, that is, a deep inspiration, is made, the effect of which is to expand the lungs and take in a large quantity of fresh air; the increased size of the lungs permits the labouring heart to rid itself of its superabundant quantity of blood, which the large supply of air serves at the same moment to purify, so that we perceive a degree of physiological accuracy in the novelist's description, "his heart was ready to burst, when a succession of deep sighs appeared to afford him some relief." A sigh carried to the deepest, and accompanied during expiration with a slow vibratory motion of the vocal cords, constitutes a groan. Sobbing also would appear to be but a modification of the same action, in which the full, deep inspiration, is broken into a number of successive short inspirations by a catch, which in weak nervous people is apt to become convulsive or hysterical, in the descent of the diaphragm.

Yawning is, in the mechanical part of its execution, extremely similar to the above, except that the expiration is generally as long and slow as the inspiration, and often accompanied with a singular voice. It seems generally consequent on a fatigued state of the muscles of the body, in which the muscles of respiration share, and thus performing their work, as it were, imperfectly, are at times obliged to take in an extra supply, for which purpose the mouth gapes, and the jaws are separated widely, so as to admit as much air as possible. During sleep, respiration is also slower, so that upon waking most animals yawn and stretch themselves, as if to awake all their muscles to the proper tone for renewed action during the day. According to Richerand the crowing of the cock and flapping of his wings are intended to serve this purpose; he adds, that the concerts with which the tribes of singing-birds fill our groves at sunrise, have their origin in the same cause, though he forgets to say whether their evening song is to be considered as yawning before they go to bed.

A cough is a sudden and forcible expiration, the object of which is to cause a rapid current of air from the lungs along the windpipe, which is, at the same moment, contracted by the small muscles which lie along its hinder part, so that the air, rushing with force through a narrow passage, may bring along with it any superfluous quantity of mucus or any foreign matter which may have come in contact with the fine lining membrane, and so have excited irritation. This is the reason why people cough after having, as it is usually termed, caught cold. The effect of cold directed, as most frequently happens, on the sensitive membrane which lines the nostrils and air-passages, is to produce an afflux of blood to this part, in consequence of which the glands with which it is supplied form a larger quantity than usual of their proper mucous secretion; this would in a short time accumulate, so as to impede the passage of air, did we not remove it from the nostrils by blowing, that is, by closing the mouth, and so causing all the expired air to pass through them, and from the windpipe by coughing, the mechanism of which we have already noticed. Sneezing differs very little from coughing, except that it is generally more violent, and the air is, as in blowing, directed almost entirely through the nose, the object generally being to dislodge some offending substance from its internal and very sensitive surface.

In laughter a full inspiration is succeeded by a number of short expirations, each interrupted, as it were, by a partial closure of the glottis, accompanied with the production of voice. It is laid down by Sœmmering, that a moderate laugh may be, under certain circumstances, advantageous to one's health—"quia intra idem tempus, quo alias nonnisi semel respiramus, plures inspirationes et expirationes breviores repetimus, ideoque insigniori conquassatione sanguinis in abdomine circulationem promovemus;" because within the same period in which we should otherwise have made but one respiration, we now make many shorter inspirations and expirations, in consequence of which we assist the abdominal circulation by giving a shake to the blood. It is pleasant to find so philosophical an explanation of the common proverb "Laugh and be fat." Men, we are told, generally laugh with the vowel sound *aw* or *o*; women with that of *a* (f*a*te) or *ee*. A long-continued laugh, as it interrupts regular breathing, will cause the afflux of blood to the head, so that we shall see a person during a hearty fit get red in the face, while the unusual quantity sent to the lacrymal glands stimulates them to the performance of their function, and, under such circumstances, the eyes first water, and then tears trickle down the cheeks, in which case a man is said "to laugh till he cries." The mode in which its physical causes, such as the titillation of the ends of certain nerves, produce laughter, is not well understood; still less can we explain how it should originate in mental emotions. In some states of the constitution, generally such as are accompanied by nervous debility, laughter occurs without any of its ordinary exciting causes, and even without being within the control of the will; this we know to occur in that class of diseases termed hysterical. In infants, also, the retraction of the corners of the lips, and other muscular actions, which usually accompany laughter, are, at times, the consequence of impressions made on different parts of their intestinal canal by worms or other irritating causes, so that where the nurse or mother suppose the child to be expressing feelings of comfort or pleasure by a smile, the physiologist will often behold a slight convulsive twitching at the commencement of the alimentary canal, indicative of irritation which is taking place within. Crying commences with a deep inspiration, followed by short interrupted expirations, which sometimes agitate the whole chest, together with the head and abdomen; expirations and inspirations continue accompanied by more or less noise, until at length it terminates in a full expiration, followed by a deep inspiration, that is, a sob or sigh. Children are often observed to cry in a certain tone and measure. The physical effects of crying are stated by Sœmmering to be nearly the same as those of laughter, though the moral causes with which it is generally connected, such as grief, anguish, &c., being of a depressing kind, must exercise a prejudicial influence. There is not, however, the same danger from excessive crying as from excessive laughter; cases are on record of persons having suddenly died from the latter, but none of such an unfortunate result to the former.

The mere pouring out of tears is not crying, as the mere contraction of the muscles about the lips is not laughter. It may, as we have shown respecting laughter, take place from causes merely physical, and with which there is no mental suffering connected. A determination of blood to the head, even where the individual may not be immediately sensible of any inconvenience from it, may so stimulate the lacrymal glands, that an effusion of tears may be the consequence; and we have ourselves more than once seen this involuntary weeping occur as a preliminary symptom to apoplexy. Dust, or irritating matters entering the eye, may also be the cause of an effusion of tears, the object of which, in this case, is to dilute, dissolve, or wash away the offending substance. The wisdom of this contrivance is fully exemplified in some cases, in which the nerve supplying the surface of the eye with sensibility has been divided, and so the sensibility lost. It is to be observed that this sensibility is totally distinct from the power of seeing, which, as we shall explain in a subsequent chapter, belongs not to the surface, but to a nerve situated in the deep parts of the eye, or rather to the part of the brain with which this nerve communicates. When the sensibility, however, of the surface is lost, notice is no longer given of the presence of offending substances, the lacrymal gland is not stimulated to a due performance of its office, they are allowed to remain, until by their presence they cause irritation, inflammation, and ulceration of the cornea, which, in its turn, becoming opaque, stops the access of light, or, being eaten through, allows the internal humours to escape, and so the individual becomes completely and permanently blind. On how many apparently trifling adjustments does our happiness, our comfort, nay, our very life, depend!

Chapter X.

THE NERVOUS SYSTEM.

In no class of created beings, except in animals, do we find a system appointed for the perception of external impressions, and the communication to certain instruments of motion, of an internal impulse to action. Such a system is the nervous. By it we gain all our knowledge of the world that surrounds us; by it, modified and assisted by certain arrangements observable in the organs of the senses, we see, hear, smell, taste, feel; by it we are made aware of the presence of such objects as are useful and agreeable, or, on the contrary, injurious and destructive; and, finally, by it we so direct our *motive* powers, consisting of muscles, tendons, bones, &c., that we may approach the one, or avoid the other. It is thus in direct and necessary connexion with the developement of the muscular system. To what use the power of seeing the approach of danger, if we were unable to fly from it; to what use the power of flying, if not directed by a perception of what was to be avoided? It is thus that, as the power of changing place becomes less and less in the lower order of animals, the nervous system becomes more and more imperfect, till in the zoophytes, which stand, as it were, on the verge of the vegetable kingdom, and spend their lives attached to the spot where they had their origin, the body presents an uniform pulpy appearance, from which muscles and nerves seem equally banished. By careful examination with a microscope, Spix conceived he made out certain nervous fibres in these animals, and, after some examination, De Blainville seems to allow Spix's discovery; but, whether they do or do not exist, it is evident from the doubtful way in which they are described, and the pains that must be used to find them, that they are extremely obscure, and barely sufficient to maintain the last faint shade of sensibility. It is, therefore, in the higher order of animals that we must look for the clearest developement of this system, and, considering it as a whole, in none will it be found so perfect as in man. Hitherto, however, anatomy has failed to ascertain any particular part superadded to the rest, and so distinct, that we could point to it as the clearly definitive mark between man and all other animals. Sœmmering, indeed, points out no less than fifteen anatomical peculiarities in the human brain, but they are rather in the complexity of organization and fulness of developement of certain parts, than in anything clearly additional. Messrs. Gall and Spurzheim, to whom we shall have occasion frequently to refer, and to whom the anatomy of this organ owes much, do not, however, appear to have shown (abstractedly from their peculiar doctrines) anything very satisfactory on this point.

The nervous system, as viewed in the higher order of animals, consists of four parts; the brain, spinal marrow, nerves, and sympathetic, or ganglionic system. In former times it was usual to speak of the brain as the root, the spinal marrow as the trunk, and the nerves as the branches springing from it. This order is now nearly reversed: in examining the formation of the fœtus, the spinal marrow is found to exist before the brain, and in tracing down the chain of animals this latter is found wanting, where nerves and ganglia still exist*.

[* As being the most facile way of accounting for the developement of the human embryo, it was first assumed that each organ pre-existed in all its complexity, although inconceivably minute, developement being only accretion; the

Now the matter out of which all the nervous system is formed would seem to be but of two kinds, the one soft, pulpy, and grayish, or rather of a light-brown colour, abundantly supplied with vessels, but exhibiting scarcely any traces of organization, appearing under the microscope to be formed of an immense collection of extremely minute globules, held together, as some say, by a fine transparent mucus; the other white, firmer, and denser in structure, and assuming in many places the appearance of fibres, of which, indeed, Gall and Spurzheim say it is all composed. These two parts are not mixed together indiscriminately in the formation of the brain, but are always found to preserve an uniform arrangement, being in some places quite distinct, in others occupying alternate layers, so as when cut through to give a striated appearance. From the immense quantity of blood sent to the gray matter, it was by many considered as a secreting organ; and those who believed that nervous influence took place by means of a subtile fluid, held that that fluid was formed here. With them the white part was a collection of filaments, which were nothing more than very fine hair-like tubes, through which the fluid passed; the nerves were composed of a certain number of tubes issuing from the brain, and surrounded with an envelope of cellular structure, and the spinal marrow itself was nothing more than a larger collection of the same kind. Of course this theory is totally disproved by the facts we have already mentioned, as to the order in which the parts are formed, and which M. Serres has traced into the general law, that developement takes place from the circumference towards the centre; but, inde-

microscope, however, refused to support this position by a single fact. An analogy taken from the vegetable kingdom formed the second æra of error upon this point; the embryo was a seed, each organ germinating from a fixed point—the vessels from the heart—the nerves from the brain, &c., but observation failed in supporting this case also. The most recent theory is the reverse of its predecessor; instead of a centrifugal developement, that is, taking place from a centre towards a circumference, it is now considered to be centripetal, or from the circumference to the centre. Although this is not a literal expression of the facts, yet it may be considered to hold good in the main, especially as regards the nervous system.]

pendently of this, they never were able to show by anatomy that the nerves were so formed, or that they did contain any fluid.

The view taken by Dr. Gall, and more fully confirmed by the researches of Reil, is that now more generally adopted. Observing that the white filaments can always be traced at either end to a ganglion, or collection of this gray matter, observing also that such ganglia occur occasionally, in the course of the nerves, which are all white, or, at the union of several filaments of nerves, termed *plexus*, and that after passing through such ganglia, the nerves always issue with increased bulk, or more numerous filaments, he concluded that the organized white filaments or fibres were the working part of the brain and nervous system generally, and that the gray mass of unorganized globules was the "*matrix* of the medullary filaments," that is the source from which they derived their origin, and through which they were supplied with nutriment. The brain of man is composed of these two kinds of matter, enveloped by certain membranous coverings, and supplied with blood by the internal carotid, the vertebral, and some smaller arteries. It is placed in the cavity of the skull, which it fills, and an idea of its size may be got by any one passing his hand across the upper part of his eyes, thence along the ear, just over its external opening, then along the neck, just where it becomes united with the head, and so round by the other ear to the eyes again. All the space above this line may be said to be occupied by the brain. It will be observed that this line sinks considerably deeper behind than before, and the lower part behind, being differently formed from the rest, of a different structure, and separated from it, except at the root, by a strong reflection of the enveloping membranes, is generally distinguished from it, the anterior and upper parts being called the *cerebrum*, or brain proper, while this is termed *cerebellum*, or little brain. This will at once be understood from the accompanying cut.

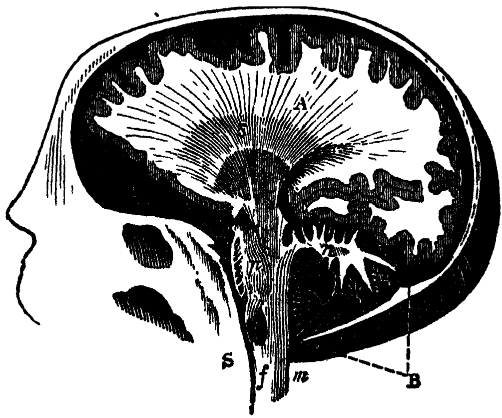
This is the first division of the brain; but the *cerebrum* is further divided, by means of a deep longitudinal furrow, running its whole length, and separating it into two parts,

Side of Skull and Membranes removed: Figure and Site of Brain displayed.
A, the *cerebrum*, B, the *cerebellum*, C, beginning of spinal marrow.

called *hemispheres*. The division is made by the strong protecting membrane, called the *dura mater*, coming from each side, and being reflected down along the central line, so as to separate the hemispheres to a depth of about an inch and a half. This dura mater is placed like a strong sheath to envelope and support the whole brain; it is immediately in contact with the inside of the skull, but between it and the brain is placed a much finer membrane, called the *pia mater*, which envelopes every part, and affords a passage to the minute vessels by which the interior substance is nourished. Between the folds of the *dura mater*, dipping down to form the division we have mentioned, is left a cavity, termed *sinus*, into which the veins of each hemisphere discharge their blood. The course of this sinus any person may trace, by laying his finger in the centre of the highest part of his forehead, then carrying it back in a straight line along the centre of his head, until he comes behind near his neck to a hard bony protuberance; so far he has exactly traced the course of the sinus, and of the blood in it. But just at this point it is joined by other vessels bringing blood from the deeper parts of the brain, and the quantity collected is so great, that it would be inconvenient that it should any longer continue in one channel. At this point, therefore, it divides; and if, placing a second finger by the side of the first, he draws one towards the hinder and lower part of each ear, he will be still tracing the course of the blood now contained in a *sinus* for each side, formed by a second reflection of the *dura mater*, which, as we before said, divides here the *cerebrum* from the *cerebellum*, so that by observing this line we are further enabled to pronounce that the former lies above, and the latter below it. When the sinus has arrived at this point, it receives its last addition of blood brought from the deep parts in the front of the brain, and turning down through a hole in the skull, it discharges itself into the great jugular vein, which commencing just here at each side, conveys the blood down the neck, and finally pours it into the heart.

The hemispheres thus divided, correspond very nearly with one another. In general a little difference in point of size is observable, the preponderance being most frequently, though not always, in favour of the right. Their surface, as seen in the above cut, is marked by a great number of eminences, rounded on the edges, and winding into one another. These are termed the *convolutions* of the brain, whilst the depressions by which they are separated are called *anfractuosities*, or furrows. The number and size of the convolutions vary exceedingly, and are seldom found the same in the two lobes: they are sometimes very large, sometimes very small, in individuals of the same age; in general they are small in fœtuses and new-born children. The furrows are equally variable, running in all directions, sometimes simple, sometimes subdivided, sometimes very long, sometimes very short. They generally penetrate the brain to the depth of about an inch, and so far of course the convolutions can be separated from one another. These convolutions Gall and Spurzheim consider as the organs of the different faculties and sentiments of the mind; we must, therefore, inquire a little more closely into their structure.

Spurzheim made a section of a brain from front to rear, and continuing it down through the upper part of the spinal marrow, produced the appearance in our next plate. Here we should first observe the fibres *f*, arising from the anterior part of the spinal marrow, which also contains gray matter for their nutriment. These fibres passing through the part *p*, termed the *pons Varolii* (from its uniting the two sides of the *cerebellum* like a bridge, and having been particularly described by Varolius), direct themselves upwards, and after being rein-



Vertical Section of Brain.

A, the *cerebrum*, or brain proper; B, the *cerebellum*, or lesser brain; S, spinal marrow, from the fibres of which they both seem to be formed.

forced by passing through two successive collections of gray matter, *i* and *s*, which Gall calls the inferior and superior ganglia of the brain, they finally spread out, as we see, in the convolutions, uniformly capped, or surrounded, by further layers of gray matter, which, from its always being found on the surface of the brain, has acquired the name of *cortical**. But there is a second series of white fibres, which arising, as it would appear, from this cortical substance, and directing themselves towards the centre, form what are called *commissures*, by means of which the several parts of the brain are, as it were, connected into one whole, and concord between their functions ensured. Such is a sketch, necessarily very imperfect, of the structure of the *cerebrum*, as evinced by the researches of Gall and Spurzheim, as well as of other anatomists, who having no theory to support, are, therefore, most trustworthy.

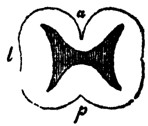
The *cerebellum*, B, seems not to have been so easily or so perfectly described. However, as seen in our plate, they connect this with the posterior fibres of the spinal marrow, *m*, which, at this part, form rope-shaped bodies, thence termed *corpora restiformia*†. These they trace into the centre of each hemisphere of the cerebellum, and there find them terminating in a *nucleus*, or ganglion of gray matter, *n*. From this white filaments are seen to branch out on every side, covered, as in the cerebrum, by gray cortical substance, from which arrangement there results the peculiar appearance we have figured, and which is usually denominated *arbor vitæ*. The *cerebellum* has also its converging fibres, and these, it would appear, constitute the external transverse layer of the *pons*, which must be removed or cut through, before the deeper fibres, running from the anterior part of the spinal marrow to form the convolutions of the brain, can be shown. That the *pons* is so formed, is further shown by its being deficient in fishes and reptiles, where the cerebellum has no lateral hemispheres, consisting solely of the central part.

* From *cortex*, bark.

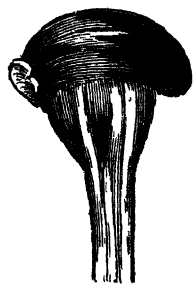
† From *restis*, a rope.

In the central part of each hemisphere of the *cerebrum*, is found a cavity lined by serous membrane. These cavities are termed ventricles; during health their sides are closely laid together, so that, in fact, no cavity can be said to exist in such cases, but as the serous membrane which lines the abdomen may, by an increased exhalation from its surface, give rise to dropsy, so the serous lining of the ventricles may, if its exhalation is greater than its absorption, give rise to an accumulation of water in these cavities, constituting the formidable disease termed *hydrocephalus*, or water on the brain. Another of these cavities is to be found at the top of the spinal marrow, or just where its bundles of fibres are said to separate, the anterior to pass to the cerebrum, the posterior to the cerebellum. Above, and a little in front of this cavity, is placed the celebrated *pineal* gland, which Des Cartes chose to make the seat of the soul. It is a little round body, about the size of a pea, formed of gray matter, and covered with the *pia mater*, which we have before mentioned as the internal membrane covering the brain. It is very singular that this little body is constantly found, after a certain age, to contain fine gritty particles, appearing like siliceous sand. The use of the body is unknown; yet, from its situation, there seems little doubt that it must be of importance, as we find two white cords, like nerves, running from it, and forming direct communication with the inferior ganglion of the brain, and with the great central commissure, by which the two hemispheres of the cerebrum are connected. From this point the spinal marrow may be traced down into the canal formed for its reception, along all the bones of the spine; and, in its passage along here, it gives out a pair of nerves at every interval left by the vertebræ.

The general appearance of the spinal marrow is that of four thick nervous columns or rods, placed together so as to make but one column. The depressions, however, are still evident, and the columns are spoken of as two anterior and two posterior. A change in the position of the gray matter is also observable here, for it is no longer placed on the surface, as in the brain, but is entirely confined to the centre, so that a horizonta cut, carried through the spinal marrow, would give this appearance. The indentation at the anterior face *a*, is much the deepest and most distinct. That on the posterior face, *p*, is also sufficiently marked, so that the division of the column, by a line from front to rear, is sufficiently obvious. The lateral grooves, *l*, *l*, are by no means so plain, indeed they are seldom to be seen, and we have represented a slight indentation there, rather to keep up, in the reader's mind, a recollection of the distinction which exists between the anterior and posterior columns, than as expressing anything our own dissections have ever shown us. The existence of this distinction will be made more evident when we come to speak of the functions performed by the nerves derived from these parts. In the centre of our plan is seen the gray matter, while that by which it is surrounded, and from which the nerves seem more immediately to take their origin, is white.



At its upper part, just where it unites with the brain, the spinal marrow becomes more complex. It no longer consists merely of four rods or columns; other parts seem to be interposed between them, as we have represented; and as those parts increase, so do the nerves arising from them perform more various offices. This part of the column is not perfectly *spinal:* it lies within the skull, gives origin to many of the nerves of the head, and those which direct the action of some important internal parts, such as the lungs and stomach; and its division close to this point is certainly and immediately fatal. At the other extremity, the spinal marrow extends as far as the loins, and there terminates by opening



Medulla Oblongata.

out into a great quantity of nervous cords, whence spring the nerves of the lower extremities.

The spinal marrow is protected, in its case, by an external sheath of firm fibrous structure, continuous with the *dura mater* of the brain. This membrane, after lining the skull and giving sheaths to the several nerves passing out, descends into the cavity of the spinal column in something of a funnel-shape, continuing to line it all through, and connected with the bones by means of a loose cellular structure. The spinal marrow is more closely embraced by another and much finer membrane, which is analogous to the *pia mater* of the brain, though Cloquet confines this membrane to the skull, and considers the second envelope of the spinal marrow as continuous with the *arachnoid* membrane of the brain. This is a third membrane, placed on the brain between the other two, partaking of the nature of a serous sac, and by one of its surfaces lining the interior of the *dura mater*, while the other rests on the *pia mater*, over the whole surface of the brain, but does not slip down with it into its *furrows* and *anfractuosities*. In the spinal canal, one of its surfaces embraces closely the spinal marrow and the origin of the nerves, while the other lines the external fibrous sheath, so as to make its internal surface smooth and polished, allowing free motion in the different positions of the spine. Having thus got an idea of the brain and spinal marrow, the central parts of the nervous system, let us next proceed to consider their functions.

The intricacy of the human mind, as an object of study, must have been felt by [all who, either as readers or writers, have been engaged in metaphysical disquisitions; the intricacy of the final structure of the human brain, and the next to impossibility of unravelling its windings and tracing the course of its fibres, have long been acknowledged by the most skilful anatomists who have attempted the task. What shall we think, then, of those who, assuming both in their highest state of complexity,—the mind of man in civilized life, moulded by external circumstances, and altered by an artificial system of education, its best feelings perhaps repressed, its whole bias changed; and the brain of the adult man, the most perfect in structure, the best developed in parts, the most inextricable in arrangement, containing in itself all that is to be found in the brain of other animals; and then placing these two, as it were, side by side, should endeavour to explain the phenomena of the one by the texture of the other; connecting what was unknown in the spiritual power with what was equally unknown in its corporeal organ? We should surely consider they were adopting a most unlikely way to throw any light upon either; yet such has been the mode of examining the brain and mind until almost the present day. But an entire change has taken place, and though it has not yet been sufficiently matured to show the full advantages which may arise from it, yet much is done when the true way is once pointed out, and the results already obtained hold out abundant prospect of much future good.

The chemist, when he gets a compound body with various qualities, may be required to determine how far such qualities are attached to the individual component parts. He will carefully free such body from all matters foreign to its proper constitution, he will remove all external disturbing forces, he will decompose the body into its simplest elements, acquaint himself fully with the nature and properties of each of those, reunite them in different proportions, or with the omission of one or more, and then be able decidedly to answer how far any quality may have depended on any component part, or how far it may have resulted from the nature of the whole compound. This, however, is a privilege not within reach of the physiologist. He cannot separate the brain into organs, if it really be composed of such, and observe the functions and office of each; he cannot dissect out one of those organs, and observe whether a corresponding faculty be removed. Even Gall and Spurzheim, who have mapped out the brain into twenty-four or thirty-five regions, and assigned to each the performance of some intellectual duty or passion, have never attempted to show how deep one of these organs can be said to go, and by what means they infer diversity where anatomy only shows us the most intricate and inseparable connexions. An analysis of this organ, then, is beyond our reach; but to a certain extent it has been performed for us by the hand of nature. There are two modes in which it may be observed; either altogether in the human subject, by commencing with the earliest appearance of a nervous fabric in the fœtus of a few weeks old, and watching the gradual addition or developement of parts until its perfect state is arrived at; or by tracing it through the different vertebrated families of the animal kingdom, from the first faint representative of a brain afforded by the scanty medullary masses that appear in the skull of a ray, merely composed, as it were, of the enlarged origins of the nerves, up to the brain of man, in which these origins, chiefly confined to the upper part of the spinal marrow (*medulla oblongata*), bear no relation to the great bulk of the cerebral lobes, which seem to have no direct connexion with the organs of sense, but to be entirely employed in performing the functions of what we call *mind*. Our principal guides, in this very interesting analytical observation, are Sœmmering, Tiedemann, Reil, Gall and Spurzheim, Desmoulins and Magendie, and Serres. We shall endeavour to explain a few of their views.

[It is said, and, as an abstract truth, the same holds good, that all differences in animal organization are embraced by one law, and included in the same formula; and to this we have already alluded, when speaking of cellular tissue. It is said that lower animals are, as it were, the *permanent embryos* of animals higher in the scale of life; while, "reciprocally, the superior beings, before they arrive at the definite forms which characterize them, transitorily offer those of the lower animals;" and this is the compass that will guide us in our present investigation. The method of acquiring a knowledge of the organization of the more complex animals has been too analytical; we have been called to view the finished master-piece of man, the most intricate of all structures, and have not only attempted to unfold each tissue, and unravel every fibre, but have expected thus to find the principle of the whole; as if nature had hidden her secret in the most tangled warp of this material frame: what wonder then if we lost the path of our inquiry in the labyrinth of the brain? If we wished to acquire a knowledge of the mechanism of a watch, confident in our own powers of observation, and stimulated by curiosity, our first impulse might be to pull one to pieces for ourselves; but, broken works and confused ideas could be the only fruit of our impatience: experience would soon send us to some skilful artist, who would teach us the form and adaptation of each separate part; and thus we should be enabled to comprehend the principle of the connected whole. And so it is with living forms, only, with this advantage,—the embryo-life of a given animal is, as it were, the index-map—the type—of all beneath that animal in the scale of living beings. The student has thus two great schools, in both of which the same method of study is observed. He may trace any organ of our frame from its simplest form in the lowest animal in which it has been observed, marking the addition of each fresh part, according to the necessities of the individual, till he comes to study its final and most perfect form in man; or else, he may trace the gradual developement of the same organ in the human fœtus. Nature starts from the same fixed point in both of these her courses; advancing from the most simple to the most complex, superadding part to part, she builds up the synthesis of life; and this is the synthesis of study which is rapidly advancing in all the higher schools of natural science, and is that which we propose to follow in our present investigation of the nervous system of man.]

Examined at the earliest period that it is cognizable to the senses, the human brain appears a simple fold of nervous matter, with difficulty distinguishable into three parts, while a little tail-like prolongation towards the hinder parts, and which had been the first to appear, is the only representation of a spinal marrow. Now in this state it perfectly resembles the brain of an adult fish, thus assuming, *in transitu*, the form that in the fish is permanent. In a short time, however, the structure is become more complex, the parts more distinct, the spinal marrow better marked; it is now the brain of a reptile. The change continues; by a singular motion, certain parts (*corpora quadrigemina*), which had hitherto appeared on the upper surface, now pass towards the lower; the former is their permanent situation in fishes and reptiles, the latter in birds and mammalia. This is another advance in the scale, but more remains yet to be done. The complication of the organ increases; cavities, termed *ventricles*, are formed, which do not exist in either fishes, reptiles, or birds; curiously-organized rts, such as the *corpora striata* or superior tubercles of the *cerebrum*, are added; it is now the brain of the mammalia. Its last and final change alone seems wanting; that which shall render it the brain of MAN. We thus see that man, considered merely as an animal, is, by his organization, superior to every other being; and that, in the growth of a single individual, Nature exhausts, as it were, the structure of all other animals before she arrives at this her *chef-d'œuvre*. But we have not yet done with the human brain. In addition to the above facts, for which we are chiefly indebted to Tiedemann, M. Serres has made the still more singular observation, that in the advance towards the perfect brain of the Caucasian, or highest variety of the human species, this organ not only goes through the animal transmigrations we have mentioned, but successively represents the characters with which it is found in the Negro, Malay, American, and Mongolian nations. Nay, further, the face partakes in these alterations. Amongst the earliest points in which ossification commences are the jaws. Their bones are, consequently, completed sooner than the other bones of the head, and so acquire a predominance which, as is well known, they never lose in the Negro.

During the soft pliant state of the bones of the skull, the oblong form which they naturally assume approaches nearly the permanent shape of the Americans. At birth, the flattened face and broad smooth forehead of the infant, the position of the eyes rather towards the side of the head, and the widened space between, represent the Mongolian form; while it is only as the child advances towards maturity, that the oval face, the arched forehead, and the marked features of the true Caucasian become perfectly developed.

Now associated with these progressive stages of the brain and head, there would seem to be a certain proportionate developement of innate faculties. Thus, as a *general* rule, the reptile, in its habits and mode of life, exhibits a higher degree of instinct than a fish, a bird than a reptile, a mammiferous animal than a bird; while at the head of all is man, who not only excels the rest in extent of intellect, but by the superaddition of the moral and religious feelings which he alone seems to enjoy. We must carefully guard ourselves here against being supposed to assert an *uniform* predominance, either in quantity of brain or developement of faculties, of *every* member of one class over *every* member of another; an elephant may have more brains than a man, or a canary bird show more docility than a sloth; still less do we mean to maintain the old ideas of a regular gradation or uninterrupted chain, according to which all animals could be arranged so as to show their relative connexions, and mark their reciprocal superiority. No; Cuvier has shown the impracticability of such a scheme; he has shown that the lines which the different classes form, must sometimes be considered as not successive, but parallel; that the beginning of one may extend considerably above the termination of the preceding. Our rule, therefore, though generally correct, must be taken as admitting of exceptions. Now considering the state of the human brain also, we find certain progressions. It is, at first, secreted as an almost fluid pap, in which there is scarcely any appearance of organization. Parts continue to be added, as we have seen, convolutions appear in the sixth month of fœtal life, and even after birth changes take place, for the necessary completion of which we know the skull remains for some time unclosed*. During all this time, too, new faculties are appearing, new powers developing themselves; it was, therefore, sufficiently natural to attempt to connect the one with the other, and to suppose that the mind might be estimated by the brain. Other facts tended to support this idea. Perception evidently took place in the brain. Cut the nerve leading from the eye, and there is no longer perception of light, though the eye, as an optical instrument, is as perfect as ever. The rays of light

[* The following diagram may assist the reader in forming a more lucid idea of the opinions of Cuvier, and, indeed, of the facts of his science.

					21
				19	20
			16	17	18
		12	13	14	15
	7	8	9	10	11
1	2	3	4	5	6

Let the figures 1, 2, 3, 4, 5, and 6, represent the developement of the digestive organs through the various classes of animals; 7, 8, 9, 10, 11, the gradual rise of the circulatory system in the same; 12, 13, 14, 15, of the nervous system, and so on · and let the columns of figures, read from below upwards, represent the various classes of animals. We shall thus see, with Cuvier, how the animals themselves form no successive links of one great chain; but rather *parallel* columns, built up with the same material from the same level, and rising to different heights, according to the necessities of the whole superstructure, as foreseen and provided for by the wisdom of the one Great Architect. But, with M. Serres, we shall see that it is the *organs* that are *successive* in their developements; the figures 12, 13, 14, 15, for instance, represent the successive additions of parts to the nervous system, traced either in the more permanent forms of each stage from animal to animal upwards, or from week to week, in the more rapid transitions of the same, in the gravid uterus of woman. Here, as elsewhere, false ideas are so interwoven with the forms of expression which we are compelled to use, that by seeming to prove too much, we fail to convince at all. It is not advanced that the embryo of a mammal, floating in the fluid of its womb, is really a fish, or any other aquatic animal; but that the necessities and conditions are the same in both, and that the organization, too, is the same at first, —the fingers, for instance, of a human fœtus are at one time *webbed*,—and it is only in anticipation of future and more important wants, that such transient forms give way to those which we call permanent.]

will strike on the cornea, they will be brought to a focus by the crystalline and other humours, they will be applied in the usual manner to the sentient extremity of the optic nerve, spread out as before in the bottom of the eye to receive them; but no perception follows, for the nerve is divided, and the impression cannot be conveyed to the brain. In the same way, if the nerve of sensation*, going to any part, be tied or divided, though the part be scratched, or bruised, or cut, or burned, no pain is felt, for the communication with the brain is interrupted. Again, if the nerve of motion*, going to a part, be cut, though any injury done to that part will be felt as acutely as before, and the *wish* to remove it from the offending substance will be as strong as ever, yet the limb will not be removed. Why then is this? The power to move the part exists; for, if you send an electric shock along the nerves, the muscles will at once contract and produce motion; we are conscious that the *will* also exists; the reason, then, why the one does not excite the other, is, that they are placed at opposite ends of a chain that has been severed; the chain is the nerve, one end of it terminates in the *muscle*, there we know is the power of motion: the other end terminates in the brain, there, therefore, must be the will. Now volition and perception are two of the operations of the mind, and we have been distinctly able to show that their seat is in the brain.

Other of the mental faculties have been also traced, though not so directly. Memory is seated in the brain; its loss is found to result from certain injuries to the brain. A Parisian beggar, who had lost part of his skull by a wound, used, for a small sum, to allow the silver plate by which it was replaced to be removed, and gentle pressure to be made on his brain. The invariable result was a loss of sense; then, of consciousness; his memory totally left him, he became lethargic: on removing the pressure, these symptoms all vanished. In apoplexy nearly the same thing occurs. A vessel, perhaps, is

* This division of the nerves, into nerves of sensation and nerves of motion, will be explained, when speaking of Sir Charles Bell's discoveries.

ruptured, and blood effused either in the substance or on the surface of the brain. By this effusion pressure is made on the brain; the patient falls insensible, and appears in a deep sleep. Relief is only obtained by a copious bleeding, which diminishes the quantity contained in the vessels, and such subsequent measures as will prevent too rapid a current being again sent to the brain. Likewise when, by a blow or fall, the skull is fractured, and part of it pressed in on the brain, insensibility results, until the surgeon trephines the neighbouring part of the skull, insinuates an instrument by the opening he has thus made, and relieves the brain by raising the depressed bone. From such circumstances we are inevitably led to one of two conclusions, either the brain is the organ of the mind, or the brain is itself the mind. The former is the doctrine of the immaterialists, or those who maintain the existence of the soul as a separate principle; the latter of the materialists, who conclude that perception, memory, judgment, &c., are merely the productions of the brain, in the same manner as the bile is produced by the liver, the urine by the kidneys, &c. Why we hold the former opinion, we shall proceed to state, earnestly deprecating the introduction of personal feelings, asperity of language, or imputation of motives, which can only serve to obscure truth, and add to the difficulties, already sufficiently numerous, which must attend on such an inquiry. "The mind," says Locke, "is like the eye, which, while it enables us to perceive all other objects, takes no notice of itself, and requires art and pains to set it at a distance, and make it the object of its own contemplation."

And first, how do we recognise any two objects as distinct? For what reason do we conclude that chalk is not cheese, or skim-milk not ebony? These are points on which all agree: on what, then, is founded this universal assent to the difference of these bodies? Evidently on the fact that they possess different properties. We know nothing of the essential nature of ebony or skim-milk, we never think of inquiring into it; we see that the one is hard, black, heavy, and solid; the other soft, white, light, and fluid, and we at once come to the obvious conclusion that they are different bodies, without asking what may be in each case the essence in which these properties are inherent. Now apply this to mind and matter. We are as ignorant of the essence of the one as of the other; but we recognise their existence by their properties. The properties of body are bulk, weight, solidity, resistance, &c.; of mind, joy, hope, fear, belief, doubt, &c.; but weight is not belief, neither is solidity joy; therefore, as skim-milk is not ebony, so neither is mind matter*.

Secondly:—Physiology teaches us that the particles of all living bodies are in a constant state of change. Supplied by the digestive organs, they are taken up by the *lacteals*, conveyed to all parts of the body, laid down there in the form suitable to each, and when they have performed their duty, are again broken down or dissolved, carried away by the absorbents, and removed from the system, while their place is taken by a new set of particles, destined in turn to undergo similar removal. But the man does not change, though his body does; he is *conscious* he is the same individual now as he was ten years since; his consciousness is joined with memory, constant and unbroken, and it yet remains for materialists to show how this memory is compatible with a mind, which we can prove to have been built up several times within that period, unless, indeed, they are contented with the supposition, that the set of particles which are passing away communicate to the particles by which they are succeeded, the impressions originally made on themselves by external objects. Indeed, materialists, in seeking to avoid one difficulty, fling themselves into a thousand.

Thirdly:—Every man is conscious of the individuality of his own existence. He knows himself to be *one*, and not two,

* It is evident that this argument may be considered inconclusive, in consequence of the imperfection of our senses: it is only used here to show that a mode of proof, which, in ordinary cases, commands universal assent, applies with equal force to demonstrate the difference between mind and matter.

or any greater number. This he is sure of, and no arguments, however refined or ingenious, can shake him in this conviction. But this unity cannot exist in his body, which is made up of thousands of particles, and is not for five minutes together the same: where, then, can it exist, but in the mind? The brain is no more a unit than the whole body; neither is any particular organ of the brain, if such there be, more a unit than the entire brain. "An organ," says the ingenious Dr. Brown, "is not one substance, but many substances. If joy or sorrow be an affection of this organ, it is an affection of the various substances which, though distinct in their own existences, we comprehend under this single term. If the affection, therefore, be common to the whole system of particles, it is not one joy or sorrow, but a number of joys and sorrows, corresponding with the number of separate particles thus affected; which, if matter be infinitely divisible, may be divided into an infinite number of little joys and sorrows, that have no other relation to each other, in their state of infinitesimal division, than the relations of proximity by which they may be grouped together in spheres, or cubes, or other solids, regular or irregular, of pleasures or pains; but by which it is impossible for them to become one pleasure or pain, more than any particle of insentient matter, or any mass of such matter, become any other mass." The unity of any organ, then, merely depends on the act of the mind in considering it as one; it exists as made up of many parts, the mind views it as one whole: take the question how we will, we still find that between mind and matter "there is a great gulf fixed."

Fourthly:—Philosophers tell us that matter is indestructible. It exists now in one form, it is dissolved in obedience to certain laws, straightway it enters into new combinations, and re-appears in another form. This seems a necessary result from the discoveries of the pneumatic chemists. There can be no doubt but that He who created matter, could, in like manner, cause its existence to cease; but such cessation of existence never occurs in the present system of things. The earth consists of the same individual particles which formed it on the day that it left the hands of its Creator, who "measured the dust in handfuls, and weighed the hills in His balance." Without a special interference of His power these particles are eternal. The general properties of matter will be, in like manner, eternal; gravity is eternal; electric influence is eternal; chemical affinity is eternal. And shall it be said, that the mind of man, which has comprehended and investigated all these properties, which has estimated their power, and set bounds to their effects, which can trace the course of the stars in the heavens, and calculate the all but limitless wanderings of a comet through space, that this mind, which elevates us from earth, and forms the link that binds us to ethereal beings, is alone mortal; that it goes down "to the vile dust from whence we sprung;" that it perishes with the disorganization of the brain, and that all our advances in science, our progression in knowledge, our extension of intellect, every effort of reason or education towards improvement and perfection, must at last terminate in annihilation?

No: reason disproves, our best feelings revolt from, such a supposition. He, without whose knowledge not a sparrow falls to the ground, who has numbered the very hairs of our head, takes not such slight account of this, His best and noblest gift to man, as to leave it dependent on our frail earthly tenement; He, with whom there is no variableness, neither shadow of turning, is incapable of that mutability of purpose which would attend on the materialist's theory, that this intellect is destroyed to-day, only to be re-created in equal vigour at some future time.

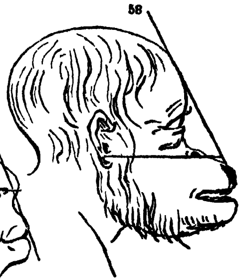
There only remains for us to notice the argument supposed to be founded partly on anatomical, partly on physiological principles. It is said the brain is a gland of a peculiarly intricate conformation; the blood sent to it is the fifth part of the blood of the entire body; but by weight the brain would not exceed the thirtieth part of the body; to what use, then, serves this immense quantity of blood, unless as the liver separates bile, so the brain separates certain principles, which it elaborates into thoughts. Now, the analogy is false, and the argument vicious. The analogy is false, for we can show in the blood the elementary particles out of which bile is formed, so that the liver is only required to change their form of aggregation, or remove some of them, leaving others; but who has ever discovered in the blood the matter of hope or doubt? The argument is vicious; for if we simply deny the brain to be a gland, and ask them for proof, it falls to the ground. They either assume the brain to be a gland, and then prove the thoughts to be secretions, *because* glands always form secretions; or going to work the other way, assume thoughts to be secretions, and then prove the brain to be a gland, *because* secretions only come from glands. Our ignorance of the exact mode in which the large quantity of blood supplied to the brain is used, is no reason why we should adopt an absurd explanation; and can anything be more absurd, or more incomprehensible, than that one material body, the brain, should, out of another material body, the blood, form immaterial bodies (if this be not a contradiction in terms), thoughts? The only way of evading this, is by boldly asserting that as the mind is material, so are the thoughts nothing but little particles of matter, variously configured; and then "it will be not more absurd to talk of the twentieth part of an affirmation, or the quarter of a hope, of the top of a remembrance, and the north and east corners of a comparison, than of the twentieth part of a pound, or of the different points of the compass, in reference to any part of the globe of which we may be speaking."

We hope our readers will now agree with us that the brain is not the mind; the other conclusion is, therefore, established, —the brain is the organ of the mind.

It becomes interesting next to inquire how far the developement of this organ may serve as an indication of the mental powers of the individual. For this purpose it is necessary to decide on some mode, according to which the measurement should be made, and of those proposed, Camper's, Blumenbach's, and Cuvier's, have attained the most celebrity. The head may be considered as divided into the face and skull: the former being chiefly occupied by the organs of sense, and the latter by the organ of mind; it was concluded that the preponderance of one or the other would indicate the superiority of the senses, as in the lower order of animals, or of the intellect, as in man. To ascertain their proportions, Camper proposed his facial line and facial angle. The former was gained by drawing a line from the most projecting point of the forehead to the insertion of the teeth in the upper jaw; the other, by causing a horizontal line, passing through the external orifice of the ear, to intersect the facial line. This will be better understood from a sketch of four heads, which we shall mark in Camper's manner.

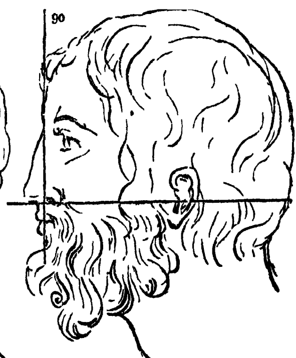
He was led to the construction of those lines by the difficulty he experienced, when young, in ascertaining the characteristic marks of the heads of different nations. This, it appeared to him, had been grievously neglected by some of the later painters, insomuch, that they made little difference between a negro and an European, except in colour. "I was set," he says, "by my master, to paint one of the beautiful pieces of Van Tempel, in which there was the figure of a Moor, that by no means pleased me. In his colour he was a black; but his features were European. As I could neither please myself, nor gain any proper directions, I desisted from the undertaking. By critically examining the prints taken from Guido Reni, C. Maratti, Seb. Ricci, and P. P. Rubens, I observed that they, in painting the countenances of the Eastern Magi, had, like Van Tempel, painted black men, but they were not Moors. The celebrated engraver, Cornelius Vischer, was the only one who appeared to me to have followed nature." Now, in this case, it happens that the painters were right, and Camper wrong, for the Moors, or inhabitants of the northern parts of Africa, belong not to the negro, but to the Caucasian variety, as we shall mention more fully when speaking on this subject; and their children, when first born, as well as their women, who are little exposed to the effects of the weather, are nearly or altogether as fair as those of the south of Europe. The Eastern Magi, too, in all probability, belonged to some Caucasian tribe; but the observation, though thus originating

Head of Negro.



Ourang.

Ancient Greek Statue.

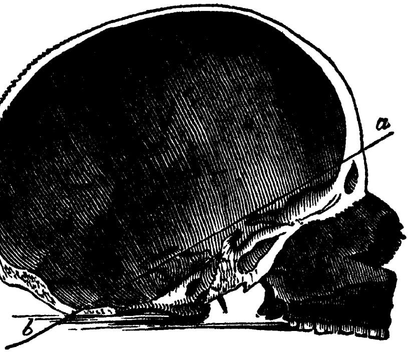


European.

in mistake, proved the cause of very useful results, for it set him on inquiring the true principles of delineating heads according to the idea intended to be conveyed.

And now, referring to our plate, we shall at once observe, what struck Camper after having drawn several heads on a horizontal plane, in order to discover the cause of their difference, that this difference may be represented by the inclination of the facial line, and is measured by the angle this line forms with the horizon, or with a line parallel to the horizon, drawn through the external opening of the ear. It is clear, then, that as the skull (the part containing the brain) augments in volume, so will the forehead be more projecting, and consequently the facial angle will increase; but as the skull diminishes, so will the forehead retreat, and the facial angle become sharper. The greatest angle is that which occurs in the human species, and in a well-formed Caucasian head, it reaches very nearly a right angle, that is, the front of the skull is situated almost perpendicularly over the face. According as this angle diminishes, so does the proportion of the intellectual to the sensorial parts of the head, and by continuing to close it, we should successively represent the facial angle of the negro, the ape, the dog, the snipe, until we at last reached fishes, in which the head going back straight from the nose, these two lines become identical or parallel, and the angle ceases altogether. The ancient Greek artists seem to have understood this point, and seeing that every diminution of the angle took away from the expression of dignity and elevation, they, in depicting their gods, to whom of course they attributed superhuman attributes, actually enlarged the angle beyond what we know it to exist in nature and in their Jupiter Tonans have made the forehead to overhang the face, as if completely to express the mastery of the intellect over the observations of the senses. It is evident that an elongation of the jaws would have the same effect on the facial angle as the diminution of the skull; and when this takes place in the lower animals, such as cranes, snipes, &c., it gives them that silly aspect, which has caused these long-billed animals to become proverbial for stupidity. Confined to the human kind, this facial angle is of much use in ascertaining the relative size of the brain, and it may even be extended with advantage to apes; because in both these, the tables of the skull are not very far from being parallel, and are not yet separated from each other but by moderate cavities, termed *frontal sinuses*. But when we descend below these to carnivorous animals, hogs, some ruminant animals, but, above all, the elephant, this measure totally fails us, as the plates of their skull are separated sometimes to a very considerable distance, and we, drawing our line according to the outer, can form no idea respecting the inner, nor, consequently, respecting the real fulness or protuberance of the brain. Blumenbach was induced to propose a different mode of estimating the proportions, but his, also, was chiefly applicable to the human head. He placed his skulls, of which he had a magnificent collection, upright, on their hinder or occipital part, and having ranged them on a table, placed himself behind, and was thus able at one glance to observe the most important points in which they differed, such as the greater or less breadth at any particular part, the projection or non-projection of the jaws beyond the level of the forehead, &c., and from these he has been able to establish many national characteristics. But the most perfect mode is that proposed by Cuvier, which consists in making a vertical section of the skull from front to rear, and then observing the relative proportions of the cavity of the brain to the part of the section, which answered as frame-work to the face, or organs of sense; in our cut the line *a b* nearly divides these parts from one another.

In the European, the area of this cavity is almost four times that of the face, not including the lower jaw. In the negro, the cavity remaining the same, the area of the section of the face is augmented about one-fifth. In the Calmuck it increases but one-tenth. The proportion is still less in the ourang-outang; in the sapajous the cavity is but double the face; n the mandrills they are nearly equal, and this is the case with nost carnivorous animals. The proportions then begin to lter; the section of the face in the hare is one-third larger han that of the brain-cavity; it is double in the porcupine,



Vertical Section of Skull.

more than double in the hog, three times its size in the hippopotamus, and almost four times in the horse. In this last example, however, it appears to us that a new element must be introduced into the calculation, as we can by no means agree that the horse is endowed with less instinct than a hare or a hog. The reason of the great elongation of the face-bones in this animal is to be sought for in the fact, that nature, while it intended it to be fleet in the course, destined it also to live on the herbage that grows on the surface of the ground. For the former purpose length of legs was evidently necessary, that it might make those astonishing stretches which enabled Flying Childers to run six miles in six minutes. But this length of leg lifted it, as it were, out of reach of its food, which, as we have said, was on the surface of the ground. There were but two ways, then, of arranging this,—either by lengthening the animal's neck, or by lengthening its head; which was preferable? The horse, being an herbivorous animal, necessarily required broad flat grinders to rub down its food into a paste before swallowing it. These grinders, then, must be inserted in large jaws, and to move the jaws, strong muscles were required. A strong muscle requires a large surface for attachment, and as the muscles which move the lower jaw have their origin on the sides of the skull, it was necessary that the skull should be large and heavy. Now, a weight is wonderfully increased by being carried on the end of a long lever, as every one knows who has seen a man attempt to raise a musquet holding it by its muzzle, at the full extent of his arm. He will probably fail, or do so with great difficulty, while we know that if he grasps the musquet in the usual way he can raise it with ease. For the same reason it would be most inconvenient to a horse, were it obliged to carry the weight of its head on the end of a long stretched-out neck; and when a horse appears with such a formation, persons who understand the subject will never buy it, because the great additional weight, thus thrown on the fore-legs, causes it soon to *founder*, and the horse is always unsafe, and liable to stumble. We see, then, clearly, why a horse's neck does not admit of being prolonged, so as to enable it to reach the ground; it was, therefore, necessary that the jaws should be so elongated as to complete the rest of the way. But this was not done with a view to giving any additional extent to the senses; therefore it would not be fair to conclude a horse the most stupid of animals, because the area of its face is four times that of its brain-cavity, though we may well affirm that man is the most intellectual of animals, because his brain-cavity is four times the area of his face. It is evident, then, that even Cuvier's principle must be adopted with restrictions; it has also this inconvenience, that it is only applicable to an animal when dead, and can give us no information while it lives.

The idea long prevailed that the brain of man was actually larger than that of all other animals, and that thence arose his intellectual superiority. In the greater number of cases this is true, and, indeed, we know of no exception but the elephant, and perhaps some of the larger cetacea. Thus, the largest brain which Sœmmering met with in horses weighed but 1 lb. 4 oz., while the smallest human brain of an adult was 2lbs. $5\frac{1}{2}$oz., and this we know to be much below the average. Another method, proposed as an improvement on this, was to consider the brain not in its absolute weight, but as compared with the weight of the entire body. This, when applied to the ordinary domestic animals, was found so satisfactory, that, without going further, it was laid down as a rule that man had, of all animals, the heaviest brain in proportion to his entire body. Subsequent investigations, however, have shown this rule to be more fallacious than the old one; in fact, the singular changes that may take place in a man's body relatively to his bulk and weight, and which, consequently, alter the proportions existing between it and the brain, while the actual size of the brain remains the same, should have indicated the absurdity of attempting an estimate in this way. Thus, say a young slender man weighs 140 lbs., and his brain 4 lbs., the proportion will then be $\frac{1}{35}$th. This is about the proportion that exists in ourang-outangs; in the coaita monkey it is $\frac{1}{41}$, in the mangabey $\frac{1}{48}$, in the mole $\frac{1}{38}$, in the mouse $\frac{1}{43}$, &c.: so far, then, he is above these animals. But suppose this young man becomes extremely fat, and rises in weight to 200 lbs., or even 280 lbs., which we not uncommonly see, the numbers representing his proportion of brain would then fall to $\frac{1}{50}$th or $\frac{1}{70}$th, and so he is all at once reduced below all those animals, which a few years previously he had ranked above, yet, all the time, his brain has not altered, for no fat can collect there. Independently, however, of this objection, a scale drawn up on this principle presents numerous anomalies. Several of the smaller birds would rank much above us: a chaffinch with a brain $\frac{1}{27}$th of its entire weight, a sparrow $\frac{1}{25}$th, a canary-bird $\frac{1}{14}$th, exceed us in a degree for which their manners and habits in no way account. The horse, whose brain is represented by $\frac{1}{700}$th, would be beneath the ass $\frac{1}{254}$th, and the "half-reasoning" elephant $\frac{1}{500}$th, reduced almost to the lowest ranks of the mammalia, would be beneath the mole $\frac{1}{38}$th, the rabbit $\frac{1}{140}$th, the sheep $\frac{1}{350}$th, and the calf $\frac{1}{219}$th!

Were any further reason necessary to show the inefficacy of this rule, it would be found in the fact that the brain at birth, when its incapacity is notorious, bears a much greater proportion to the body than the brain of an adult, when in the full exercise of all its functions. The cause of this preponderance is to be sought for in the fact, mentioned by those who have studied the growth of the fœtus, that the upper part of the body is sooner formed and earlier developed than the lower; and the final cause of this seems to lie in the greater utility of those parts to the preservation of the animal; thus, it is obviously useful that an infant should have the government, in a certain measure, of its hands, before it is able to go alone, while in other animals, such as the walking birds, the order is reversed; here it is of advantage that the anlmal should run before it flies; accordingly, the young partridge follows the mother with the shell still adhering to its back. There still remains one other mode of estimating the brain, and that is, not absolutely, or in proportion to the bulk of the whole body, but in proportion to the bulk of the nerves to which it gives origin. This mode was proposed by Sœmmering in 1788, and is founded on the supposition that the whole nervous matter of the body can be divided into two parts, the one *sensorial*, or employed directly about the operations of the senses, and, therefore, connected with animal life; the other *mental*, or reserved for the service of the thinking and reflecting principle. To the former of these divisions belong all the nerves, with the spinal marrow, and as much of the base of the brain as seems directly connected with their origins, and, therefore, necessary to the proper execution of their functions; to the latter, all the upper remaining part of the brain, for which no other office can be assigned than that of the organ of the intellect. His assertion, then, founded on this division, is, that in man the *mental* nervous matter bears a greater proportion to the *sensorial* than in any other animal; and that in all animals the degree of perfection of their instinct will be in direct proportion with the preponderance of the former over the latter.

Cuvier undertook to refute this theory in his *Leçons d'Anatomie Comparée*, but in doing so, he only took into account the spinal marrow, and omitted noticing the nerves. How far this may alter his facts, we cannot say; but it is clear that he has not taken the whole standard as laid down by Sœmmering, and since confirmed by Ebell, Munro, Blumenbach, and Vicq d'Azyr, therefore we cannot admit his argument as decisive. As, however, the table which he has constructed shows the general accuracy of Sœmmering's principle, there being but one *apparent* exception, we shall give its substance.

In man, the breadth of the brain is seven times as great as that of the spinal marrow, just where it is leaving the skull: in the Chinese bonneted-monkey four times; in the short-tailed magot five times; in the dog about twice; in the cat nearly three times; in the hog and ram about once and a half; in the stag and calf twice and a half; in the ox and horse nearly three times; and in the *dolphin* thirteen times. This is the only exception stated, and, as we have shown above, it proves nothing, because the nerves are completely left out of account*; we might add, that measuring the parts only in one direction, breadth is incompetent to afford satisfactory information as to their bulk. We are, therefore, inclined, under the sanction of such great names as we have quoted, to admit Sœmmering's standard, and say that man has, of all animals, the largest brain in proportion to the rest of the nervous system.

But we have no means of estimating this before death, and even then the measurement is very difficult, which may be one of the causes why exceptions are not known.

The next question which presents itself, having settled *how* man should be considered as exceeding in brain all other animals, is, whether the excess of intellectual powers of one

* In fact, this alters the whole statement; for, in the "*Dissection of the* brain of a Dolphin" by Tiedemann, who expressly asserts the accuracy of Sœmmering's test, it is stated that "the *cerebrum* of the dolphin, in proportion to the size of the nerves, spinal marrow, and cerebellum, is of much smaller size than the human cerebrum."

man over those of another are accompanied by a greater portion of cerebral matter, or, in other words, whether the wisest man has the largest brain? And, as we have just shown that absolute size of brain will not make an elephant wiser than a man, we might almost conclude *à priori*, that absolute size of brain will not make one man wiser than another. However, this is a point which we should rather have determined by observations than by argument, did we know of any sufficiently numerous and trustworthy to be admitted as proof. Phrenologists have taken a good deal of pains respecting this question, yet their conclusions do not seem very decided. It appears, according to Mr. Combe, their most ingenious defender, that size of brain must be considered under certain modifying circumstances, such as health, form, activity, and temperament, or fineness of texture. The not attending to these modifying circumstances will, he says, account for the common saying about large heads having "little wit." If, however, all these circumstances are the same, he then asserts that the larger brain will denote the superior intellect. This is a very *safe* assertion; but the necessity of taking into account modifying circumstances, some of which can in no way be known until the individual is dead, would seem at once to put an end to the science as a means of estimating faculties and feelings. Mr. Combe, indeed, asserts that the constitution of the brain may be guessed from the general temperament of the body: thus, that a person of lymphatic temperament will have "a brain slow, languid, and feeble in action," while in a person of nervous temperament the "mental manifestations will be proportionally vivacious*;" but, in the first place, this connexion of certain dispositions with the general habit or temperament of the body was not left for phrenologists to observe, and in the second place it has nothing to do with the point before us, which is not the mode of action, but "the fineness of texture of an organ," which is mentioned as one of the modifying causes. We might also add the extreme difficulty of deciding a man to be of this or that

* Combe's *System of Phrenology*, pp. 32-3.

temperament, and the minute shades by which these temperaments run into each other, so as to render their appreciation in the highest degree uncertain, and conclusions founded upon them, of course, extremely liable to fallacy. Furthermore, it is well known that the same individual may, at different periods of his life, be of different temperaments. In fact this modification, though generally admitted as necessary to the theory of phrenology, and useful, as occasionally affording a convenient mode of escape from a mistake, is seldom, if ever, had recourse to in practice, the phrenologist undertaking to pronounce on character from a dead skull or a plaster cast, without making the least inquiry respecting this "modifying circumstance."

Size, then, would appear to be the standard they apply to estimate intellect, for though they reject this doctrine, and insist on the necessity of considering other circumstances, we have just passed in review one of these, which they neither appear to apply themselves, nor can they show how another may apply it. Yet, as a general proposition, it will, we apprehend, be admitted as true, that persons of very remarkable talents have usually* a full well-developed brain, though it by no means follows that people with large heads have distinguished talents. Dr. Milligan has given a table, furnished by a hatter in extensive business, whose conclusions were, therefore, founded on a sufficient number of examinations, and were also unbiassed by theory, from which it appears, that in the upper and educated classes of society, the head is generally superior in size to that of the lower orders. The same fact has

* We need scarcely say that the observation was made before phrenology was thought of, and has nothing to do with the peculiar doctrines brought forward under that name: it is, at the same time, an observation to which many exceptions must be admitted. The heads of Byron, Shelley, and Keats were all remarkably small; whether the deficiency existed in the intellectual faculties occupying the front of the head, or the animal propensities at its back, will, we think, puzzle phrenologists to decide. "Keats's head," says Mr. Leigh Hunt, "was a puzzle to the phrenologists, being remarkably small in the skull, a singularity which he had, in common with Lord Byron and Mr. Shelley, neither of whose hats I could ever get on."—*Life of Byron*, p. 246.

been asserted by a gentleman who carefully examined in London the hats made at the west end, and also those made by manufacturers who chiefly supplied sailors, coal-heavers, and such persons, and in all cases the average size of those latter hats was considerably inferior to that of the former. A want of attending to this fact is also stated to have caused a serious disappointment to a Parisian speculator, who sent out a number of hats to the colonies, and had them all returned as too large.

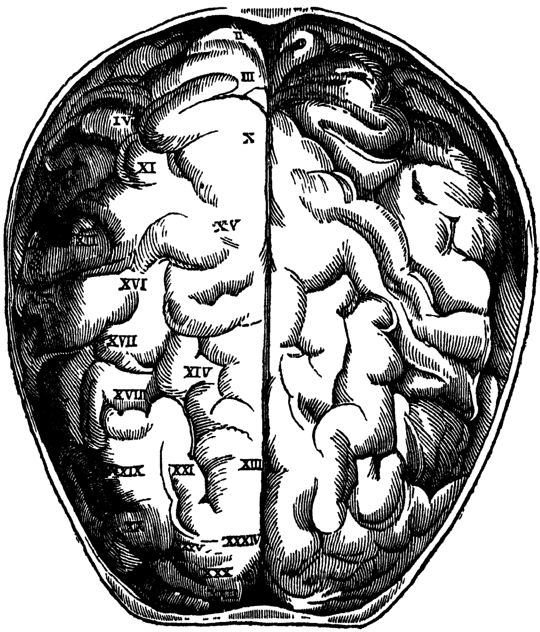
To generalize facts of this nature, admitting of so many exceptions, into scientific principles, and assume them as universally correct, and as suitable foundations for the erection of a new doctrine, is truly absurd: yet, this it is which craniologists have done. Gall, say they, observed certain regions of the skull unusually prominent in persons noted for the possession of some faculty or propensity in a very high degree. He thence inferred a connexion between the formation and the mental manifestation; thence that the latter would always have its accompanying protuberance or fulness; next, that this fulness was caused by the subjacent part of the brains pushing out the skull; thence, that the brain, as it might sprout out at twenty-four different places, was composed of twenty-four different organs; and, finally, that, therefore, from a careful measurement of those organs, the faculties and disposition of the mind might be ascertained. In all this, it is evident, there was never a word about temperament, structure, or other modifying circumstances; it was all size—downright, absolute size. Such a doctrine as this we could at least understand; however improbable, there was nothing in it actually impossible, and it seemed a fair subject for actual examination. By this rule, accordingly, it was tried, and, with a measuring compass in his hands, Mr. Stone, of Edinburgh, quickly showed that, were there any truth in the doctrine, as delivered above, Voltaire should have been a better murderer than Thurtell, and a greater thief than Haggart, that this latter should have had more wit than Sheridan, besides possessing great histrionic and pictorial power; that Clara Fisher, at eight years old, had all the elements for becoming a female Raphael; and that Thurtell, with veneration *large*, benevolence *very large*, and adhesiveness *very large*, must have been a religious, pious, and amiable man, totally incapable of outraging the laws of God, or murdering one whom he had so long considered and called his friend! The attempt made by phrenologists to reconcile this latter developement with the actual character of the man, we look on as a more complete disclosure of the utter absurdity of their entire system, than *could* be offered by their most determined opponents; we give it in their own words from the *Phrenological Journal*, vol. i., p. 331, begging attention to the lines in italics.

"The murder committed by Thurtell was a predetermined, cold-blooded deed; nothing can justify it. Revenge against Weare, for having gambled too successfully, and, as he imagined, unfairly with him, prompted it; *but there is every probability that Thurtell laid the unwarrantable unction to his soul, that he would do a service to others by destroying Weare. He considered Weare as a complete rascal, one who had robbed many as well as himself, and one who, if he lived, would have robbed many more!!*"

A theory which can thus convert benevolence into the active cause of murder, needs no further examination on these grounds: "by its fruits ye shall know it."

Let us, however, consider what are termed the anatomical proofs of the theory, for which, as being matters of which they are entirely ignorant, the great mass of phrenologists profess the highest respect and veneration.

A favourite object of speculation with the older anatomists and physiologists, was, what they termed the *sensorium commune*, the common point of the brain, to which they supposed all impressions brought by nerves, before perception was produced, and from which, they argued, all volition must emanate; in short, their *sensorium commune* was neither more nor less than the seat of the soul. In this search abundant absurdities were perpetrated, and ridiculous assertions ventured. The parts of the brain, termed the *pineal gland*, the *corpus callosum*, the *pons Varolii*, the *corpora striata*, besides the *medulla oblongata*, and the water in the ventricles, or fine exhalation with which they are bedewed, were, in turns, assigned this honourable office. To us it appears that a cause of error existed in the nature of the search, as its object was to invest an immaterial principle with one of the attributes of material bodies,—locality. The attempt made to trace the nerves of the senses to a common origin, though more rational, has been equally unsuccessful. On the contrary, the accurate dissections of Spurzheim have render it highly probable that there is no such part of the brain existing, but that fibres originally diverging from the top of the spinal marrow, and reinforced at different parts by collections of gray matter, form the general structure of the hemispheres, while other fibres arising in those, and crossing from one side to the other, tend to combine the actions of the brain, as though the object were that it should act as one whole. And, be it observed, he has never shown, nor, as far as we are aware, attempted to show, that these fibres of connexion run between *similar organs on opposite sides*, (for all organs are maintained by phrenologists to be double, one on the right, the other on the left, side of the brain,) but merely between these two great divisions of the organ. Therefore, as far as their own anatomy bears on this point, it would rather indicate a unity of action between the two hemispheres, than between any particular portions of those hemispheres; *i. e.*, it would rather evincé the brain to be a single organ, than made up of many organs. But, in fact, as far as anatomy can decide the question, it is altogether against the phrenological theory. So far is the brain from presenting to the eye, or the knife of the dissector, a number of distinct organs, uniform in situation, and capable of having their size and shape appreciated or measured, that it originates from a common bundle of fibres, spread out, and folded on the surface into convolutions, which convolutions we can show to be absolutely continuous, presenting no appreciable line of separation, irregular in their situation, size, and form, in different heads, and *on the different sides of the same head;* in short, presenting no more approach to uniformity, than the windings of the small intestine. To put this matter beyond doubt, we present our readers with a representation of a brain, from which the skull and membranous coverings have been removed, copied from one of Spurzheim's own plates, in which, therefore, we may suppose that he has gone as far in selecting and depicting an instance of uniformity, as could be done at all consistently with nature; and in this plate we beg our readers to compare for themselves the convolutions of one side with those of the other.



We also request them to take a pencil, and endeavour to point out, or ask any of their phrenological friends to point out to them, where any of those organs, which we have marked after Spurzheim, terminates, and where the next to it begins; or suppose one of the organs, as phrenologists say, becomes "much developed," so as to encroach on a neighbouring organ, say that No. XIII., Benevolence, has encroached on No. XIV., Veneration; how are we to know that it is not No. XIV. which has enlarged and encroached on No. XIII.? In short, how are we to decide an inch of convolution at the place where two organs unite, to belong to one of them, rather than the other? And if this be impossible, as we unhesitatingly assert, and as no phrenologist has yet attempted to demonstrate* the reverse, we are not justified in considering it truly absurd to talk of the size of an organ, when, for all the phrenologist knows, he may actually be measuring in half the adjoining organ? But this refers only to the measurement of an organ on the surface, or where its base is supposed to bulge out in one of the convolutions: there is another of its dimensions which also requires to be considered, for the organ being a cone, extending from the top of the spinal marrow, it becomes necessary to ascertain its long diameter, and for this purpose we are directed to measure from the opening of the external ear to the prominence beneath which the organ is situated. Now, this may do indifferently well to measure an organ, which terminates completely in front, or completely on the hinder part of the head, though anatomy again interferes, and teaches us that the orifice of the external ear is by no means an exact indication of the situation at the top of the spinal marrow, from which these cones are supposed to set out.

To ascertain this matter, we have taken a large number of skulls, as any one can do by going to the Hunterian Museum at the Royal College of Surgeons, and stretching a string between the centre of the openings of the external ears, found

* We use the term anatomically: we are aware that Spurzheim addressed a paper on the subject to the Royal Society, which appeared too contemptible to merit a place in their *Transactions*.

that it most frequently passed just over the anterior condyles, answering to the front of the spinal marrow as it enters the brain; in other cases the string cut the whole at about a third from its anterior edge, while in others it passed altogether in front of the hole, sometimes to the third of an inch, and this, we may remark by the way, was exactly the case in the head of the pongo. In all those heads, therefore, supposing, which is almost the first phrenological proposition, that the difference between the intellectual faculties and the animal propensities was to be estimated by the length of line from the opening of the external ear to the projection of the front of the forehead in the one instance, and to that at the back of the head in the other, it is clear that we should add to the latter sometimes two-thirds, sometimes the whole, and sometimes even more than the whole breadth of the spinal marrow at its top, and yet, this is a difference of which phrenologists take no notice, and which does not even enter into their calculations. But the sources of difficulty increase when we come to measure the length of a lateral organ, such, for instance, as Secretiveness, No. VII., or Acquisitiveness, No. VIII., in which a moment's consideration will show any one that the line included between the leg of his callipers placed in the external ear, and the other leg placed over the organ in question, can never give the linear diameter of that organ, in other words, the length from the top of the medulla oblongata to the surface of the organ; and if we attempt to gain our ends by measuring from the organ on one side to the organ on the other, the approximation must be equally rude, as it could only be in the case of the included line, and the two organs occupying exactly the same plane and direction, that its bisection could give their linear measurement, and we beg to know which of the organs at all approximates to this coincidence? In fact, the great error of phrenologists has been, the attempt to reduce to the scientific accuracy of measurement and division, certain propositions which were matter of popular, we had almost said of instinctive, belief: and the more they have attempted to depart from the original vagueness and generality of this belief, the deeper have they run into erro and the more fully have they manifested the folly of their pre-tensions. All people believe, in a general way, that a well-shaped and full-sized brain is the organ of a more active anc powerful intellect, and that this cannot be present when the organ is defective or misshapen; but when theorists attempt to break up the mind into a number of supposed original faculties, such as no metaphysician will, for a moment admit, and the brain into an equal number of organs, which the anatomist in vain asks to be shown, and then proceeds to attach one of the former (unadmitted suppositions) as a mode of action to one of the latter (undemonstrated existences), and, further, to explain how each of these organs may modify, or be modified by the action of any, or all the rest, they get enveloped in such a labyrinth of baseless speculation and visionary fancies, that they are utterly bewildered by the complexity of their own imaginations, and are left to seek, amidst a balance of errors, the possibility of an approximation to the vague general principle from which they had originally started. This is, in truth, all that craniology can do, and to this it is fast returning. The unanswerable fact that, for all they can tell during life, one-third of the most important organs* may be situated within a frontal sinus, of which the external wall may be removed from the internal by a variable distance, and not bear to its surface the slightest parallelism or resemblance, shows the complete untenableneness of their fundamental proposition, that the shape and size of the brain is faithfully represented, and can be seen and measured upon the external plate of the skull. Every anatomist also knows, that protuberances on the different bones of the skull, at the points where ossification commenced, result from thickness of bone, not from increase of

* Perhaps, also, we should add that about one-third of the convolutions of the brain are situated on its base, and to these *no faculty at all* is attributed, the whole mind being mapped out, and apportioned to the superior and lateral convolutions. Will craniologists have the kindness to tell us why one convolution should be an organ and another not? In truth, the great difficulty to be overcome in refuting their doctrine, is to find out what they consider its point of

th rain; and they also know how much greater may be this a thickness in some heads than others. The impossibility, indi- bated by these facts, of obtaining any thing like accurate ideas f respecting the minute portions of brain, to which craniologists l confine certain faculties, scarce requires being insisted on.

We think we have now shown that there is no evidence from anatomy of the brain being divided into many organs, and that there is direct evidence, that did these organs really exist, still the methods proposed for ascertaining their size are altogether inadequate.

The only reply attempted by phrenologists is, that we have made the mistake of arguing respecting absolute size, while they speak of relative size; and that we talk of comparing organs in different heads, while they compare the organs of the same head. But this is a simple evasion. Let us admit for the present (says an acute American writer on this subject) that there are no such difficulties in the way as the difference between the outer and inner surfaces of the skull, a fact of which any one may satisfy himself, by passing a piece of the bone between his thumb and finger. Let us leave these out of the case, and, in the very teeth of our senses of sight and touch, let us suppose that skulls are, as to their outer and inner surfaces, equal and parallel. Let us enter with an humble teachableness the schools of phrenology. We are first pointed to a head, in which a particular organ is large. Large and small being relative terms, we naturally set about examining different heads, to settle an average or standard. This method of proceeding, however, is cut short by the remark, that the size of organs is not to be estimated by the organs of other heads, but by those of the same head. The destructiveness is large, in comparison to the benevolence, which is small. This attempt to escape from the difficulties of an average we take to be utterly futile: there is no escape at all. of course, compared with each other, are necessarily or small. Thus, if we judge from the plaster busts, the of destructiveness in any man's head is always larger than the *organ of music*; but the question in any particular case, is not whether the organ of destructiveness is absolutely large, compared with the organ of benevolence, but how the excess of the former above a certain average, or normal standard, compares with the excess or deficiency of the latter in regard to the same standard. Thus, we are continually driven back to the necessity of a standard; and for a standard we in vain call on the craniologists: they seem too well aware how fatal it would prove to their pretensions.

There is one organ in the brain which certainly is distinct, and may be pointed out by the anatomist as sufficiently and fairly separable from the rest of the mass; this is the *cerebellum*. Now, to this, craniologists attribute a peculiar propensity or feeling, common to us with the lower animals, and, as we here admit the existence of the organ, it becomes a simple question of experience, how far it is found to be proportioned in developement to the propensity which has been assigned to it. The arguments generally adduced in its favour are from comparative and human physiology: we shall select an instance of both. The frog is, of all reptiles, perhaps that one which exhibits most unequivocally the feeling in question: in the frog the cerebellum is so extremely small, that its very existence was, until lately, a matter of dispute. In Férussac's *Bulletin* for October, 1831, under the head Sciences Médicales, may be found the details of a case, in which this part of the brain *did not exist at all*, while the propensity was rather remarkably developed. We recommend both these facts to the attention of craniologists, and request they will oblige us with any explanation of them that their ingenuity may suggest: until we receive that, we fear we must consider them fatal to the organ No. I., the *only* organ which they can show to exist!

We have thus mentioned a few of the anatomical objections which occur to this theory: its present importance would not warrant us in pushing the subject further, than briefly to notice a few other objections to which it is liable. Pathology furnishes an important one of these. A slight injury to the brain will often cause total alienation of the mind, not an affection of that particular faculty or propensity, of which the injured part was supposed to be the organ. On the other hand most extensive injuries may take place, and even a great part of the substance of the brain be removed, without any apparent diminution of mental power, or loss of any particular faculty. "The truth is," says Dr. Roget, "that there is not a single part of the encephalon which has not, in one case or other, been impaired, destroyed, or found defective, without any apparent change in the sensitive, intellectual, or moral faculties." Haller made a large collection of cases, tending to establish this fact; and Dr. Ferrier, in the fourth volume of the *Manchester Transactions*, has given several additional cases, so complete and indisputable, that Spurzheim could find no further reply to them, than a vague charge of inaccuracy, or mistake in the observers. It has been attempted to escape from this difficulty, by alleging the duplicity of organs; and that though the organ on one side may have been affected, still the organ on the other may have been entire, and capable of its proper function; but, independently of the fact, that this duplicity of organs is a mere assumption, and one involving great and unnecessary difficulties, when attempted to be reconciled with the well-known unity of mental action, the explanation totally fails in the case of defective cerebellum before alluded to, in which *both* sides, or, if you will, *both* organs were gone; neither will it answer in those cases of hydrocephalus, in which every convolution of the brain is unfolded and distended, while the mind still remains entire. Indeed, we might almost leave this theory to be refuted by the facts brought in its support, such as Gall's story of the man who was mad at one side of his head, and observed his madness with the other side!

Pathology supplies another objection to Gall's theories in the well-known fact, that in mental derangement, the faculties most frequently impaired, are memory, volition, judgment, and attention; but these in Gall's system are *no faculties at* *all*, have no organ, but are represented as affections of all faculties.

It is also clear, that in cases of monomania, the affection of the brain should always exist in, and be accurately confined to, the organ of the peculiarly disordered faculty. That this is the case, we scarcely know any one who will venture to assert. As one instance of the contrary, we shall cite a case given by Dr. Haslam, of a young woman aged twenty, whose madness was occasioned by religious enthusiasm and a too-frequent attendance on conventicles. When admitted, she was in a very wretched and unhappy condition, and terrified with the most alarming apprehensions for the salvation of her soul. She sang, wept, and prayed alternately; and, after continuing some time in this forlorn and pitiable state, she died. Of course, craniologists would here lay it down, that there was considerable disease of the organ of veneration, and that little derangement would be found elsewhere. An examination took place, and the result was, that the *pia mater*, or membrane investing the different convolutions of the brain, was found inflamed, and an extravasated blotch about the size of a shilling was seen upon the membrane in the middle of the lateral part of the right lobe of the cerebrum. There was no effusion between the membranes or into the ventricles, but a general determination of blood to the contents of the cranium.

These facts appear to require no comment.

Phrenologists, however, when driven from all tenable ground of argument, usually as a last resource, exclaim, "But our science is founded in nature and truth; experience attests its universal applicability; to that we appeal as full and sufficient confimation, and on that we rest our whole cause." If they did so honestly, they would long since have resigned their whole cause. In 1829, Mr. Stone read before the Medic‹s Society of Edinburgh, of which he was the President, ‹ot "Observations on the Phrenological developement of Bur‹ to Hare, and other atrocious murderers; measurements of ‹gy heads of the most notorious thieves confined in the Edinbu‹ ‹he jail and bridewell, and of various individuals, English, Scotch, and Irish, presenting an extensive series of facts subversive of Phrenology." His measurements, that there should be no question of their accuracy, were made always in the presence of other persons, frequently of craniologists, who all admitted their perfect fairness. He took, for the purpose of an average, fifty skulls, chiefly British, belonging to Sir William Hamilton's collection, and fifty skulls collected by Dr. Spurzheim, and deposited by him in the Edinburgh Museum. He not only took the length, breadth, and height of each, according to the mode directed by craniologists, but ascertained the weight of brain they had contained, and the absolute and relative size of the organs, and from all these data carefully and impartially collected, he demonstrated, that in fifteen murderers selected chiefly for their notorious blood-thirstiness and depravity, *every one of them* had the organ of destructiveness *absolutely* less than the average of ordinary heads; and that thirteen of them had it, also, *relatively less* when compared with the whole contents of the skull. He further showed, that twelve of these men had the organ of benevolence more largely developed than the average, that their conscientiousness was also full, and that the skulls generally exhibited no remarkable deficiency of brain before the ear, or preponderance of developement in the region to which the animal propensities are referred. To render his investigation still more complete, he took the measurements of the head of Dr. David Gregory, who had been Professor of Mathematics in the University of Edinburgh, and subsequently appointed Savilian Professor of Astronomy in Oxford. He was the distinguished friend and companion of Sir Isaac Newton. He was the learned author of several valuable works on mathematical science; and a man of high moral and intellectual virtue. The skull was well thenticated by the gentlemen who took it from the place of terment, and presented it to the person in whose museum r. Stone had an opportunity of examining it. The result of is examination was, that the organ of destructiveness in the learned Professor was, in its absolute size, *larger* than the same organ in every murderer included in the induction; and even in proportion to the general size of the brain, larger than the same in Burke, Haggart, Anderson, Glen, Balfour, Pepe, Mortimer Collins, Clydesdale, and Divan.

The organ of combativeness in the Professor was also *larger* than the same organ in every one of the murderers.

His organ of acquisitiveness was the same as Balfour's, and *larger* than the same organ in all the rest, including even Gordon, M'Keon, and Haggart, who were noted thieves.

His organ of secretiveness was also *larger* than in each of the murderers.

As to the organ of benevolence, Burke had it in *absolute* size the *same* as the Professor. Four other murderers *nearly the same;* and seven others, all atrocious miscreants, had it actually *larger*. Even in proportion to the entire size of the brain, eleven out of these twelve had the organ of benevolence *larger* than the learned and virtuous Professor.

The organ of conscientiousness was next examined, when it appeared that Clydesdale and Kerr had this organ in its absolute size *larger;* and, in proportion to the entire brain, Burke, Anderson, Gordon, Lingard, Pepe, Mortimer Collins, Clydesdale, and M'Keon had each this organ of *greater size* than the Professor.

He then proceeded to the intellectual organs, and measuring the organ of comparison on the heads of the murderers, found that four of them had it *the same*, three *nearly the same*, and three *larger* than the Professor.

Causality was next tested, and as this is the organ to which is attributed the power of tracing the relations of cause and effect, and of reasoning closely, we beg attention to the results which we state in full. On the skull of Dr. David Gregory, the measurement of this organ taken from the opening of the ear to the organ on the *opposite* side, was 5.1 *inches*. By taking the measurement in this way, an accurate report is also given of the general anterior cerebral developement.

The organ measured in the same manner on the skulls of the murderers, was:—

In Haggart . . .	5.25 *inches*,	which is *larger* than the Professor's.
Scott	5.2 . .	which is also *larger*.
Anderson . . .	5.3 . .	which is also *larger*.
Glen	5.35 . .	which is also *larger*.
Balfour . . .	5.4 . .	which is also *larger*.
Macmillan . .	5.2 . .	which is also *larger*.
Mortimer Collins	5.5 . .	which is also *larger*.
Clydesdale . .	5.3 . .	which is also *larger*.
M'Keon . . .	5.4 . .	which is also *larger*.
Buchanan . .	5.3 . .	which is also *larger*.
Kerr	5.7 . .	which is also *larger!!!*

Hence all these criminals appear to have had a greater quantity of brain before the ear, that is, a finer intellectual developement, than Dr. David Gregory, Savilian Professor of Astronomy to the University of Oxford.

But one thing remained: the animal propensities are, we are told, situated in the posterior region of the brain, so that they are to be measured by the quantity of it contained in the space behind the ears, and this is to be measured from the opening of the ear to the spine of the occiput. Examined in this way, the cranium of Dr. Gregory gave 4.5 *inches*.

Of Haggart . . .	4.05 *inches*,	which is *less* than the Professor's.
Scott	4 05 . .	which is *less*.
Glen	4.3 . .	which is *less*.
Anderson . . .	4.05 . .	which is *less*.
Pepe	3.6 . .	which is *much less*.
Balfour . . .	3.7 . .	which is *much less*.
Gordon . . .	3.5 . .	which is *very much less*.
Lingard . . .	3.75 . .	which is *much less*.
Macmillan . .	3.8 . .	which is *less*.
Mortimer Collins	3.8 . .	which is *less*.
Clydesdale . .	3.7 . .	which is *much less*.
M'Keon . . .	3.7 . .	which is *much less*.
Kerr	4. . .	which is *less*.
Divan	3.9 . .	which is *less*.
Buchanan . .	3.5 . .	which is *very much less!!!*

So that this grave, learned, and virtuous professor, had less intellectual power and more animal propensity than the whole string of brutal, debauched, abandoned, and atrocious murderers given above!

We hope our readers will consider this a sufficient reply to the constantly proposed appeal to experience: phrenologists themselves say, "Assail our facts, and we are undone; *Phrenology admits of no exceptions**."

We have thus attempted to prove three propositions; first, that the brain is not the mind; second, that it is the organ of the mind; and third, that it is not divisible into twenty-four or thirty-five distinct organs, each exercising a peculiar and appropriate mental faculty or function, as is supposed by craniologists. Certain parts, however, exist in it, and can be seen sufficiently distinct from others; and experimental attempts have been made to assign to them their proper offices, if such they should be found to possess apart from the rest of the mass. To such attempts, it has been objected that the general disturbance which must arise in the entire system, when so delicate a part is wounded or cut away, together with the painful and unnatural situation in which the animal is thereby placed, must render all observations respecting its faculties and actions in such circumstances extremely liable to error and confusion. Thus, a bird operated on in this manner, will no longer sing, though the organs of voice are perfect, and have not been in any way interfered with: but the conclusion which might be drawn, that the bird had ceased to sing because certain parts of the brain had been interfered with; and, *therefore*, that the organ of singing was situated in the brain, would evidently be erroneous. In the same way, if certain mental faculties appear lost after the removal of certain parts of the brain, we can by no means safely conclude that these faculties were exercised by these parts as their organs; inasmuch as the loss may have been merely consequent on the general disturbance produced by the injury. From this objection experiments may be to a certain extent freed, by keeping the animal until it recovers, and then observing (if the in-

* *Phrenological Journal*, Vol. iii., p. 256.

juries be of such a nature as to allow of its perfect restoration to health) whether any of its faculties have been permanently lost; in which case we might, if the results were invariable, fairly connect the faculties with the parts removed. Another objection, however, and one which is particularly applicable to the experiments of Haller and a host of experiment-makers in his time, and that immediately succeeding, is that the parts of the brain are held together by such a continuity of structure, and present such numerous communications, that the difficulty becomes very great, of saying exactly to which of them you have limited the injury inflicted, and consequently, to which of them should be referred the phænomena produced. The improvements gradually making in our acquaintance with the minute anatomy of the brain, evidently present the only mode of avoiding this objection, and we think every possible advantage of these has been taken by M. Flourens in conducting his admirable experiments; of which, as conceiving them the most trust-worthy we have on the subject, we shall give a brief notice. It is but fair, however, that we should first give honour to him to whom honour is due: our own countryman, Sir Charles Bell, by his demonstration of the perfect distinctness in function between the two great classes of nerves, the one destined for sensation, the other for motion, pointed out the way to almost all the discoveries which have since been made in that field; and we regret to say, that our French neighbours, with more ingenuity than honour, while availing themselves of his facts, have neglected to acknowledge the obligation. His claims, however, are now so generally acknowledged, that it is unnecessary we should say anything on that head.

M. Flourens first set about re-demonstrating, with some additional circumstances, the difference between the seat of sensation and that of motion. He found, that when he pricked or in any way irritated the spinal marrow, proceeding from its extremity towards its centre, he uniformly produced strong muscular contractions, until he arrrived at a certain point almost at the level of the brain, where the contractions ceased, and the animal remained as quiet and undisturbed as though no irritation was being applied. He then made a counter-experiment, by commencing in front of the brain, and proceeding to prick and cut it in different points which produced no effect until he had arrived at the point already indicated; as soon as he had passed which, the contractions again commenced. Now below this point was the spinal marrow, including the *medulla oblongata* already figured: above it was the brain. The conclusion then was obvious, that the nerves proceeding from the spinal marrow were those immediately concerned in producing the motions of the body; the brain had some other office—what was that? To the resolution of this question, M. Flourens applied himself, and as he found it impossible to see the organs of which phrenologists speak, he determined that his experiments should rather be directed to those parts which he could see: observing, therefore, the obvious separation, which we have already mentioned, between the *cerebrum* or brain proper, and the *cerebellum;* observing, also, certain rounded little tubercular masses (usually named *tubercula quadrigemina*) situated just at the point where his irritations had ceased to produce contractions, and which, from their connexion with the root of the optic nerves, and position at the junction of the brain and spinal marrow, appeared to be of importance; he resolved to attempt ascertaining the functions or offices of these three parts, the *cerebrum*, *cerebellum*, and *tubercula quadrigemina*, and for this purpose made the following experiments.

He removed, by successive small slices, the cerebellum of a pigeon; and as he proceeded, the bird lost, first, the power of flying, next of walking, next of standing steadily. It remained in any situation in which it was placed, not because it did not *wish* to change, nor because it wanted muscular contraction, but because it was incapable of *combining* that muscular contraction so as to produce motion of the kind desired. Thus, if menaced by a blow, the bird evidently was aware of its danger, wished to avoid it, and writhed itself into a thousand contortions to escape; but the muscular contractions, not being combined or directed to one end, proved of no use. Again, when placed on its back, it disliked the position, made a thousand vain efforts to rise, and finished by remaining as it was.

In another pigeon, the cerebellum was also removed by layers from before backwards, and the effects are thus described. The equilibrium was lost almost completely; the animal had great difficulty in keeping itself standing, and could only accomplish it by the aid of its wings and tail. When it walked, its steps were unsteady and tottering, and gave it all the appearance of an animal that was *drunk;* so that frequently in its efforts to advance it fell and rolled over. When the last layers had been removed, all sort of harmony or combination of motion was entirely lost: it could no longer either fly, walk, or stand. These faculties were lost by little and little, as each successive layer was removed; and M. Flourens found, that you could with certainty, by continuing your excision to a certain extent, destroy either or both of the former, without affecting the latter. These faculties, even the last, are lost in a gradual manner, becoming more and more imperfect before they are quite abolished. The animal, as regards standing, commenced by being unable to remain long balanced on its legs: it tottered almost every instant; then its feet no longer sufficed; it was obliged to assist itself with its wings and its tail; finally, every upright position became impossible, the animal made incredible efforts to gain such a position, but in vain. The power of walking was lost in a manner similarly gradual. The animal at first had a tottering gait, quite similar to that of a drunken man; then it assisted itself with its wings, then it could no longer walk at all. "At the removal of the middle layers," says M. Flourens, "the pigeon on which I was experimenting saw and heard perfectly well; it uttered no complaint, its appearance was gay and lively. From its general air, no person would have suspected that it already wanted half its cerebellum; but *en révanche*, its gait was very tottering and uncertain, and it soon began to assist itself with its wings. I continued to cut. The animal lost totally the power of walking; its feet no longer sufficed for standing; it could merely support itself on its bent legs by the aid of its tail and wings. Frequently it endeavoured to fly or walk away, but these useless attempts served only to remind us of the first efforts at flight or walking made by the young bird when it leaves the nest. If you pushed it forward, it rolled on its head; if backward, on its tail. I pursued my sections, and the animal could no longer support itself on its knees, tail, and wings; it rolled constantly round without being able to remain in any fixed position. When worn out by this exercise, it would remain for a moment in whatever position it chanced to be placed, sometimes on the flat of its back, sometimes on its belly. All this time, it saw and heard perfectly. During its interval of rest the least menace, the least noise, the slightest irritation, renewed the tumultuous scene of its contortions; but in the midst of all these contortions, so wild, so violent, so unregulated, there never was anything like convulsions."

It follows, then, from these experiments, made with the greatest care, and repeated frequently, that the office of the cerebellum is to *combine* muscular action so as to make it subservient to flying, walking, running, leaping, standing, &c. If this be so, what becomes of the doctrine of the craniologists, who make it the organ of an animal propensity or passion? What experiments have they so decisive and undeniable? But we forget: Gall and Spurzheim objected to experiment as a mode of testing the offices performed by different parts of the brain; perhaps, they had some notion of the conclusions to which such experiment would lead.

M. Flourens next turned his attention to the *tubercula quadrigemina*, which we have already said are the roots of the nerves of sight, and are situated at the boundary-line between the brain and the spinal marrow; the line at the one side of which irritation produces convulsions—at the other, not. It may be necessary to add, that the nerves going from these bodies do not run to the organ of the same side, but after meeting, are said to decussate, the fibres of each crossing those of the other, and so proceeding to the opposite organ. The result of this, which also occurs in other parts of the brain, is, that an injury done to either side of that organ is frequently felt at the opposite side of the body; thus effusion on the right side of the brain will produce paralysis on the left side of the body. We shall see that a similar effect resulted in M. Flourens's experiments.

"I removed from the brain of a pigeon one of the tubercles: the excision was accompanied by a convulsive general flutter, but not of any duration. The eye of the opposite side immediately lost its sight, but the *iris* remained for a long time moveable. The animal stood, walked, flew, heard, and uttered sounds expressive of pain. It often turned round, and chiefly towards the side on which the tubercle was wanting: it saw perfectly with the eye on this side. This latter fact probably explains the former, which had no connexion with the removal of the tubercle, but with the natural inclination of an animal to move towards the side at which it sees best. This is rendered probable by the experiment of covering up one eye in several pigeons, when they will each be found to turn most frequently towards the side at which is the uncovered eye. When both tubercles were excised, complete blindness was the result; but the animal retained all its powers of hearing, feeling, standing, walking, and flying. As soon as the immediate pain of the operation was over, the animal became tranquil and quiet, and in every respect as before, save that it was totally and completely blind. The conclusion then is clear, these *tubercula quadrigemina* are, as it were, the internal organs of vision; the means of communicating to the brain the sensations brought in by the optic nerves."

His third, and by many degrees his most interesting inquiry, was that into the functions of the *cerebrum*, or brain proper, the organ, as it would seem, of intelligence and instinct, the centre to which impressions, made on the sense, are all referred, and without the action of which these impressions would pass unnoticed and unknown. In these experiments, he made, as it were, a singular analysis of the animal's existence; he deprived it of animal life, that by which it maintained its relations with the external world, and left it only organic life, that by which it converted into nutriment substances placed within the action of its digestive organs. A stranger, as M. Broc observes, to everything by which it was surrounded, insensible to everything that acted on it; it saw not, heard not, smelled not, tasted not, touched not,—not even that which touched it. Without desires, without cares, without pains, without pleasures; indifferent to everything, it lived without being conscious that it lived, or rather it had ceased to live though it still vegetated. It still breathed, its heart beat, its animal heat was preserved, it could even move when urged to it by an external impulse; but the impulse never came from within, it had ceased to have any volition.

"I deprived at once of the two hemispheres of its brain a fine healthy chicken. This chicken, deprived of both hemispheres of its brain, lived ten entire months in the most perfect health: it might still be alive had I not been obliged, in coming to Paris, to abandon it. During all that time, I never lost sight of it for a single day: every day I spent many hours in observing it; I have studied all its habits; I have followed it in all its ways; I have noted all its proceedings; and I now give the results of this long and careful observation.

"No sooner had I removed the two cerebral lobes, than it lost the sight of both eyes: it no longer heard; gave no sign of volition; but maintained itself on its legs with perfect ease and steadiness. It walked when goaded or pushed forwards; when thrown in the air it flew; it swallowed water when forced into its beak. It never, however, made any motion, unless when irritated. When placed on its legs it remained on its legs; when laid on its belly, in the manner in which fowls sleep, it remained on its belly. Constantly it was plunged in a deep somnolence, from which neither voice, nor light, nothing short of direct irritation, by means of blows, pinches, assumed the attitude of deep and profound sleep, that is to say, it turned its neck, and hid its head beneath its wing, as animals of its species do when sleeping. I left it almost half a quarter of an hour in this situation; I then irritated it suddenly, and it awoke with a start; but scarcely had it awoke when it again relapsed into a sleep as deep as before. Eleven hours after the operation, I made my chicken eat by opening its bill, and pushing down it some food, which it swallowed very well.

"The next day, it seldom awoke from the sleep in which it was plunged, and when it did so, it was with all the usual gestures of a chicken when awaking. It shook its head, ruffled its feathers, sometimes even dressed them with its bill; occasionally it changed legs, for often it rested only on one, as is common with birds. In all these cases, it reminded us of a man asleep, who, without quite waking, or rather still half asleep, readjusts his posture, &c., so as to assume one less fatiguing, stretches himself, yawns, and then drops off again.

"On the third day it was no longer calm as ordinary; it was in constant motion, went here and there, but without any determinate aim or object; and if it met with any obstacle in the way, it could neither avoid nor turn away from it. Its caruncles were of a fiery red; its skin was intensely hot; it was suffering from a burning fever: I confined myself to pouring down its throat abundance of water.

"For the rest, there was no sign of convulsions, no difficulty in balancing itself, no want of harmony in its motions: in two days the fever had ceased, and the chicken then became quiet and somnolent as before.

"I now pass over many entries in my journal, and arrive all at once at the second month from the operation.

"The chicken enjoyed perfect health; as I had carefully fed it, it had grown fat: it was almost constantly asleep, and when not asleep was still dozing. Some days past, the bones of the skull, exposed to the air, had exfoliated and fallen off; the scar was now rapidly healing.

"Five months after the operation:—I never saw a chicken fatter or in better health than this one. The round of the skull is entirely scarred over; a fine, smooth, white skin clothes the whole surface, and beneath the skin is formed a new osseous layer, still thin but solid.

"I have many times allowed this chicken to fast for two or three days together, then I have placed food under its nostrils, I have buried its beak in grain, I have placed corn in the end of its beak, plunged its beak in water, and placed it on a heap of corn. Under all these circumstances it has neither smelled, pecked, nor drunk; it remained immoveable on the heap of corn, and would, assuredly, have died there of hunger, had I not resumed my method of feeding it myself.

"Twenty times, in place of grain, have I placed pebbles at the bottom of its beak, and it has swallowed them just as it would have swallowed grain.

"Furthermore; when this chicken meets an obstacle in its way, it knocks up against it, and the shock makes it stop and reel; but to *knock* against a body is not to *touch* it; the chicken never feels its way, or examines by the touch; it never hesitates when advancing; it knocks and is knocked, but it does not touch.

"Thus, then, the chicken, without its cerebral hemispheres, has really lost sight, hearing, smell, taste, and touch, yet none of these senses, or, to speak more perfectly, no organ of these senses has been directly interfered with.

"The eye is perfectly clear, uninjured, and its iris moveable: the organ of hearing has not been touched; the organ of taste is perfect, and so is that of touch. How wonderful! Sensation no longer exists, though all the organs of sense remain: it is clear, then, that sensation does not reside in these organs.

"Finally; the chicken without hemispheres has lost all its senses, for it neither hears, nor sees, nor smells, nor tastes, nor touches. It has lost all its instincts, for it never eats of itself, to whatever length of fast it may be subjected, it never takes shelter, however great the inclemency of the weather, it never defends itself against the other chickens, it knows neither how to fly nor to fight, it feels no more the sexual desire, and remains indifferent or insensible to the caresses of the male. It has lost all intelligence, for it no longer either wishes, or remembers, or judges.

"The cerebral hemispheres, therefore, are the peculiar and proper seat of the sensations, the instinct and the intelligence."

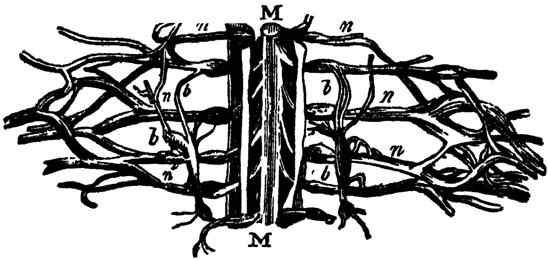
From this series of experiments, clear, complete, and convincing, M. Flourens has established the offices of the cerebellum, the tubercula quadrigemina, and the cerebrum; attaching to the first the power of regulating and combining the motions of the body; to the second that of connecting an impression made on the visual organ with the place where it is to become a sensation; while the third is the immediate receptacle of those sensations as well as of the instinct and understanding. The next question which evidently presented itself was, whether all these instincts, sensations, &c., occupied different seats in the cerebral hemispheres, or whether they all concurred in occupying the same seat; and as we have already shown from anatomy, the probability that the latter was the case, in other words, that the brain was an individual organ, we shall now show the more than probability which experiment brings to bear out our conclusion.

M. Flourens removed, in successive slices, the brains of a great number of pigeons; beginning in every possible direction, cutting sometimes from behind, sometimes from above, and sometimes peeling it off, as it were, from around a central nucleus. The invariable result of all these experiments was, that he could proceed to a certain extent without destroying the functions of the hemispheres; in fact, that a sufficiently small portion of each hemisphere was enough for the performance (in a manner) of *all* its functions; that these functions, however, became gradually enfeebled and impaired as the sections advanced, and that, at a certain point, they disappeared suddenly and *altogether*. "It follows, then," adds M. Flourens, "that there are *no* different seats for different faculties, nor for different sensations. The faculty of perceiving, judging, or wishing a thing, resides in the same place as the faculty of perceiving, judging, or wishing any other thing, and, consequently, this faculty, essentially one, resides also in an individual organ."

We need scarcely say, this conclusion completely destroys craniology from the roots: the brain is one organ, not many organs.

We must now leave this subject, however interesting, and proceed to consider the remaining parts of the nervous system, the spinal marrow, with the nerves which it gives off, and the great sympathetic nerve, reserving for a separate chapter what we have to say regarding the organs of sense, and the peculiar class of nerves by which they are supplied. And, in this part of our task, we are most opportunely met and assisted by the labours and discoveries of Sir Charles Bell, who had originally set out nearly with the same object as M. Flourens, but afterwards restricted his views to the parts which we are now about to consider. "I have to add," he says, "that, after making several experiments on the cerebrum and cerebellum, I laid the question of their functions entirely aside, and confined myself to the investigation of the spinal marrow and the nerves; a subject which I found more within my power, and which forms the subject of the present volume."

We have already described the spinal marrow as composed of four columns or rods of nervous matter, two anterior and two posterior, laid together and enclosed in a common sheath. As the eye runs along this sheath, it perceives that, in the interval between every pair of vertebræ, a nerve is sent out to each side of the body; and, on looking more closely, it becomes evident that each of these nerves has two roots, one from the anterior, the other from the posterior column, or root of the spinal marrow on its own side; that these roots join to form the nerve very soon after leaving the spinal canal, but that, previous to joining, a ganglion, or little enlargement, containing gray matter, is always formed on the root coming from the posterior column. An idea of this may be formed from the accompanying cut, in which we have represented a portion of the spinal marrow removed from its canal, the sheath laid open, and the origin of the nerves displayed.



Origin of Spinal Nerves with Ganglia, &c.

m, Spinal Marrow. *n*, Nerves arising from it by a double root.
b, Sympathetic Nerve, lying across the others, and receiving a root in it passage from each.

Now, in examining the bodies of animals, anatomists always find that the importance of any particular arrangement is to be estimated, not so much by the size of the parts concerned, as by the constancy with which they assume the same order; and as the spinal nerves invariably present two roots and a ganglion on the posterior, as the distribution of certain nerves also to certain organs is never wanting, or if wanting, the organ is deprived of its particular function, it follows, from the above principle, that there must be some good reason why these nerves should have two distinct roots, and why the distribution of others should so constantly follow the same law; and the most obvious explanation is, that the two roots confer different powers, and that certain nerves have peculiar functions. In speaking of the Alexandrian School of Physiology, we have mentioned that the former of these explanations had occurred to Erasistratus, and that he had actually divided nerves into nerves of sense and nerves of motion, to which he assigned different origins: he appears also to have had ideas of the peculiar functions of certain nerves; but his discoveries, in a great measure, perished with him and the school to which he belonged, and for many succeeding generations it seemed to be the doctrine, that the function of nerves depended on the organs to which they were sent; thus, that any nerve would see as well as the optic, if sent to the eye, or any nerve taste as well as the gustatory branch of the fifth, if distributed into the fine papillæ on the surface of the tongue. Objections to this doctrine were, however, frequently made, and, though generally taught, it was felt not to be satisfactory. The tongue is supplied with nerves from no less than three different sources; to what use, it was said, can this answer, if they all supply the same faculty? To this, even Sœmmering could find no better reply, than that the tongue required a great deal of nervous excitement, and that, perhaps, two or three small nerves might do the work of one large. Wrisberg, Scarpa, Prochaska, Paletta, and Munro, each approached us, either through anatomy or physiology, something nearer to the true explanation; but it was left for Sir Charles Bell ultimately to propound and demonstrate, that each of these nerves supplied the part with a peculiar endowment, which could never be communicated by a predominance, however great, of the other nerves; that the roots rising from the anterior columns of the spinal marrow, uniformly conveyed the principle of motion to the muscle to which they were distributed; that sensation was the property of the posterior roots; that the filaments arising from them, to whatever length they might run, however they might be interwoven or bound up with other filaments, never lost their original function, and that this unchangeableness of office belonged not only to the nerves of sensation and motion, but was extended to a peculiar class of nerves, destined to produce the combined actions necessary for respiration, as also to the nerves supplying the organs of the individual senses. To this discovery, he says, he was led, by a diligent study of the anatomy of their roots, and the mode in which he laid down the principle was, that "nerves have different functions, according to the divisions of the brain and spinal marrow, from which they take their origin." Having satisfied himself of the truth of this principle by anatomy, he next proceeded to demonstrate it to others by experiment.

"After delaying long," he says, "on account of the unpleasant nature of the operation, I opened the spinal canal of a rabbit, and cut the posterior roots of the nerves of the lower extremity; the creature still crawled, but I was deterred from repeating the experiment by the protracted cruelty of the dissection." The result, however, as far as it went, was clearly consonant with his views; the animal had moved after the posterior root of the nerves had been divided, therefore these were not the roots which served for motion. It next occurred to him, that as life does not leave the muscles and nerves directly on an animal's being knocked down and rendered senseless, he might experiment on it in this state, and thus save it the torture of being dissected alive. For this purpose a rabbit was struck behind the ear, so as to deprive it of sensibility by the concussion, and the spinal marrow was then exposed. On irritating the posterior roots of the nerve, no action could be perceived consequent on it in any part of the muscular frame; but on irritating the anterior roots of the nerve, at each touch of the forceps there was a corresponding motion of the muscles to which the nerve was distributed. Every touch of the probe, or needle, on the threads of this root, was attended with a muscular motion, as distinct as the motion produced by touching the keys of a harpsichord. These experiments fully proved that the different roots and different columns from whence these roots had their origins were devoted to distinct offices, and that the notions drawn from anatomy were correct. The explanation was, therefore, obvious, why one part should be supplied with nerves from two to three different sources; but to reduce this also to the test of experiment, he selected the face, which is supplied with two nerves, the fifth and the seventh: on cutting across the nerves of the fifth pair on the face of an ass, it was found that the sensibility of the parts to which it was distributed was entirely destroyed; on cutting across the nerve of the seventh pair on the face of an ass, the sensibility was not in the slightest degree diminished. From this it followed, that the fifth pair was the nerve of sensibility of the face, that is, the nerve by which the face felt all impressions made upon it; and, in tracing this nerve back to its origin, it was found, soon after leaving the brain, to present a ganglion, so that it in all respects answers to the nerves arising from the posterior roots of the spinal marrow, and which, as we have already shown, tend to the same office for other parts of the body. But the similitude does not terminate here; Paletta had shown that all the filaments of the fifth pair did not enter the ganglion; a few passed it by, forming, as it were, a separate root to the nerve; and, on tracing these carefully, they were found distributed to the muscles that move the lower jaw: could these be, like the anterior roots of the spinal nerves, destined to produce muscular motion? "The opinion," says Sir C. Bell, "was confirmed by experiment. The nerve of the fifth pair was exposed at its root in an ass, the moment the animal was killed; and, on irritating the nerve, the muscles of the jaw acted, and the jaw closed with a snap. On dividing the root of the nerve in a living animal, the jaw fell relaxed." Thus the functions of the fifth pair are no longer a matter of doubt;—it is to the face what the spinal nerves are to the body; it arises, like them, by a double root, one supplied with a ganglion, the other wanting it; and also, like them, it contains two sets of filaments, the one for sensation, derived from the former root, the other for motion, owing their origin to the latter root.

It appears, then, that each nerve, or, more properly, each nervous filament, for filaments of different power may be bound up in one common sheath, performs but one function; consequently, that if a part be required to execute more offices than one, it must be supplied with nerves from more sources than one. Of this we obtain a satisfactory illustration from comparative anatomy, by contrasting the feeler of any of the insect, or crustaceous tribes, with the trunk of the elephant: the former is destined solely for sensation, therefore it is found to be furnished with a single nerve supplied by the fifth pair, or that conferring common sensibility; but the proboscis of the elephant is not only destined as an organ of touch, but being hollowed into a tube, shares also in the motions of respiration; consequently it is found not only to have nerves from the fifth pair, as above, but also large branches from another (the seventh), of which Sir Charles Bell has shown the influencing the muscles in respiration to be the peculiar function. It may strike our readers that these nerves of respiration are a new class, and do not properly come under the head either of sensation or motion, therefore that they should have some peculiar origin of their own, but that no such appears in the spinal marrow, which merely consists of the four columns, two anterior, for motion, and two posterior, for sensation. And this, it must be admitted, is a difficulty which anatomy does not enable us to remove in its full extent. Confining our attention, however, to that part of the spinal marrow, termed the medulla oblongata, placed like a capital on the top of the column, and forming the part which immediately connects it with the brain, we perceive that between the four rods, of which we have spoken, others are, as it were, inserted or let in; from these the superior respiratory nerves can be clearly shown to have their origin; and Sir Charles Bell supposes, that though these inserted parts cannot be traced to any distance in the spinal column, yet that a fine streak of medullary matter must be sent along it from them, endowed with the same peculiar power, and communicating this power to the respiratory nerves, which are given off in its downward course.

We have thus given as full a view as our limits and the nature of our work will permit, of the discoveries and theory of Sir Charles Bell, to which we must add, that they have been by no means allowed to pass unquestioned. In fact, in 1815, Mr. Cross propounded the diametrically opposite doctrine, that the anterior pillars and roots were destined for sensation, and the posterior for motion; Mr. Walker thought this so far the truer doctrine, that he wrote to claim it as his own; while Burdach, who, with Baer, in 1818, made a series of experiments on frogs, altogether denied the distinctness of function of the anterior and posterior roots, and arrived at the conclusion, that the united influence of both is necessary to produce, in a spinal nerve, the perfect discharge of either of its functions, sensation, or motion. In 1822 Magendie, being made acquainted with Sir Charles Bell's views by Mr. Shaw, immediately commenced a set of experiments, the result of which was to afford them the strongest and most decided confirmation. Thus in a young dog, having divided the posterior roots of the spinal nerves, he says, "the sensibility was always completely extinguished:" when the anterior roots were cut, "the limb became relaxed and motionless, while it evidently retained its sensibility." And, finally, he thus expresses himself at the conclusion of his essay: "the posterior roots appear destined more particularly to fulfil the functions of sensibility, while the anterior roots are more especially connected with the functions of motion." Subsequent experiments do not appear to have been altogether so decisive; as we find him, in a second paper on the subject, coming to the conclusion, that sensation does not derive its origin *exclusively* from the posterior nerves, nor motion from the anterior. Since then, the interesting nature of the question has caused very many physiologists to attempt its solution. Fodera gained results very dubious, and, in many instances, opposed to Magendie. Bellingeri framed a theory of his own; viz., that the posterior roots of the nerves served for the extension of limbs, and the anterior for their flexion; a theory which it appears to us we should be almost justified in terming ridiculous. Schöps, Backer, and Béclard, made their experiments with various results, all, however, tending towards Sir Charles Bell's views, which appear to have received their final confirmation from the experiments of the accurate Müller, published in 1831, as well as those made by Panizza, in presence of Scarpa, and by Seubert, in presence of Tiedemann, about the same period. Dr. Stannius was, we believe, the last experimenter in this line; but, as his testimony goes chiefly to confirm the accuracy of Müller, and, consequently, the correctness of Sir Charles Bell's views, we may be excused entering into it, referring those who may be anxious to see an account of his experiments to Hecker's *Litterärische Annalen*, for December, 1832, from whence they were transferred to the pages of the *Dublin Journal of Medical and Chemical Science*, a periodical which has now attained a marked priority in introducing the labours of foreign physiologists to the notice of their British brethren.

The principle of nervous action has been much contested, and little understood: it shall, therefore, detain us but for a very short time. Three theories are ventured on the subject: 1st, that a very fine subtile fluid is transmitted from the brain to the nerves, and *vice versâ*, and so conveys the commands of the will, or notice of an injury; 2ndly, that this takes place by vibrations or undulations along the course of the nerve; and, 3rdly, that this principle is neither more nor less than the galvanic current. The first opinion is very old, and seems to have originated in the idea that the brain was a gland, and, from the great quantity of blood sent to it, must secrete some kind of fluid. This fluid could not be shown, therefore it must necessarily be of a very subtile nature, and capable of moving with the necessary velocity, or, as Stuart describes it, "tenuissimum, dulcissimum, mobilissimum, et minimè cohærens, aut coagulationi sanguinis obnoxium;" that is, most subtile, most bland, most mobile, possessed of the least possible tenacity, and not liable to coagulation like the blood. It is, in short, the animal spirits of the philosophers of two or three centuries back, and to which the genius of Descartes gave the principal celebrity. Researches are still being made by German physiologists after this, as yet, imaginary fluid, and Autenrieth, we believe, is said to have *all but* demonstrated it. Until he does so completely, we will take leave to doubt its existence, the more particularly, that even if we were to admit the nerves to be tubes, and containing a fluid, both of which facts we deny for want of evidence, we do not see how the fact of a fluid moving backwards and forwards would assist our understanding the nature of sensation and volition.

The second hypothesis, or that of vibrations, owes its chief celebrity to Hartley, and supposes that the nerves are something like the strings of a musical instrument, which, when touched, vibrate, and that this impression, made at one end, is communicated at the other. Those vibrations were supposed to be continued into the brain, and were even made use of to explain the association of ideas: but there is nothing so absurd that an ingenious man cannot colour over, and invest with a certain degree of plausibility. All the world knew that the common conditions required before a chord can vibrate are, that it should be tense, or stretched between its extremities, and isolated, or not allowed to rest along another body: but every one who had eyes, could see that a nerve was so far from being tense, that, if cut, its cut ends actually overlapped each other, and so far from being isolated, that it was the whole way imbedded in soft, moist, cellular structure, often surrounded by fat and other yielding substances; yet, though they knew the one, and could see the other, they still persuaded themselves that somehow or other a nerve could vibrate: certainly when they had got so far, subsequent difficulties were not likely to stop them.

The third hypothesis, or that of electricity or galvanism, has been most elucidated by the researches of Dr. Wilson Philip, and we shall briefly consider the experiment on which he most insists, as proving its truth.

The hair was shaved off the skin over the stomach of a young rabbit, and a shilling bound on it. The eighth pair of nerves (the pair by which the stomach is supposed to be endowed with the faculty of digestion) were then divided, and about a quarter of an inch of the lower part of each coated with tin-foil. This was done to render them more convenient conductors of the galvanic fluid, which was then sent along them in the usual way. For five hours the animal continued in a perfectly natural state, and exhibited none of those symptoms of derangement of the functions of the lungs and stomach, which usually follow the division of the eighth pair. It had neither vomited, nor been distressed with difficulty of breathing. It had not eaten anything after the nerves were divided. The power of the galvanic mixture was, by this time, getting exhausted, and, in proportion as it failed, so did the animal's respiration become disordered: in a quarter of an hour it had become so difficult, that the animal lay gasping, and apparently at the point of death. Acid was now added to the mixture in the trough, and the galvanic power raised, till as high as at first. Soon after this the animal ceased to gasp, and breathed with much greater freedom. The galvanic process was several times discontinued and renewed, and always with the same effects. The animal died in six hours after the division of the nerves, and on being opened, it was found that some parsley, which it had eaten previous to the experiment, had disappeared, or at least was deprived of all its peculiar appearance and smell, and reduced to such a pulp as is usual in healthy digestion. "Both Mr. Hastings and myself," says Dr. Philip, "who have been much accustomed to examine the stomach of rabbits, under various circumstances, thought that digestion was nearly as perfect, as it would have been in the same time in a healthy rabbit. This rabbit had not eaten anything for twelve hours, till within three hours of the experiment; it was then very hungry, and was allowed to eat as much parsley as it chose."

This experiment Dr. Philip varied and repeated in different ways, and added others similar, which also gave similar results; in conclusion, he says, "We here see the influence of the brain removed, that of a galvanic trough substituted in its place, and the result the same as if the influence of the brain had still continued;" he therefore concludes, that the nervous influence is the galvanic fluid, collected by the brain and spinal marrow, and sent along the nerves; and asks, Whether it be possible to explain the result of his experiments without admitting the identity of the nervous influence and galvanism?

Now, if we consider this advanced as a strict logical proof, a fallacy is at once evident, though Dr. Philip has ingeniously kept it out of view, by making his syllogism an *enthymeme*, and placing the fallacy in the suppressed proposition. For his argument is this: galvanism produces the same effects as the nervous influence sent from the brain, therefore, galvanism *is* the nervous influence sent from the brain. The suppressed proposition is, "sameness of effect, infers identity of cause;" and the fallacy of this we can demonstrate without leaving the ground Dr. Philip has chosen; for if he select the contraction of a muscle as the effect, we know it can be caused by pinching with a forceps the cut end of the nerve going to it, and it can also be caused by sending a galvanic shock through the nerve; but it is evident, that pinching with a forceps is not, therefore, a galvanic shock.

Leaving, however, the strictness of logical proof, which is seldom to be expected in such a case as the present, we would in the first place remark, that the accuracy of Dr. Philip's experiments has been denied on very high authority; and the following experiment which Dr. Cooke relates, as having been made for the satisfaction of some of the members of the Royal Society, certainly tends to support the denial.

EXPERIMENT 1.—"Two rabbits, which had had no food for seventeen hours, were allowed to eat as much parsley as they chose; the nerves of the *par vagum* (eighth pair) were then divided at the neck of both the rabbits. One of the rabbits was subjected to the influence of a voltaic battery, and the process was continued for five hours; the other rabbit was allowed to remain quiet. At the end of five hours the two rabbits were killed; and, on examining the stomachs of both, the appearances were exactly alike, except that the contraction of the centre was somewhat greater in the galvanized stomach than the other." This is totally inconsistent with what should have happened, if Dr. Philip's theory were correct; but in fact, it seems by no means generally admitted that the functions of the stomach are dependent on the eighth pair, which, it will be observed, is taken for granted by Dr. Philip, but expressly denied by Sir Benjamin Brodie and other eminent physiologists, and that on the faith of such experiments as the following, which Dr. Cooke seems to give on his own authority.

EXPERIMENT 2.—"In a young cat, the termination of the nerves of the eighth pair on the cardia of the stomach were carefully divided; the animal was perfectly well afterwards, was lively, ate its food as usual, and the respiration was not affected. At the end of a week, and three hours after having been fed with meat, the cat was killed. On dissection, digestion was found to be going on as usual; the food in the stomach was, in a great measure, dissolved, and the thoracic duct and the lacteals were distended with chyle, having the ordinary appearance. The nerves were carefully traced, and it was ascertained that not the smallest filament had been left undivided. This experiment was repeated with exactly the same results, and the Editor of the *Quarterly Journal*, commenting on it, observes, 'it appears to set the inquiry at rest, and disprove the experiments made by Dr. Wilson Philip.'"

But though Dr. Philip has failed to establish his own opinion, he has given a very satisfactory refutation of the theories of Descartes and Hartley. He cut a nerve, and after retracting its extremities to the distance of a quarter or half an inch from each other, found that it was still capable of conveying the stimulus to act: of course, this would have been impossible, had it consisted in vibrations, nor do we see how it was to take place, if dependent on a subtile fluid flowing through very fine tubes.

[Physiologists, however, are anxiously watching the progress of discovery in animal electricity, than which, no science has told deeper secrets in more familiar language. Generalization has been carried so far, and so happily, in electrical researches, that, notwithstanding the philosophical caution which keeps back the physician from yielding to the hope of being able to identify nervous with galvanic power; yet, that there is some intimate, though still latent, connexion between these subtile principles, is a matter of very general belief. "He who predicted, and showed," says Dr. Walsh, in a letter to Dr. Franklin, "that electricity wings the formidable bolt of the atmosphere, will hear with attention, that in the deep it speeds a humbler bolt, silent and invisible. He, who analyzed the electrical phial, will hear with pleasure that its laws prevail in animate phials. He, who by reason became an electrician, will hear with reverence of an instinctive electrician, gifted in his birth with a wonderful apparatus, and with skill to use it." It is singular (and we are not aware that the observation has before been made) that the ancients generalized the electricity of the torpedo, to which Dr. Walsh alludes in the preceding extract, with the powers of the magnet, when they recommended both for the cure of gout; thus, unconsciously anticipating the great discovery of M. Œrsted of the identity of the electric and magnetic currents. To compare the blind coincidences of past practices with present opinions opens up a curious proof that both rest on common ground. The cause of gout, says the physician of to-day, is "weakened nervous organic power;" the Roman and Arabian physicians recommended the shock of the torpedo as a remedy for the same; Œtius says that those afflicted with the gout, either in the hands or feet, should hold a magnet in the hand to relieve the pain: and the electrician sees but one and the same principle in the empirical remedies, in the physiological opinion, and in the disease itself.

Let us turn, however, to the facts: Sulzer, as early as 1767, described the influence upon taste caused by the contact of different metals with each other and with the tongue. In 1773, Dr. Walsh proved that electricity is an animal, as well as an inorganic product; that the back and breast of the torpedo are in different states of electricity; and that, to receive the shock, it is necessary that the upper and lower surfaces of the animal should communicate by some conducting substance. Before the time of Galvani, it had been observed that muscular convulsions were sometimes caused by electricity, but in 1790, he discovered that these take place when a muscle is connected with a nerve by a metallic conductor: soon after this, Volta discovered that the mere contact of bodies is sufficient to disturb electrical equilibrium, and that a current of electricity flows in one direction through a circuit of three conducting substances.

If we analyze these few fundamental facts, we shall see that Dr. Walsh discovered organic electricity, or that which exists as a natural product of animal organization; that Galvani showed the conditions necessary to produce one of the most startling effects of electricity, artificially excited, upon organized beings; while the results obtained by Volta explained the facts recorded, but not understood, by Sulzer. "The principle once established," says Sir John Herschel, "that there may exist in the animal economy a power of determining the developement of electric excitement capable of being transmitted along the nerves; and it being ascertained, by numerous and decisive experiments, that the transmission of voltaic electricity along the nerves of even a dead animal, is sufficient to produce the most violent muscular action, it became an easy step to refer the origin of muscular motion in the living frame to a similar cause, and to look to the brain, a wonderfully constituted organ, for which no mode of action possessing the least plausibility had ever been devised, as the source of the required electrical power."

That such has not yet been proved to be the case is perfectly true; and it must be confessed that electricians are far more sanguine than physicians upon this point: but we agree with Professor Daniell, that "there never was a more tempting field of research, or one that offered a higher reward for its successful cultivation." "In these electric fish," says the same writer, "we behold nervous power converted into electric force; it cannot be doubted that the converse of this is possible. We are, however, only upon the threshold of this inquiry of surpassing interest*."]

It only remains, to conclude this chapter, that we should say a word of what is called *the great sympathetic nerve.*

This has properly neither beginning nor ending: it resembles none of the nerves of which we have hitherto been speaking, and which can all be shown to originate at some determinate place, either of the brain, or spinal marrow. The sympathetic, on the contrary, seems to spring up, as it were, everywhere: and to be, in fact, a collection of ganglia united together by innumerable nervous filaments, and sending out others to all the organs found in the great cavities of the chest and abdomen, and generally known by the appropriate term of vital. In fact, wherever an ordinary nerve comes off from the spinal marrow, there the sympathetic is sure to have a distinct filament sent to it also (see last plate); insomuch, that Le Gallois concludes it to arise from *all* the spinal marrow. The filament, in the first instance, runs into one of these small collections of gray brain-like matter termed a ganglion, and it is here that it becomes, as it were, incorporated with the other filaments of the sympathetic system, and endued with its peculiar properties. It was at one time thought that ganglia were peculiar to this nerve, whence it was supposed that they might be so many centres for combining the actions and feelings of the different parts which derived nerves from this source, and thus being the means of producing *sympathy*, the name of *sympathetic* was given to the entire system. Bichat even went so far as to consider it a distinct system, and quite independent of the other, or cerebro-spinal system. The latter, he supposed to be the centre of *animal* life; that life by which we perform all voluntary motions, and maintain our connexion with other animals: the former, he considered as the seat or

[* Another has been added to our short list of electric animals; on May 6, 1839, Mr. Yarrell exhibited to the Entomological Society of London a large and very hairy *caterpillar*, a native of South America, which, together with the electric eel, the torpedo, and the Trembleur of Broussonnet, possesses the power of communicating the electric shock.]

centre of *organic* life, that life by which we maintain our individual existence,—and as the brain and spinal marrow, through the nerves which they give off, direct all our actions in the one, so did he suppose that the ganglia were so many distinct little brains for presiding over all the internal motions necessary to the healthy maintenance of the other. This idea of the ganglia being so many brains is given up, but the distribution of functions is nearly such as is now-a-days admitted, though the distinctness of the two systems is no longer maintained.

An important difference in the mode of action of this nerve, is, that it is not under the direction of the will. The use of this is great and obvious: the parts supplied by it, and deriving their vital energy from it, are of such a nature that their functions are required to proceed independently of our volition or attention; in fact, while we are asleep, as well as when we are awake. Thus the heart, which is abundantly supplied by branches of the sympathetic nerve, beats night and day, from the moment of our birth to that of our death, without requiring from us any care or pains, and its cessation would be instantly fatal. How wise then the provision, thus to withdraw from the reach of our will or caprice, an organ on the action of which our whole life depends; and bestow on it a new and different principle of action, which, while it impels its muscles constantly to contract, at the same time relieves them from ever feeling that sense of lassitude and weariness so overpowering under continued exertion of what are called the voluntary muscles. Equal wisdom is observable in the peculiar kind of sensibility with which it is endued. The nerves that arise from the posterior columns of the spinal marrow and terminate every where on the surface of the body, serve, by their power of conveying impressions, to give instant notice of the approach of whatever, by its continuance, would be injurious or detrimental to the entire frame. A man who accidentally suffers his hand to touch any body of a temperature higher than is consistent with the existence of an organised part, is at once warned, by the pain of the burn, to withdraw it. Were the injury accompanied by no pain, it is evident, he might allow it to proceed until it had reached some vital part, when his life would be the sacrifice.

This obvious and simple reasoning at once enables the physiologist to reply to those discontented visionaries who rail at the existence of pain as an evil, and imagine how we might have been framed so as to be insensible to its existence. The same reason, however, by no means will extend to internal organs supplied by the sympathetic nerve. Any destructive cause, to reach them, must have already penetrated the sensitive surface, where, of course, abundant notice of its presence has been given, and all further is needless. We find, therefore, that of ordinary sensibility, the sympathetic system is totally devoid. No man can tell what part of his stomach or bowels is full and what part empty, though he would have no difficulty in saying whether one of his hands was full and the other empty; nay, so completely is this nerve devoid of ordinary sensiblity, that it is said, its plexuses and branches may be cut, or pulled, or twisted, without the animal appearing to suffer the least pain. But we know, that this insensibility does not extend to cases in which derangements occur in the functions over which it is set to watch; let a man be seized with inflammation of the stomach, or spasms of the intestines; let him have a stone in his bladder, or an obstruction in the gall-ducts, and then ask him whether his sympathetic nerve is not capable of conveying the sensation of pain, and thereby giving warning that something in the system is going wrong, and requires correction?

We have thus completed our view of the general nervous system.

Chapter XI.

THE ORGANS OF SENSE.

Five senses are generally attributed to the most perfect animals, viz. sight, smell, taste, touch, and hearing, of which the eye, the nose, the tongue and palate, the skin or general surface of the body, and the ear, are considered the appropriate organs. Every animal possesses one or more of these faculties, which enable it to maintain its connexion with the external world, and deprived of which it would, in fact, cease to be an animal. For had it no sensations, it would want all stimulus to action; but thought and motion are both action, and would both, therefore, be extinct; and the animal, fixed to the spot and incognizant of all the objects by which it was surrounded, would cease to be an animal,—it would be a plant. On the contrary, the more sensibility an animal possesses, the more energetic and frequent are its movements: the oyster, which in its perceptions is extremely limited, scarcely ever leaves the same place, its movements being chiefly confined to such muscular contractions as take place within its shell; while the bird, endowed with sensibility in a high degree, is always in action. It has even been thought that the same distinction might be extended to man, and that those who receive very lively impressions from their senses, exhibit also a greater portion of energy and activity; the modifying causes, however, become here so extensive and numerous, as to make us extremely cautious how we admit any general rules.

Touch is the most generally diffused of our senses, and the most generally useful. It enables us to acquire notions respecting the figure, size, weight, hardness or softness, temperature, distance, &c., of bodies, and the great number of different objects to which it can be directed have caused, particularly of late years, a pretty general impression that it should be considered rather as many than as one sense, though the mode in which it is to be divided seems not well agreed upon. Sir Charles Bell particularly, and we think with just grounds, insists on the necessity of distinuishing a sense of muscular contraction, or what he terms, "a consciousness of the state or degree of action of the muscles." That we possess such a sense, is evident, from our feeling the effects of over-exertion and weariness, from the pain which is excited in us by spasms, which are nothing more than the sudden, forcible, and involuntary contractions of muscles, and from our being capable of estimating the weight of a body held in the hand, which is only judging of the quantity of muscular exertion necessary to keep it from falling, by its own gravity, to the ground. It is this sense also, that enables us to regulate all our positions and motions, which are, in all cases, the effects of muscular contraction; so that it applies to a group of objects perfectly uniform, and quite distinct from the operations necessary to judge of temperature, or perceive pain; we may, therefore, reasonably admit, that it is a peculiar sense, and, according to Sir Charles Bell's theory, is therefore ministered to by peculiar nerves.

It is true, as he observes, that those nerves, in almost all cases, become intimately connected with the nerves of common sensibility returning from the skin, so as to render their anatomical separation difficult or even impossible; and this has been, doubtless, one reason why the sense of pain and the sense of muscular action, though evidently so distinct, have for such a long time been united under the common name of touch or sensibility. Dr. Bostock proposes very nearly the same distinction, confining the term touch to "the sense of resistance," and treating the sensations of heat and cold, of hunger and thirst, &c., as specifically distinct. M. Magendie uses the two distinct terms of *tact* and *touch*, which chiefly differ in this, that in exercising the former, the animal is passive, but in exercising the latter, active. Thus, if while we are looking another way, any object should be brought into contact with any part of our body, we are sensible that such contact has taken place, and we have notions rather general and indistinct of a few of the qualities, such as the temperature and hardness, of the body; this is *tact*. But if we see a body, and wish to inform ourselves respecting its weight, figure, consistence, &c., we stretch out the hand, feel it, examine it all round, or attempt to raise it up; this he calls *touch*. The former then is involuntary, the latter voluntary;—the former is diffused over the entire surface, and even seems to be possessed by almost every organ; the latter is chiefly exercised by a peculiar and appropriate organ, as the hand in man, the tentacula in different animals, &c.; finally, the latter may not inappropriately be considered as the perfection of the former, with certain additions, for *touch* includes *tact*, but superadds the knowledge of muscular contractions directed by the will.

M. Adelon proposes a division, which may appear still more philosophical. He considers, that all the senses have two kinds of functions; one immediate or primary, the other auxiliary: thus, the eye judges of light, the ear of sound; these are their primary or immediate functions, and in the performance of these, the ear receives no assistance from any other organ. But both the eye and ear can assist the touch in judging of distance; and this is said to be in all these organs an *auxiliary* function. Now the primary function of the sense of touch, M. Adelon conceives to be the judging of temperature. It is certain, that by the touch (M. Magendie's division *tact*), we do judge of temperature, and that no other sense would enable us to do so. We might hear and see, and taste and smell, as we do now, but without touch, we should never be aware of the existence of heat and cold. Furthermore, the sense of touch is always exercised in performing this function as we are always sensible of the temperature of the surrounding atmosphere, and in this field the sense of touch acquires its greatest extent, as it not only enables us to judge of solids and liquids, but even of gases, which are usually described as impalpable, that is, imperceptible by the touch. We may, therefore, concludes M. Adelon, admit this to be the true primary function of this sense, while the others, such as judging of form, weight, size, mobility, distance, &c., are its secondary or auxiliary functions, those in which it assists or is assisted by the other senses.

The object of the senses being to make us acquainted with the qualities of foreign bodies, it therefore became necessary, as a primary condition, that their organs should be placed in the surface of our bodies; an internal organ could not maintain an external communication, save through the medium of others. A further condition we may also notice to have been adhered to, in their structure;—they must consist of two parts, the one situated more deeply, consisting of the expansion of a nerve, in direct communication with the brain, and constituting, as it were, the more immediately vital part of the organ; the other external, placed on the surface, meant to concentrate or modify the external impression in such a way as to adapt it to the peculiar sensibility of the first part, and itself constructed generally more in accordance with the laws of mechanics, and capable of being imitated or explained on their principles. The most beautiful examples of this, we shall presently have occasion to notice in the eye and the ear, which are severally the expansion of the optic and auditory nerve behind a telescope in the one case, an ear-trumpet in the other; but it will be found equally applicable to the organ of touch, which we must now proceed to consider.

The whole skin is, in man, an organ of touch. It consists essentially of two distinct layers, the *dermis* or true skin which is internal, and the *epidermis* or scarf-skin, which is external. The former, which constitutes the immediate and proper envelope of the body, is formed of fine, pliant, flexible and extensible laminæ, closely matted together and perforated by innumerable exhalant and absorbent vessels, for the purpose of carrying on the perspiration and absorption which take place from the surface, as well as by the sentient extremities of the nerves, which a microscopic inspection shows rising through it in minute papillæ destined to exercise the sense of which we are now speaking. These, therefore, constitute the internal part of the organ; but were they directly brought into contact with the objects of which they are to judge, they would, from their extreme sensibility, give us scarce any other perception than that of pain, which we know to arise when any sensation is carried to excess. To prevent this, therefore, the external part of the organ of touch is added, viz., the scarf-skin, which is a fine transparent flexible envelope, placed over the entire body, completely insensible itself, and sufficiently blunting the sensibility of the nerves of touch by interposing its thin membranous substance between them and the bodies which they are to examine. It is this scarf-skin which is removed by the application of a blister, and we well know what pain then results from the simple exposure to atmospheric air of the unprotected ends of the nerves.

The uses, then, of the two parts of this organ, are perfectly distinct, and they have this peculiarity, that the external is used to diminish the force of the impression before it reaches the internal, while in the eye and ear the object seems to be to concentrate and increase. Some philosophers have started the idea, that the touch is to be looked on not only as the most generally diffused sense, which we know it to be, but as the common sense, the parent sense, that of which all other senses are but modifications; and certain speculative physiologists have transferred the idea from the sense to its organ, and assert, that all other organs are merely modifications of the skin, which, as we have shown, is the general organ of touch. As long as we confine our view to the organs of smell and taste, there appears even much plausibility in this opinion, as we have already shown, that the mucous membrane, which lines the cavities of the mouth and nose, and so constitutes the external part of these organs, may fairly be looked on as a continuation of the skin endowed with new properties suited to its new situation; but when we come to consider the eye and ear, the theory becomes altogether untenable; there is no part of the skin with which they bear any such analogy as to entitle us to consider them as modifications of it, and the defenders of the doctrine can here invent no explanation more feasible than that which arises from considering these organs respectively as the perfect developement of the *bulb of a hair!*

Besides being an organ of touch, the skin is also meant to be an organ of protection: the conditions necessary for each of these ends are so inconsistent, that the one can only be perfected at the expense of the other; and as delicate sensibility is evidently more important to man than to other animals, while these latter, being deprived of the resources afforded by reason, are more dependent on their structure for defence against external injury, and so stand more in need of shelter, we accordingly find that the skin is best adapted in man to answer the former purpose, and in the lower animals the latter. It is further adapted for this, by the addition of fur, bristles, hair, feathers, crust, shell, &c., all of which must evidently diminish its utility as a delicate organ of tact. When the latter condition, however, becomes again requisite, means are taken to ensure its presence, and the wide membranous wings of the bat, thickly supplied with nerves, are so extremely sensitive, as to enable it by this means alone, even when its eyes are put out, to avoid numerous obstacles placed in its way. But the perfection of this sense seems to be situated in the human hand, than which there is no organ more beautifully adapted for its exercise. Situated at the extremity of a long flexible lever, it can be easily applied and moved in all directions round the object to be examined; composed of several small bones (so many as twenty-seven), it obtains from their motions on each other, a sufficient degree of flexibility, which becomes much increased towards the end, where the division into separate fingers takes place; supplied with nerves numerous and highly sensitive, supported, particularly towards the ends of the fingers, by a soft pulpy cushion, which enables them to be applied with the greatest accuracy and effect, while they are stimulated and excited to the act by the rush of blood to the fine vascular tissue in which they are imbedded, the hand concentrates in itself every necessary qualification for exercising this sense in its greatest perfection, and must enable us to obtain perceptions far excelling in accuracy and clearness any that can be obtained through such organs as the lips, the paw, the tail, the tentacula, the antennæ, or the barbels by the lower animals.

From Touch we pass by an easy transition to *Taste*, which, in fact, is by many considered merely a modification of the former sense; nor does the idea seem to be without sufficient grounds of support. As it was necessary that some sense should be bestowed on the exterior surface of our bodies, to give warning of the approach of any injurious or noxious substance, so would it appear advisable that the access to our internal, or alimentary surface, should, in like manner, be guarded by its peculiar sense, the office of which should be to examine all matters which were to come in contact with it; and refuse to admit them, if their sensible qualities appeared to denote that such contact would prove deleterious. Now this office is performed by the sense of taste, which is thus to our internal surface what touch is to our external surface—a guard to warn it against such contact as, if prolonged, might be productive of injury. This analogy is further borne out by examining the anatomical structure of the tongue, the principal seat of this sensation. The tongue, like many other parts of the frame, has more than one function to perform; and a consideration of the nature of these functions will, in general, be found the best guide to the structure of the part. Thus, in the present instance, the tongue is required both to aid in the formation of speech, and to constitute the principal organ of taste; for the former purpose it must be extremely mobile, and therefore furnished with abundance of muscles; for the latter, extremely sensitive, and therefore profusely supplied with nerves: both these conditions are complied with. Furthermore, as these nerves are to constitute an organ of sense, it will be necessary, as we before stated, that they should be distributed on the surface; we may therefore conclude that the muscles must occupy the lower and inner parts of the tongue, and the nerves the upper and superficial—this, too, is the case. But we can advance another step: the object of this sense is the sapid qualities of bodies; but these can only be appreciated when in a state of liquefaction or solution,—if a perfectly dry body be applied to a perfectly dry tongue, there is only a sense of *touch*, not of *taste*,—therefore, we may conclude, that the sentient extremities of nerves which are to judge of the taste of bodies will be covered by a fine moist membrane, and placed in such a situation that provision for constantly maintaining this moisture shall be made; and a moment's consideration of the mouth and tongue, with their mucous and salivary glands, will show how beautifully and successfully every one of these conditions has been complied with, and how admirably the organ is adapted for the performance of its important duties.

The tongue derives its nerves from no less than three sources; and this, again, is a necessary consequence of the complexity of its functions. The sense of taste seems to depend on the branch which it derives from the fifth pair, and as other branches of this same pair are those which supply the general surface of the face with its sense of touch, we find here another and very strong point of connexion between these two senses. It has been doubted whether the fact be as we have stated, respecting the sense of taste, which many physiologists were inclined to attribute to a peculiar nerve (the ninth), rather than allow it to be a property of a branch of the nerve of common sensibility; but M. Magendie's observations seem to us quite decisive on this point; when the trunk of the fifth pair was diseased or cut, all sense of taste was lost; "Everything I ate," said a patient of his, labouring under this affection, "seemed to me to be earth,—I felt as though I were eating earth."

For motion, the tongue is supplied with the ninth pair of nerves, and comparative anatomy indicates this to be their appropriate office, as in fishes, in which the tongue no longer moves but is bound down to the floor of the mouth, it no longer receives this pair of nerves. But there is a motion perfectly distinct from that required for speech, and which it is not less essential the tongue should possess; this is the motion of the tongue necessary to assist in swallowing, and to stimulate it to this peculiar action, it is supplied with branches from the *glosso-pharyngeal* nerve*, the remaining branches of which are distributed along the pharynx and gullet. By this a most important end is answered, for as soon as the morsel, after being chewed, is transmitted to the back of the tongue, all these parts are at once called into harmonious action, and the safe transmission of the morsel from the mouth to the stomach is ensured.

The contrivance, by which as much as possible of the sentient extremities of the nerve is exposed to the sapid body, is simple and obvious. The surface of the tongue is not smooth, but roughened by numerous papillæ, in which the nerves terminate, and which rises above the general level. By this means the sapid body, when dissolved in the saliva, is applied not only to the end, but all round the extremity of the nerve, so that this latter may be said to be literally soaked in the substance which it is intended to examine.

Attempts have been made to ascertain to what peculiar constitution or formation it is owing, that bodies possess different tastes. Bellini and the mechanical school endeavoured to explain it by the form of the atoms, or molecules, of which the body was composed; thus they supposed that if these were round, the body would be sweet; if angular, that the body would have a sharp pungent taste. This mode of accounting for sensations, by referring them to physical properties, which a moment's reflection will show they resemble only *in name*, and that in consequence of the imperfection of language, is now justly and universally abandoned. With some more show of reason, others were inclined to attribute the sapidity of bodies

* *Glosso-pharyngeal*, supplying the tongue and pharynx; from γλοσσος, the tongue; and φαρυγξ, the pharynx, or top of the gullet.

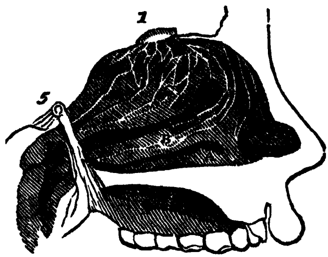
to their chemical composition; but this was only shifting the difficulty, and they were never able to agree amongst themselves to which of the elements of bodies they should suppose this sapid principle to be attached. Macquer defined sapidity to be the tendency which a body has to combine with the tongue; and Magendie having observed that vinegar, the mineral acids, and certain salts, produce an effect on the epidermis, or investing membrane of the tongue, changing it to yellow, white, &c., seems inclined to adopt the same opinion: "perhaps," he says, "to this sort of combination may be attributed the different kinds of impressions made by sapid bodies, as well as the variable duration of those impressions." We confess we have no conception of this combination between organized and unorganized bodies; we can see how the latter, as in the case of caustics, may destroy the former, but that a little bit of our tongue becomes united with everything we taste, which is the doctrine of combination put into plain English, seems to us so extremely improbable, and, at the same time, affords so little information as to how taste takes place, that we must decline receiving it until some bettter proof be offered. For our parts, we frankly confess we do not know why one body has taste and another not; we look on sapidity to be a quality inherent in some bodies and not in others; but of the reason for this difference we are completely ignorant, nor could any one determine *à priori*, respecting a new body which was presented to him, whether it should have taste or not*.

We have now considered two of the senses, which we have found occupied chiefly with the qualities of matter existing in masses of appreciable bulk. Thus the touch is principally occupied with solid bodies, of which it estimates the weight,

[* "Sweetness and bitterness, like acidity, seems to depend upon no particular principle, but to be regulated by the state of combination in which the same principles exist at different times." *Sir John Herschel*.—As the state of combination in which these principles do exist is being daily more and referred to electric action, it is possible that their effect upon our senses may, in time, be also referred to the same cause. When the positive wire of a galvanic pile is applied to the tip of the tongue, and the negative wire touches some other part of it, an acid taste is caused; when the piles are reversed, the taste becomes alkaline.]

form, cohesion, and other properties which molecules possess when united in the block: the taste requiring their liquefaction may be said to judge of them just at the moment when about to be separated; while a third sense, the smell, to which we now proceed, appreciates only certain odorous molecules after they are entirely separated from the mass, and conveyed, as it were, in a gaseous solution, to strike on the delicate lining membrane of the nose, which being abundantly supplied with nerves, is thus prepared for taking cognizance of their qualities. Thus, these three senses are affected by actual *contact* of the body, or parts of the body, which they examine, and, therefore, present still another point of view, in which they may be looked on as *touch* and its modifications. In the two remaining senses, *hearing and sight*, no such contact takes place; in the first of them, it is universally admitted that no part of the vibrating body need be in any way brought in contact with the ear, in order to the producing of sound, the vibratory motion communicated to the air being sufficient for this purpose; and, in the second, the theory that luminous particles, or molecules, are shot from the visible body and impinge against the eye, is fast falling into disrepute; and the undulatory theory, supported by Herschel, Brewster, Lardner, and most of the mathematical school, is now generally adopted in its stead. Thus, if we view the senses in the following order, touch, taste, smell, sight, and hearing, we find them becoming, as it were, less material, less occupied with the grosser particles of bodies, and the same order will nearly represent the extent to which these senses are found diffused through the scale of animal beings, all posessing the first, and, perhaps, we may add, the second, while the third, fourth, and fifth, are frequently imperfect or deficient, more particularly in the invertebrate tribes.

The smell is connected by so many links with the taste, that the description of the one naturally follows that of the other. Both primarily destined to inform us respecting the nature and qualities of our food, they are both situated at the entrance of the alimentary canal, and it would even appear as though the one was only a more refined exercise of the other: taste informing us of the qualities of bodies when dissolved in a liquid, smell when in a gaseous or volatile form. Even this distinction does not appear always to exist, at least if we allow the faculty of smelling to fishes, as they must receive the odorous particles through the medium of water, not of air. The immediate seat of this sense is generally known to be in the first or *olfactory* pair of nerves, spread out in the nose behind a very fine membrane, termed pituitary, or from its discoverer *Schneiderian;* and we thus perceive that this, as well as the other organs of sense, presents the two parts which we have described, as necessary to their perfection; the interior or vital, which serves for the actual exercise of the sense, and the external or mechanical, which is useful for the concentration or modification of the impression. "The olfactory apparatus," says Magendie, "ought to be represented as a sort of sieve, placed in the passage of the air as it is introduced into the chest, and intended to stop every foreign body that may be mixed with the air, especially odours." To enable it the more perfectly to do that, it is lined with a membrane of extreme fineness, yet still but a reflection of the external skin, endowed with the power of constantly secreting a viscid matter, familiarly known as the mucus of the nose. By this means two objects are gained; the odorous particles are, as it were, arrested in their passage, and kept for some time in contact with the pituitary membrane, and this latter is itself preserved moist and pliant, necessary conditions (as in the case of the tongue, we have already shown) to enable the nerve to perform its proper function. The inside of the nose is not one smooth uniform passage, but is divided, in the first place, into three principal passages, termed the superior, middle, and inferior *meatus*, by certain extremely slender bones, which project from its sides, fold downwards in somewhat of a rounded form, and are invested by the lining membrane, of which we have already spoken, and which thus acquires an increased extent of surface. This will be best understood from a reference to the subjoined cut, which is intended to represent the nose, divided by a vertical section, and all the right part removed, so as to admit a free inspection of the interior of the left nostril.



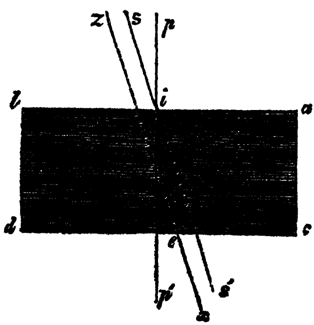
A, B, and C; inferior, middle, and superior Meatus.
1. First, or Olfactory Nerves.
5. Fifth pair of Nerves, or Nerves of common Sensibility.

But there is a still further complexity; for the air passes from the two superior *meatus* into certain cavities, which exist in different bones of the head, (chiefly the frontal, æthmoidal, and superior maxillary,) and are lined with a continuation of this same mucous or pituitary membrane. It does not, however, appear that any branches of the first pair, or true olfactory nerves, can be traced into them, and accordingly M. Richerand found that, in a patient in whom accident had formed an opening into these cells, highly perfumed injections could be introduced into them without producing any sense of smell, provided the return into the upper part of the nostril were prevented. M. Deschamps made a similar, and, we think, more satisfactory experiment, by introducing *air*, strongly impregnated with the vapour of camphor, into these cavities, as he here used what we have before shown to be the appropriate medium for bringing particles in contact with this sense; and we may even be permitted to doubt whether a man, if his nostrils were stopped behind, and completely filled with rose-water, would have any perception of the scent: divers, we know, can employ their eyes very freely under water, but we never heard of their using their noses. The result, however, of M. Deschamps' experiment, was the same as M. Richerand's; and from these and other observations, it seems well ascertained, that the first pair of nerves is that which peculiarly ministers to this sense; and as a reference to our plate will show that this nerve is almost entirely distributed upon the pituitary membrane of the superior *meatus*, it must be there chiefly that olfaction takes place; consequently, when people wish to increase the power of smell, we observe them close the mouth, cause all the air they inhale to enter through the nostrils, and furthermore, by narrowing the passage through these, increase the force with which the air is made to impinge against their lining membrane, while at the same time they give it an upward direction, so as to cause it to reach the part more peculiarly destined to appreciate its odorous contents. The same may be also noticed in persons taking snuff, who always endeavour to draw it up as far as possible. It is in performing this and similar offices that the external nose, which is itself insensible to scents, contributes to the perfect exercise of the faculty. Persons who have lost this organ, smell very imperfectly, or not at all; and M. Béclard has established the interesting fact, that such persons are very much assisted by the use of an artificial nose, or simple funnel-shaped tube, which may serve as a conductor. It seems not a little strange that, with the knowledge of such a fact before him, M. Magendie should suggest any doubt as to the uses of this part in smelling.

But, in addition to the power of distinguishing smells, the pituitary membrane is also endowed with a sufficiently acute share of common sensibility; for the purpose of bestowing which, we observe it is supplied with some branches from the fifth, which we have already said is the nerve of common sensibility for the entire head. The use of this provision is extremely obvious, as it at once informs us of the presence of any irritating matter on the surface of the membrane, and warns us of the necessity of attempting its removal. Some persons have thought that this office might have been performed by the olfactory nerve, but this evidently could only be the case, when the offending substance was odorous; and Magendie has shown that when the fifth pair was cut through, even the strongest stimulants might be applied to the membrane, without producing any sense of uneasiness. Indeed, he even goes so far as to say that, with the division of the fifth pair, the sense of smell completely ceases, while the effect is not so complete if, the fifth pair remaining, the olfactory nerves are destroyed; whence he infers that the former are absolutely necessary to enable the latter to perform their function. We are inclined, however, to think that here he went a little too far, in his anxiety to prove the fifth the nerve of all the senses; he seemed to assume, that because an animal sneezed, therefore it smelled, which is evidently a false assumption, as tickling with a feather will produce the former without the latter effect; and, furthermore, that because an animal did not sneeze, or withdraw its head from strong vapours, such as ammonia or acetic acid, therefore it did not smell; a conclusion equally unfounded, as its withdrawing its head would be the result of pain, and pain would appear to follow the undue excitement, not of the olfactory nerves, but of the nerves of common sensibility. Doctor Breschet relates a very interesting case of a person who had inherited from his father a great obtuseness or almost total deficiency of the sense of smell. He was perfectly incapable of distinguishing a rose from the carrion-flower (*Stapelia hirsuta*) if his eyes were shut; he felt no inconvenience from the most fetid gases, until their entrance into his lungs produced irritating effects there; to the scent of snuff he was, of course, perfectly insensible, yet he took it, was capable, by its effect on his pituitary membrane, of discerning between coarse and fine, and even sneezed very readily, if the snuff happened to to be fresher or more pungent than usual. In this case, a more perfect analysis was made than could be effected by any of M. Magendie's experiments on living animals, the functions of the fifth pair were perfect, of the first almost obliterated.

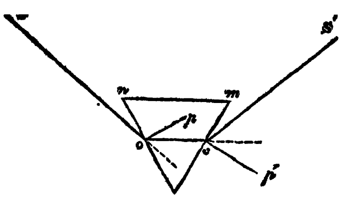
The two remaining senses, *sight* and *hearing*, have been so frequently made the subject of popular disquisition, while optics and acoustics have become so much a portion of general, rather than physiological, science, that we may treat them with more conciseness than their importance would otherwise have required; our object being, not to trench on subjects already familiar to the general reader, but to endeavour to introduce to his notice those parts of physiological science, with which, from the nature of the works in which they appeared, or the language in which they were enveloped, he has hitherto had little opportunity or inducement to become acquainted. It is necessary, however, that we should briefly allude to a few of the principal characteristics of light, for the purpose of showing more clearly the perfect adaptation of the mechanical part of the organ of sight to the laws by which it is governed.

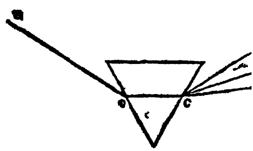
Light comes to us from the sun, and other luminous bodies: it has the properties of always moving in straight lines, where there is no obstacle; of being reflected, and so making bodies visible; of being refracted in passing through certain media; and of being decomposed by means of a prism, so as to show that, though in its ordinary state colourless, it is yet the cause of every varying shade and tint in the countless objects by which we are surrounded. Of these properties, refraction is the most important, as on it the whole mechanism of vision may be in a manner said to depend. It only takes place in transparent bodies, that is, such bodies as permit the rays of light to pass through them, and even



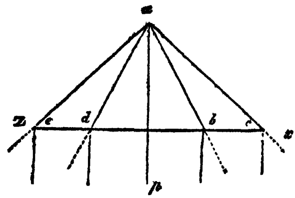
these fail to refract, if the ray come in a direction perpendicular to their surface. Suppose, for instance, that *a b c d* were a piece of glass, or any other transparent substance, having a density greater than atmospheric air: a ray of light, *p*, falling on it in a perpendicular direction, will traverse it to *p′*, in a perfectly straight line, and without suffering the least deflection in its course. But, should the ray come in a slanting or oblique direction, as from *s*, it will no longer continue in the direct line *s s′*, but will, as soon as it meets the surface at *i*, be *refracted*, that is bent from its own proper course, and made to assume a direction, *i e*, nearer the perpendicular *p p′*, than its own proper direction, *i s*. In this direction it will traverse the body of the glass, but, on leaving it, at at the point *e*, will, a second time, be refracted; this time, however, it will be bent *away* from the perpendicular, exactly as much as it was before bent *towards* it, so that when the glass has its opposite sides parallel, the continued course of this ray, *e x*, after having passed through the glass, and again emerged into air, will be exactly parallel with its former line of direction, and will just have the same effect as if the ray had been moved a little to one side, or would appear to a spectator at *x*, as if it had originated, not at *s*, but at *z*. Now the angle, *s i p*, which the slanting ray makes, with a perpendicular drawn to the point *i*, at which it meets the surface of the glass, is termed the angle of incidence; and the angle *e i p′*, which the broken ray makes, with the same perpendicular continued, is the angle of refraction; and it has been ascertained that the proportion which the sines of these angles bear to each other, is always the same when the refraction is made by a body of the same nature. Thus, when the refraction takes place from air into water, the angle of incidence is *invariably* about one-third greater than the angle of refraction; if, therefore, the refractive power of atmospheric air be taken as unity, or 1, that of water will be represented by $1\frac{1}{3}$. Estimating in the same manner, that of common glass will be $1\frac{1}{2}$, and that of diamond $2\frac{1}{2}$.

These laws are invariable, but we may alter some of the conditions of the experiment, and consider how this will affect the ray. Suppose, then, that in place of the parallelogram *a b c d*, we allow the ray *s* to fall on one side of the triangular glass prism *m n r*, it will, by the law laid down, be refracted into the line *o c*, approaching *o p*, the perpendicular to the surface *n r*. Arrived at *c*, it will be again refracted, but as it is now passing from glass to air, the refraction will be away from the perpendicular *c p'*, so that we shall have nothing like the parallelism which, in the former case, existed between the incident and refracted ray, but *s o* will have assumed the doubly bent direction *s o c s'*. This, at least, would be the case, were a ray of light perfectly simple, but this very experiment has served to demonstrate its compound nature, and, at the same time, let us into the secret of the origin of colours. For the several parts of which it is composed have not the same capability of suffering flexure, they would, therefore, arrange themselves on a screen, or wall, according to this capability; and we all know that a ray of solar light, *s*, is broken by a prism into several distinct rays, forming what is usually termed the *solar spectrum*, in which the red ray, *r*, as being the least refrangible, is always found at the bottom, and the violet ray, *v*, as being most refrangible, at the top.

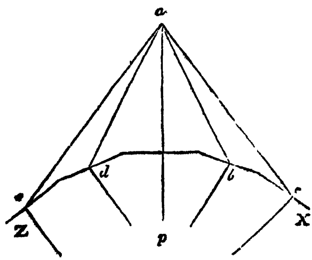




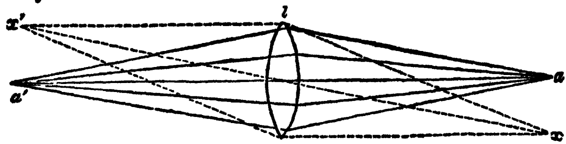
If we now proceed to consider, not a single ray, but a pencil of rays, that is, any number of rays diverging from one point, such a pencil would have its divergence in some measure checked by such a parallelogram as we first represented. For let *a* be the object from which the central ray, *a p*, is directly perpendicular to *x z*, the surface of the refracting body, while its lateral rays meet it with an obliquity constantly increasing, and are, therefore, more powerfully refracted in proportion as their divergence is greater. This refraction, however, is merely sufficient to prevent or diminish divergence;



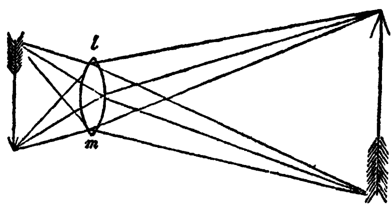
it cannot produce *convergence*, that is, make them all tend again to one central point. This, however, may be managed, for though you cannot alter the direction of the rays, you can alter the direction of the surface on which they fall, and, as it is with reference to the perpendicular erected on this surface that they are bent, you can, consequently, by increasing the obliquity, increase this bending. Thus, if *x z*, in place of being a plane surface, is bent away from the object *a*, so as to form as many distinct faces as there are rays, it is evident the obliquity with which these rays meet it is thereby very much increased, and so also will be the force with



which they are refracted, insomuch, that they will be completely bent in, so as again to meet the continuation of the perpendicular, *a p*, in some part of its course. Now, as the object, *a*, was originally seen only by the rays reflected from it and entering the eye, it is evident that, if we could make all these rays, after leaving it, once more converge at a common point, an image of the object would be formed at that point, which should be visible if received on a screen or other body interposed for the purpose. But experience shows that this may be done by a *lens*, that is, a refracting body, the surface of which constitutes part of a sphere, and which, therefore, may be considered as merely a polygonal figure like the above, except that the sides have become infinitely small and numerous. If, then, a pencil of rays fall on such a surface, the central ray will pass in an unchanged direction (the line drawn through the centre of a circle being always perpendicular to its surface); but all the rays on each side will be bent towards this perpendicular, and that in such proportions that they shall all ultimately meet it precisely at the same point. This point is termed the *focus*, and it will be more or less remote, according to the nature and form of the lens, and the direction in which the rays meet its surface.

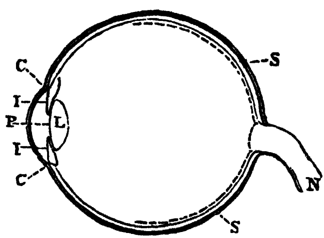


We here see, in *l m*, a section of the form of lens most commonly used, and termed the *double convex;* we also see how all the rays from any point, *a*, of which the central ray is perpendicular to the surface of the lens, are made to converge at the point *a'*, and those from *x* at the point *x'*, so that these points would be accurately represented. If, therefore, these points existed in the surface of any extended body, a representation not only of them, but of all other points in the same surface, would be found at the other side of the lens, in the place we have indicated as the focus, that is, a picture of the



body would be formed at this situation. Thus, if in the only aperture leading into a darkened room, you insert a lens, *l m*, the pencil of rays from each point of an object placed without, such as an arrow, will, in their passage through the lens, be made to converge, so as to meet their central ray at the focal distance; here, therefore, an image of the object will be formed, but uniformly inverted, as we see above. This is the whole principle of the *camera obscura;* it is also the principle of the refractive parts of the eye, to the consideration of which we may now proceed.

The eye, like all other organs, is composed of an internal vital part, the optic nerve, and an external mechanical part, the general globe of the eye, or eye-ball, which is so constructed as to be suited for maintaining a communication with external objects. The anatomical situation of these parts is very easily learned, and will be readily understood from the accompanying cut, which is supposed to represent a vertical section of the eye. Here we notice, in the first place, the general case, or investment of the eye, which is made by a thick opaque strong membrane, evidently intended to protect the delicate parts within, as well as to afford attachment to the muscles by which the organ is moved. This coat, s s, is termed the *sclerotic*, from its hardness*, and, being imperviable to light, it places the chamber of the eye just in the situation of the room we mentioned above. For this sclerotic is not continued all round, but has an aperture cut in the front, from c to c, in which aperture is inserted the *cornea*, that beautiful lustrous transparent part in front of the eye, which serves to admit light into the darkened chamber, and



through which alone all the rays coming from external objects can find admission. But were this aperture entirely open, too many pencils of rays would enter the chamber, and so interfere with one another that no distinct picture could be formed, as

* From σκληρος, hard.

we know would also be the case in the darkened room, if in place of a small aperture the entire window were thrown open. To remedy this in the room, the shutters are closed, and a small hole made in them; in the eye an exactly similar provision occurs, a screen, I I, termed the iris, is hung across, and a small aperture, P, named the pupil, left in the centre. Still the apparatus is not complete: it is true that, under such circumstances, a picture of an external object would be formed both in the room and the eye; but we have already shown that the pencils of rays from each point uniformly diverge; we therefore place a glass lens in the aperture of the window-shutter, because reason and experience both evince its utility, and we find that a lens, L, superior to any glass lens, has been placed just behind the pupil of our eye, so admirably arranged by a gradual diminution of its refractive power towards the edges, that even the ray which reaches it most obliquely, is just so far refracted as to ensure its coming to the same focus with those nearest the perpendicular.

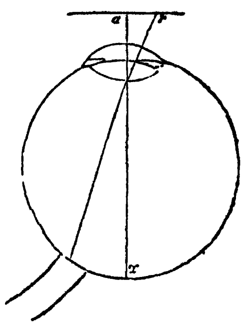
So far the resemblance is very striking, but here it ceases. In both cases a picture is formed by the refraction of the rays of light coming from the external object; but in the room, the picture falls on a screen or a wall, and there is no result; in the eye it falls on a living sentient screen, and vision is immediately produced. This screen is the *retina*, which we have indicated by a fine dotted line within the sclerotic, and which is nothing more than the sentient extremity of N, the optic nerve, which we see behind, coming from the brain, and which here expands into a membrane, beautifully fine and almost transparent. This last property would have the effect of again permitting the rays of light to disperse, after they had been collected at a focus, were it not for the *choroïd*, the third coat of the eye, which we see marked by a fine line interposed between the sclerotic and the retina, and which constantly secretes a quantity of dark colouring matter, that serves to render the retina opaque, and absorb all the light that may traverse its substance. It is this dark colouring matter that, seen through the aperture of the pupil, always makes that appear black: Albinoes, that is persons in whom the colouring matter is wanting, are said to have red eyes, because the tint given by the numerous blood-vessels of this coat is then evident. The same fact is of constant occurrence in white rabbits, white ferrets (the term ferret-eyed has, in fact, become proverbial for the appearance), and other animals in whom there is a deficiency of colouring matter as evinced by the whiteness of their hair and skin. The colour of the eye, however, is ordinarily estimated by that of the iris, and this, in a great measure, depends on the greater or less transparency of its texture; for the colouring matter, of which we have spoken, is also spread on its back or inner surface, and it is chiefly to the reflection of this, shining through and variously modified according to the more or less refracting structure which it traverses, that the colour, as seen in front, is owing. The iris is supplied with two sets of fibres, the one circular, which serve to contract, the other radiating, which serve to dilate, the pupil. Whether these fibres are muscular or not, has been much disputed; but as to the power, there is no question. Any one may convince himself of it, by closing his eyes before a looking-glass, and then suddenly opening them, so as to let the light fall full on them, when he will perceive the pupil which had dilated when the eye was shut, now contracting with more or less rapidity, according to the intensity of the light. And this experiment will also show him the object of the contraction, which is to regulate the quantity of light admitted into the back of the eye, and which, if too great, would injure the retina; so that the iris has a double function to perform; the one as regards the quantity of light necessary to form a distinct image,—this is mechanical, and common to it with the hole in the shutter; the other, as regards the degree of brightness tolerable by the expanded nerve, and this is vital, or, at least, under the immediate direction of a vital principle.

To conclude our anatomical view of the eye, it is merely necessary to add that it contains three distinct humours; 1, the aqueous, which is found immediately inside the cornea, occupying all the space between it and the lens, so that the iris may be said to hang floating in this humour; 2, the crystalline humour, which seems scarcely to deserve the name, as it is a solid transparent substance, in fact the body of the lens, but contained in a capsule; and 3, the vitreous humour, so called from its likeness to melted glass, and which occupies all that large space posterior to the lens, not less than three-fourths of the entire eye-ball. These humours are of different degrees of density, all, however, greater than that of water, and therefore contribute in different degrees to the proper refraction and convergence of the rays of light necessary to produce a distinct image. The aqueous humour seems also of use in producing that bulging out of the cornea, whereby its anterior surface is made a segment of a circle, and therefore endowed with the properties of a lens. Its quantity in the adult is said to amount to about five grains, and, as may be observed in our diagram, it is contained in two chambers partially separated by the iris, but communicating through the pupil; the posterior, which is very narrow, containing only about one-fourth, and the anterior three-fourths of the whole. This was best shown by M. Petit's experiment of freezing an eye, and then cutting it open, when the plate of ice in the posterior chamber was found to be extremely thin.

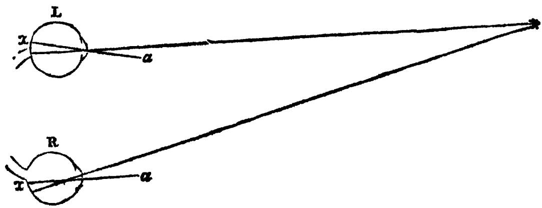
This is as much as we can say respecting the refracting part of the eye; but we must add a few words respecting its more immediately vital and sentient part, which we have already said is formed by the *retina* or net-like* expansion of the optic nerve. This, we may perceive, is spread out immediately behind the vitreous humour, and embracing it like a capsule so as immediately to receive the rays that have traversed it, and by its refracting power been finally brought to a focus. As soon as their image is formed on the retina, the brain is informed of it through the medium of the optic nerve, and perception takes place; if the optic nerve be cut, there is no communication with the brain,—no perception,—and though

* From *rete*, a net.

refraction takes place, and the image is formed as perfectly as ever, the eye is thoroughly and permanently blind. There is, however, one point of the retina on which light may fall without producing any perception, and it will, at first, appear strange that that point is found to correspond exactly with the entrance of the optic nerve. The discovery was made by the Abbé Mariotte; and the conclusion which he attempted to draw from it was, that the true seat of vision was not in the retina and the optic nerve, but in the choroïd, which a reference to our figure will show to be wanting at this identical spot. The argument, however, is invalid, as we know that nerves perceive not by their stumps or trunks, but by their fine extremities; now, when a picture (as in the case of vision,) is to be formed on these extremities, it is necessary they should be expanded into a surface to receive the picture; but this expansion does not take place precisely in the optic nerve itself, but on each side of the point where it enters. The fact, however, is undoubted, though we have shown that M. Mariotte's conclusion was erroneous; it therefore becomes necessary to consider how this insentient point is so placed as not to interfere with our vision of objects. And, in the first place, we perceive that it is taken out of the direct axis of vision,—that line in which vision can be most advantageously performed, and which is indicated by a right line, *ax*, drawn through the centre of the cornea, pupil, and lens. This is the line in which we attempt to bring all objects that we wish to see distinctly; and it is to enable us to do this, that the eyes are endowed with such a facility of motion, as were they completely fixed in their sockets, oblique objects would be seen very imperfectly, or not at all, without he trouble of turning the entire



head or body. Still, if the object be somewhat prolonged, we see that a ray from some point of it, as *r*, must strike on the insentient part of the eye, while the axis is directed fairly towards the centre of the object, so that, did the entrance of the optic nerve, in each eye, receive, at the same moment, the rays coming from the same point, that point would be invisible, and all objects, at a certain distance, would appear to us to present a minute black spot at some point of their surface. This, however, is guarded against effectually, by the circumstance that the entrance of the optic nerve takes place at a different side of the axis of vision, in each eye (that is, as seen in the cut, to the left of it in the right eye, R, to the right of it in the left eye, L); but the rays coming from any object, must always strike the retina of each eye on the *same* side of



the axis; therefore, as seen in the cut, when any object is so situated as to be opposite the insentient part of the left eye, it is sure to be opposite a sentient part of the right. As this insentient part, however, is very small, it more frequently happens that every ray, from every point of an object, strikes at the same time on a sentient part of both eyes. In this case, two distinct pictures of the object are produced, yet we know that we see the object but as one. How is this to be explained? M. Dufour took the easy method of denying that we do see the two pictures at once: the mind, he said, only took notice of one at a time, though it might change with great rapidity from one to the other. This theory is refuted by a fact within everybody's knowledge: if you look with one eye at an object, placed between you and any screen or wall, and then with the other eye, the object appears to occupy different positions in the wall. Now open both eyes, and the object will no longer appear in either of the positions previously observed, but in a position between them both: it is evident, then, that we are not attending to the impression on either eye, but to the result of the impressions on both eyes. This is plain, but we are sorry to say we cannot give so satisfactory an explanation of why we see but one object: of course there has been no lack of theories. One will have it that, as both optic nerves meet before entering the brain, the unity is produced at their point of junction: others say that "the effect depends upon some law of the constitution, or some general principle of vision, which enables us to see the object single, independent of any mental impression," and this opinion we have given as we find it, though we are utterly at a loss to see how it can be said to explain anything. There is still another theory, which seems that most generally followed, viz.:—That single sight is the result of experience, and that, at first, infants see everything double, until the sight is corrected by the touch. It is certainly very hard to offer any proof of such an opinion, therefore we do no know that any has been attempted: persons born blind, and restored to sight when adults, have been questioned as to their sensation, and, though it is difficult to obtain anything very clear from persons in such a situation, it appeared tolerably well established that they did not see objects double, which, so far as it goes, is against the last-mentioned theory. Should a person squint accidentally, as occurs sometimes during an attack of fever, or commonly when a person gets drunk, and so loses the command of the muscles which direct the eyes, vision immediately becomes double. We can produce this effect in ourselves, by fixing our eyes on any object, and then, with the finger, gently pressing one eye from above, or towards one side, while the other remains fixed: we shall then see the object double. In all these cases, an interference with the parallel motions of the eye takes place; in consequence of which, the rays no longer fall on corresponding points in the retina of each. It appears, then, that the mind can only notice two impressions together, if they be made on corresponding parts of the sentient surface.

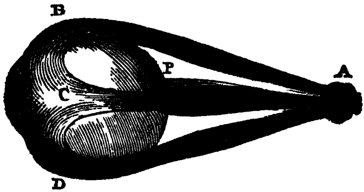
[If a cube, or any other solid body, be placed at a short distance before the eyes, two pictures, perfectly unlike each other, will be projected upon the two retinæ, yet but one object will be presented to the mind. The object is seen singly, because, in consequence of the simultaneous perception of the two dissimilar pictures, *it is seen in relief*. To prove this, let these two dissimilar pictures of the cube be drawn separately: that which is seen by the right eye, the left being closed, and that which is perceived by the left, the right being shut. Let these be presented one to each retina, in such a manner, that they fall on the same part as the pictures of the object itself would, and the mind will perceive the object singly, *and in relief*, and no effort of the imagination will induce the observer to suppose it to be two pictures on plane surfaces. By means of a stereoscope*, which enables the observer to throw the artificial pictures upon the same part of the retina as that upon which natural projections of the real object would fall, marbles, architectural models, flowers, and any solid geometrical forms, may be represented in relief. Taken in conjunction with the known laws of single vision, Sir David Brewster says, that these facts explain all those phenomena of vision by which philosophers have so long been perplexed: while Sir John Herschel considers this discovery "as one of the most curious and beautiful for its simplicity, in the entire range of experimental optics." After the mention of these illustrious men, and adding that the discoverer is an Englishman, we need scarcely say that his name is Professor Wheatstone.]

In persons who squint habitually there is not double vision, for the habit generally results from an inequality in the power of the two eyes: that which was weaker, therefore, is turned awry not to interfere with the more distinct impressions received from the other, and by degrees the habit is acquired

[* Derived from στερεος, solid, and σκοπεω, I view.]

of attending solely to those latter, so that but one object is seen.

There remains another point to be explained: on reference to the image produced by the glass lens, it will be found to be inverted; the same effect must be produced by the lens of the eye: how then do we see objects erect? One of the latest explanations offered of this, has been Sir Charles Bell's, which, as it involves little theory, and appears in many respects consonant with facts, we shall subjoin. We have already stated that he has distinguished from general sensibility a perception of the state of muscular action or relaxation, which he has, with much reason, described as a separate sense. Now the eye is directed towards objects by means of four muscles, by

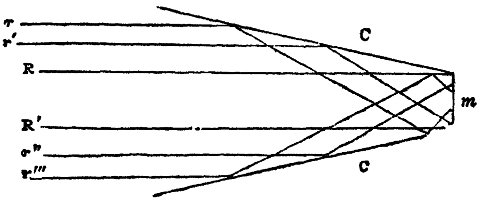


which it is surrounded, and which are inserted, as we see, into its cardinal points. If we suppose our figure to represent the left eye, it is evident that it will be directed to an object above it, by the superior muscle, A B; to an object below it by the inferior muscle, A D; to an object on the left by the muscle, A C, which is to the left *of its axis*, and to an object on the right by A P, which is to the right of its axis, and has its insertion just opposite that of A C. Now, in all these cases, we judge, with perfect correctness, of the position of an object with respect to ourselves, though it is evident that the image of an object above us, is painted on the lower part of the retina, or of an object on our right, on the left part of the retina. It is clear, then, that we do not judge of the position of an object by the position of its image on the retina, but, by a knowledge of the muscle which is called into action to direct the axis of vision towards that object. Having thus shown that it is by means of this muscular contraction that we judge of the relative position of one object as regards another, Sir Charles Bell infers, as a corollary, that the same sense enables us to judge of the relative position of the different parts of the same object, that is, which of them is top and which bottom, and that thus we see an object straight, the image of which is inverted, just as we see an object to the right, though its image on the retina lies to the left: this we believe to be Sir Charles Bell's meaning*, though, with regard to this point, he does not speak so clearly as with respect to the first. Neither do we consider the explanation equally satisfactory: we can very well distinguish the top from the bottom of a small object placed below us, though the same muscular adjustment enables us to take in both at once; consequently we are deprived of that sense which, in the other instance, enabled us to correct the position of the image. To us it appears that the whole inquiry is rather premature, and that, until we know *how* the image acts on the retina, so as to produce sight, it is useless to inquire how the top and bottom of the image act on the retina, that is, why we see the object erect, not inverted.

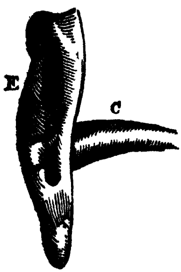
There is the less necessity that we should enter minutely into the structure of the ear, inasmuch as we have by no means a clear or satisfactory knowledge of the mode in which its several parts are subservient to the faculties of hearing. It is usually divided into three portions: 1, the external ear, which serves as a sort of conduit to the sound; 2, the middle ear, in which, it is said, the sound is in some way modified or prepared for striking on,—3, the internal ear, which answers to what we have more particularly named the vital part of the organ, that in which the nerve is expanded, and in which the last corporeal change, necessary to perception, takes place. Of each of these we shall speak briefly. The external ear is constructed for the obvious purpose of collecting the rays of sound,

* See Bell on the *Nervous System of the Human Body*.

which, like the rays of light, uniformly diverge from a central point, and, like them, may be made to alter their direction, or be brought to a focus. It is more usual, however, to speak of sound as propagated by undulations than rays, that is, as dependent on corpuscles, which vibrate or oscillate within a given distance, and so communicate their motion to the next series of particles, but have not themselves an actual progressive movement. Sound, however, like light, diffuses itself in right lines, and may be reflected by bodies which refuse to transmit it; in which case, the position and form of the reflecting surface produce, on its direction, exactly the same effects as on that of rays of light. Thus, if two plane surfaces be inclined towards each other, like the sides of a cone, and the wide end be now turned towards a sounding body, it is evident that a great number of rays entering it will, by reflection, be made to reach its apex, and so produce a more forcible impression upon any vibrating body placed there, than if it had simply been exposed to their effects. Thus let C C be a cone, which has its point



cut off, and a vibrating membrane, *m*, inserted at its lesser extremity. Let *r r′* R R′ *r″ r‴* be sonorous rays, coming from a vibrating body, placed at some distance from the membrane, but nearly in the same horizontal line, in which case we may consider them as being nearly parallel to the axis of the cone. It is evident that, were the cone removed, no rays could reach *m*, but such as lay between R and R′; but the presence of the cone causes all the other rays, *r r′ r″ r‴*, to reach the membrane after a certain number of reflections; consequently, were the membrane connected with a sentient organ, the impression made on it would, by these means, be considerably increased. This is the principle attended to in constructing ear-trumpets, which we know are always of a funnel shape, and this is the principle exemplified in constructing the external part of the human ear, where, in addition to the conical tube, termed *auditory passage*, we find a still further means employed, for concentrating sound, in the broad elastic cartilage, hollowed out into different sinuosities or concavities, all inclining towards the common opening, which is attached round the wide end of the cone.



This may be seen, in the accompanying cut, where E is the external cartilage, commonly called the external ear, and C the cone or auditory passage, through which the sound is reflected in; and it is in this passage that the wax of the ear is formed, which, with the fine hairs that grow round its entrance, seems destined to prevent the entrance of minute insects, or other offending bodies. At the end of this passage, is really placed a membrane similar to that which we have above supposed to be placed at the summit of our cone, and at this membrane terminates the external part of the ear, while the little cavity beyond it, commonly known by the name of *the drum of the ear*, constitutes its second or middle portion. And this cavity is, in some respects, not unlike a drum: it has at one end the membrane we have described, which may be compared to the drum-head, and is usually called *membrana tympani*, though in common conversation, it is not unfrequently spoken of as being itself *the drum*. But this is incorrect; the drum is the cavity beyond it, and when people talk about having the drum of the ear broken, they really mean a rupture of this membrane. The other side of the drum has another membrane, and this serves to form the partition between the middle and internal ear, which is situated yet deeper. But here occurs a very nice and accurate point of resemblance: a drum would give but a very faint sound, unless an aperture were left in its side, through which the vibrations might be communicated from the air within, to the exterior air, such an aperture, therefore, is constantly left; and in like manner the side of the drum of the ear is perforated by a long tube, called the Eustachian tube, which coming from the upper part of the *pharynx*, just behind the mouth, affords a free passage for air into the cavity of the drum, and so allows its membranes to vibrate, and the impression to be transmitted to the internal, or properly sentient part. The existence of this passage is curiously exemplified in persons who have had the *membrana tympani* ruptured, as such persons can cause smoke, which they have inhaled with their mouths, to pass out through their ears, for which purpose it is only necessary to allow it to reach the back of the throat (without swallowing it), when it will pass through the Eustachian tubes into the drum, and then out through the ruptured membrane, with as much ease as, in ordinary cases, it is passed through the nostrils: a feat which almost every habitual smoker is able to perform. The deafness accompanying a cold and sore throat is another proof of the existence and use of these parts, as it merely arises from the inflammation stopping up the entrance of the tubes, and so preventing the entrance or exit of air from the drum of the ear, in consequence of which its membranes can no longer vibrate to slight noises. The drum of the ear, however, has superadded a distinct structure, such as finds no parallel in any common drum. This is a fine chain of very minute bones, continued from one of its membranes to the other, and so arranged as to increase in strength the vibrations which they transmit inwards. These bones are further supplied with very minute muscles, by which the *membrana tympani* can be tightened or relaxed, so as (it is supposed) to accommodate itself to sounds of different degrees of intensity. Finally, the object of all this apparatus is to convey the impression to the internal ear or *labyrinth*, which consists of three parts, the *vestibule*, *cochlea*, and *semi-circular canals*, all hollowed out of the hardest bone in the body, all completely shut out from communication with the external air, but containing in its place bags or tubes, filled with a fine limpid fluid, which is set in motion by the slightest vibration, and lies in contact with the delicate expansions of the acoustic nerve, to which the sense of such vibrations is thus immediately communicated. It would be useless to expatiate on the structure of these parts, as we are perfectly ignorant of the mode in which they are subservient to the faculty of hearing, or whether, as is probable, they each perform a separate function. It has been suggested that the *vestibule*, which appears the simplest part of the internal ear, may be for taking notice of simple sound; that the semi-circular canals may serve for the perception of melody, that is, an unaccompanied musical strain; and the *cochlea* for appreciating harmony, that is, the more complicated music of an orchestra: this is all very possible, but we have not the slightest proof that it is true.

Chapter XII.

OF MAN, AND THE VARIETIES OF THE HUMAN SPECIES.

We have thus taken a survey of the principal organs of which the human frame is built up; we have considered its structure, and seen that it is fearfully and wonderfully made; we have examined the various contrivances by which nutriment is introduced, purified, distributed, returned when exhausted, and again expelled; we have noticed the wonderful apparatus by which we are rendered capable of acquiring sensations from external bodies, and the nervous centre to which these all are referred, and which alone enables us to know and judge of the impressions thus produced: it only remains to the completion of our present task, that we should say a few words of man as he exists; and inquire whether the various appearances under which he is found in different countries, are such as may admit of explanation, on the theory of sameness of species under the influence of accidental circumstances, or whether we shall be obliged to hold, with certain physiologists, chiefly of the French school, that there was no original *individual* man created, but a number of men, either at the same, or at different times, specifically distinct from each other, and bequeathing this distinctness of species to their posterity.

Man is distinguished from all other animals by many and important characters. Destined to rule over "every beast of the earth, and every bird of the air," yet inferior to many of them in size, in strength, in velocity, and even, apparently, in instinct, there remained but one means for enabling him to assert his superiority, and that was to endow him with reason. This has taught him to subdue force by stratagem, and power by craft; to shelter himself from dangers which he could not overcome, and evade attacks which he could not repel. This has caused the untutored savage to prepare the pitfall, to lay the snare, to bait the trap, to construct the canoe, or shape out the arrow, the spear, and the bow. But for these things two provisions were necessary, the mind to contrive, and the skill to execute; the former finds its corresponding organization in the large, the complicated, and the weighty brain; the latter in the hand,—an organ so exquisitely finished, so admirably adapted for working out the most ingenious devices, that Helvetius was inclined to look on it alone as sufficient to account for man's superiority over other animals.

Now, from these two necessary peculiarities of structure, flow two of man's most characteristic distinctions: he must be erect,—and capable of using his two anterior extremities, as hands; erect, because the weight of his brain and skull would, if he assumed a horizontal position, be constantly weighing down, and wearying his neck, while the blood, rushing with unchecked force, would render him constantly liable to headaches, vertigoes, and apoplexies; capable of using his two anterior extremities as hands, for, were they employed as feet, their fine sense of touch would soon be lost, the skin, thickened and hardened, would be deprived of its delicacy of feeling, the fingers, swollen and stiffened, would want their easy pliancy and flexibility, and could no longer adapt themselves to any tasks requiring neatness or care. We thus see that man was destined by his constitution to be an intellectual animal, upright in position, and furnished with two hands and two feet, and this enables us at once to search out his most important characters, and embody them, if required, in a definition. In fact, from these flow almost every other peculiarity of his structure.

In other animals, the hole through which the spinal marrow passes out from the skull, is nearly opposite the face or jaws, and the weight of the skull is, in a great measure, sustained by a ligament (the *ligamentum nuchæ*), which we have already described: in man, the hole is in the centre of the base of the skull, which is thus nearly balanced on the vertebral column, and needs no ligament for its support, consequently there is no ligament, or merely a vestige of what may be considered as such. In animals, also, the blood rushing to the head, which is so often lower than the heart (as when a cow is grazing), would come with a fearful power were not its course delayed by a beautiful and wonderful contrivance, to which there is no parallel in man, because his head is not intended to be in that position. The contrivance is the sudden breaking up of the internal carotid arteries, just before they enter the brain, into a perfect network of little vessels, through all which the blood must pass, to be again collected before it can reach the brain. The force of the heart is thus entirely broken; but in man the blood has to rise against its own own gravity, which sufficiently answers the purpose. Again, animals that are to live on flesh, are provided with fangs, or beaks and talons: man has no fangs and no talons, but he has the mind to devise implements of destruction, and the skill to construct them. Endowed with the moral sentiment, with feelings of delicacy, man naturally seeks to cover himself with dress, and this is more than a counterbalance to the want of feathers or fur, which besides would so considerably blunt the fineness of his sensations. In the same way we could proceed to account for the length of his heel-bone, the form of the foot, the muscular swelling of the calves and buttocks, the form and direction of the pelvis, and many other circumstances in which he differs from all other animals, but as this is a subject presenting very little doubt, let us rather turn to consider those points in which men differ when compared amongst themselves.

Zoologists have much disputed whether mankind are to be considered as forming one *genus* with several subordinate *species*, or one *species* with several *varieties*. Either hypothesis will serve to explain the numerous differences which we everywhere meet with, in size, colour of skin and eyes, nature and colour of hair, general form, &c.; but, according to the former, a creation of several original pairs, endowed each with the peculiarities which characterize their descendants, becomes necessary; while, according to the latter, a single pair will suffice, and then zoological deduction will coincide with what appears to be declared in the Mosaic narrative. Many circumstances tend to favour the prevalence of the first opinion. We compare the delicately fair Caucasian with the intensely black Negro of Guinea, the giant Patagonian with the dwarf Laplander, the long-haired Greek with the woolly-headed Hottentot, the oval-faced European with the broad and flat-faced Mongolian; we find it difficult to account for such wide deviations from a common stock, and we indulge our indolence, and save ourselves the mortifying confession of our ignorance, by saying they had each their own stock. The same explanation is of equal use in accounting for the mode by which distant islands, difficult of access, became peopled with inhabitants, too numerous to allow of the supposition of their recent importation, and too barbarous to admit of attributing to them any further skill in navigation, than consisted in the management of a wretched canoe. If we suppose them to have been created on the soil where they were discovered, we at once relieve ourselves from the trouble of framing an hypothesis regarding their immigration, and spare ourselves all attempts of tracing analogies with known tongues in their language, which, perhaps, is truly and radically distinct. A further difficulty is also thus overcome, we should rather say avoided; and it is one which, in an *à priori* argument, would necessarily be of considerable weight. It is this: we learn from historical records, from sepulchral tablets, and from the figures in the Egyptian temples—too accurately delineated and coloured, and too well preserved, to admit of doubt—that, at a period of remote antiquity, races of men existed, as distinct from each other as they are at the present day, consequently such varieties must have had their origin previous to this time, that is, say, in the thousand years, or thereabouts, that intervened between it and the deluge; but man was then nearly in a state of nature, and much less subject to the numerous modifying circumstances which might be supposed to give rise to varieties, than he has been for the last three thousand years: during which, however, no one has ever seen the origin of a new variety. We think we shall be allowed to have stated, in its full force, this objection to the theory which we mean to adopt, and we shall take an opportunity of returning to it when we have developed the true grounds on which the question should be argued. We think, also, that we have shown sufficient reason why the theory of a plurality of species, so gratifying at once to our vanity and our indolence, should have found such numerous supporters; nor need we wonder, from its very obvious nature, that a writer, at all times more distinguished for brilliancy than depth, should be found to assert, "Il n'est permis qu'à un aveugle de douter que les blancs, les Nègres, les Albinos, les Hottentots, les Lappons, les Chinois, les Américains, soiènt des races entièrement différentes."

The question, however, is not to be decided by declamation; it is simply, as we view it, one of zoological science, and resolves itself into this:—Are the differences between the inhabitants of various countries and climates so great as to render it impossible they should be of the same species? And, of course, the first step towards our answer must be the deciding what is meant by a species.

By species, then, we mean all those individuals descended from a common origin; and if there be a doubt as to whether an individual does or does not belong to a species, we compare it with the individuals known to be of that species, and ascertain whether it is marked by any more decided particularity than those by which they are distinguished the one from the other. If it be, we conclude it of a different species, and assign it a different origin; if not, we look upon it as a *variety* of that species, assign it the same origin, and term its particular characters accidental.

This is our idea of species, and of the criterion by which it may be decided: several others have been proposed.

The following is John Hunter's:—"Si duo quælibet animalia, quibus inter se similitudo non ita perfecta est, ut per certo eidem speciei adjudices: prolem tamen alterutri parenti aut jam similem, aut *aliquando futuram*, procreent; tum quantum inter se differant, illa ejusdem tamen speciei esse habenda sunt:" which he illustrates thus. Of all that bear the human name select a male and female the most unlike possible, say a Congo black and a fair Circassian; suppose that from their union spring a male and female child, and that the former of these intermarries with the father's race, the latter with the mother's; if then, after some generations, the offspring of the male child resemble the father in everything, and the offspring of the female the mother, then it follows that the parents were of the same species. But that such will be the case is proved daily, by the results of intermarriages between blacks and whites.

This appears to us unsatisfactory: the canary, it is well known, will breed with different birds of the finch tribe, their offspring is prolific, and there can be no doubt that if mated only with birds of either family, all trace of the other would be obliterated after a few generations, probably as soon as traces of black blood are lost by the descendants of a Mulatto. The same circumstance is known to occur in the production of Hybrid plants.

Still less can we admit the criterion proposed by Ray, and supported by Buffon, that all those animals which breed together, and produce a prolific offspring, are of the same species; though, could we adopt it, our own views would be at once proved, for all varieties of the human kind come within the law. But, as Mr. Lawrence observes, the rule involves a petitio principii. It is true, that in general, mules, produced between a horse and an ass, are incapable of procreating, and thence has come the popular generalization, that no hybrid can breed. But to this, numerous exceptions are now known; the mule itself has at times broken through the rule; and Aristotle mentions instances in which a mule had engendered with a mare, and the less dubious case, in which the she-mule had conceived. The he-goat breeds with the ewe, and their offspring is prolific: the case of the canary-bird and goldfinch has been already mentioned; the common cock will breed with the hen-partridge, or the cock-pheasant with the common hen; and, according to Pallas, the Chinese goose copulates readily, in Russia, with the common goose, and produces a hybrid, but perfectly prolific offspring: "the race soon returning to the characters of the common goose, unless crossed again with the Chinese species."

This criterion, then, being quite untenable, Doctor Prichard has proposed another mode of determining the identity or diversity of species; viz., "by referring to the principal laws of the animal economy;" and this, as being a physiological test, and having its basis in the operations of nature, we should willingly embrace, but for the very limited extent of our acquaintance with those laws, and our consequent ignorance how far they may admit of modification. Thus, Doctor Prichard assumes as one of his examples, the period of utero-gestation, and from the fact, as stated by Buffon, that the wolf goes with young more than one hundred days, while the bitch is known to carry hers but sixty-two or sixty-three, gives it as his decided opinion that they are of different species; though, from such tests as those before mentioned, John Hunter, and several other excellent physiologists, were inclined to consider them as of the same. But though, in the human kind, we know the general law which confines the child to the womb for a period of nine months, we also know that this period may be considerably anticipated; but, as we do not know the cause of the general law, so neither can we tell the extent to which it will admit of particular exceptions; such exceptions, therefore, may be but accidental; and we have already shown that accidental peculiarities do not constitute species but varieties. Doctor Prichard seems to us still less happy, when he assumes, as a standard, the common liability to certain diseases. It is certainly true that the small-pox has raged in every climate, and amongst every race; and, before this dreadful scourge, all have confessed their common humanity: but it is also true that apes, inoculated with it, have shown regular pustules; the vaccine disease, none can doubt, we share with cows; itch and other cutaneous maladies seem common to us with inferior animals, and a late but terrible experience, has fully proved that glanders can be communicated from the horse. It is singular that this very test, which Prichard chose as establishing the variety of the human species, should have been selected by others for disproving it. Virey alludes to the frequency of *yaws* among the Negroes, while they are seldom known to attack whites, and the latter suffer dreadfully under yellow fever, from which the former are comparatively exempt. Other authors have attempted to show that the species of louse found on the Negro, differs generically from the parasitical insect of white men; and Rudolphi has extended the argument to the worms by which their bodies are infested: "*Tænia lata*, L.," he says, "is found in the bodies of the Russians, neighbouring Prussians, and Swiss, while in the other Europeans, and the Greeks generally, *Tænia solium* prevails. I have only seen one example, in a young female, where both of these presented at the same time, but it is probable that this person was of mixed descent!" The idea of making this a standard of species is certainly not a little amusing, when we recollect that the *Ascaris lumbricoïdes*, L., is to be found without any sensible difference, in the intestines of man, horse, zebra, ass, mule, ox, and hog.

We shall only mention one more—that proposed by M. Cuvier, in the Preliminary Discourse to his *Ossemens Fossiles*. "Generation," he says, "being the only means of ascertaining the limits to which varieties can extend, we should define species to be the assemblage of individuals descended one from the other, or from common parents, and of those who resemble them as strongly as they do each other." This definition, M. Desmoulins pronounces false, for the following reason. The American bison is clearly a distinct species from the European domestic ox, as is evinced by the difference in figure, the shape of the head and cranium, &c., as well as by its possessing two additional ribs on each side. But a great part of the black cattle, to be found in the states of the American confedracy, at the other side of the Alleghany, is the hybrid breed, between the European cattle and these bisons. "These hybrids," says M. Desmoulins, "form really a new species." To this we can by no means assent, as it would go to prove every productive *cross* a new species, a doctrine perfectly monstrous: had M. Desmoulins said that such hybrids, if bred previous to our knowledge, and since propagated by direct descent, would now be probably ranked as a new species, he would have been right; but he would have been assuming a case which he knew did not, and we may say could not, occur; such crosses are artificial, they occur only in animals under subjection to man, and are not known to occur in a state of nature, where there seems to be an instinctive aversion to all intermixture of species; they cannot, therefore, with any show of fairness, be introduced into a dispute regarding the original and natural distinctness of species. But M. Desmoulins' own test, "the permanence of type under different circumstances," cannot be admitted as sufficient, when we see the red eye invariably accompanying the white skin, in the leucæthiopic race of rabbits, mice, &c., which we can show to be but a variety, or the universal prevalence of black hair on the swine of a certain district, or the uniformity of colour, mentioned by D'Azara, as marking the numerous troops of horses, now running wild on the spacious South American Pampas, which, nevertheless, all owe their origin to those originally imported by the Spaniards. In truth, M. Desmoulins, though nominally one of the most violent opposers of the unity of the human species, is really not a direct contradictor of our views. He denies that species can be formed by the influence of climate, but asserts they may originate by generation; this is nearly what we hold respecting varieties; the dispute, then, resolves itself into one about words,—what we call varieties he calls species, and admits they may have a common origin.

We therefore return to the definition with which we set out; we consider all descended from common parents, as being of the same species; and we accept Blumenbach's test of analogy, and judge of the extent of variety which may occur, by a comparison with that which has occurred.

Our next step shall be to state, as briefly as possible, the most striking differences observed in the human species, for which purpose we shall arrange them under the five heads originally proposed by Blumenbach, and since generally received. We shall then apply our test, and show that greater differences have, to our knowledge, arisen in individuals allowed to be of the same species; and, lastly, shall consider the causes to which the origin of varieties may be referred.

1. At the head of the human kind stands the Caucasian race, distinguished for pre-eminent grace and beauty of figure. The face is oval, the skin fair, inclining to brown, deepening in shade as the exposure to sun and climate becomes greater, yet generally permitting the blood to be seen through the skin in the cheeks, and at the lips. The hair of the scalp and the beard is abundant, soft, long, and flowing in undulations, more

or less approaching to curls. In colour, it may be described as brownish, deviating, on the one side, through auburn, red, and yellow, to a delicate flaxen colour; on the other, through different degrees of intensity, until it becomes a clear and glossy black. The forehead is high and expanded; the features moderately distinct; the nose narrow and straight, or inclining to aquiline; the cheek-bones not in general prominent; the mouth small; the lips, particularly the lower one, slightly turned outwards; the teeth perpendicular in each jaw, and the chin full and rounded.

The head is of a symmetrical appearance, nearly globular; this character is particularly observable in the Turks. The general outline of the figure is free and flowing, the port erect, the back part of the head rather projects, so as to cause a curve in at the neck, the lower extremities are straight and well-placed under the body, the sole of the foot lies nearly smooth on the ground, not resting, as in monkeys, on its outer edge, and the swell of the calf is gradual, and at some distance beneath the knee. The facial angle is more open in this than in any other variety; though in this point much difference exists from the ideal forms of Grecian beauty, in which the angle approximates a right angle, the forehead being thus perpendicular over the face, to the sloping forehead of the Pole represented in Blumenbach's *Decades Craniorum* (iii. 23), and in which the angle is identically the same with that of a Negro's head, which he has also represented (ii. 10). We may here observe, *en passant*, upon the total and evident insufficiency of so constantly varying a mark for the establishment of any original difference between races of mankind; yet this is the character upon which M. Virey chooses to divide them into two distinct species, which he again subdivides into races distinguished by their colour, as follows:

Species.	*Race.*	*Families.*
I. Facial angle 85 to 90 degrees.	1. White	Arabo-Indian. Celtic and Caucasian.
	2. Tawny or yellow .	Chinese. Kalmuck-Mongolian. Lapono-Ostiack.
	3. Copper-colour . .	American or Carib.

Species.	*Race.*	*Families.*
II. Facial angle 75 to 85 degrees.	4. Deep-brown	Malay or Polynesian.
	5. Black	Caffer. Negro.
	6. Blackish	Hottentot. Papuan.

It is evident our Pole at once destroys this distinction, as according to it he would have been of the second species, while his father or brother, or any more fortunate member of the family would have belonged to the first. And this, in fact, is the strong point, from which we must ultimately admit the unity of the human species, that you can take no mark so decided, that will not occasionally be found occurring in some of the other divisions: for by such insensible gradations do they run together, that though the extremes seem remote, the intermediate steps are as nothing. We proceed from change to change, scarcely knowing how we advance; the fugitive character still eluding our grasp, and refusing to exhibit any stableness or fixity, till at last we join in the conclusion of one whose best attention has long been given to the subject, and who declares, that so far from finding mankind to consist of different species, he has become totally unable to discover any decided grounds for distinguishing them into varieties.

To revert, however, to our Caucasian race, of which we have noted the prominent physical characters; they are no less distinguished for moral endowments. Amongst them civilization probably originated, as amongst them it certainly attained its greatest perfection. Whatever may have been the colour of the ancient Egyptians, the form of their skull clearly indicates them to have been of this variety. This it is which has produced the greatest men in every art and science; legislators, poets, painters, astronomers, divines, physicians, naturalists, all have appeared most pre-eminent amongst the nations belonging to this race. Its characters are pretty widely extended: in Europe they are universal, if we except the Laplanders and some of the Hungarians, tribes who seem rather to belong to our second division. In Asia they are found stretching, even to the west banks of the Ganges, through Turks, Syrians, Armenians, Georgians, Circassians, Jews, Mingrelians, Persians, Arabs, and Hindoos of high caste. In Africa they may be traced in the Moors, the Berbers, some of whom, as represented by M. Rozet, present a physiognomy perfectly Roman, in the white and yellow-haired tribes of Mount Auress, described by Shaw and Bruce, in the Egyptians, the wandering tribes of the desert, and at the extreme west, in the mummies of the Guanches, or former inhabitants of the Canary isles. In America we cannot say that any of the race exist, except as descended from European colonists. The tribes termed indigenous agree amongst themselves in characters sufficiently numerous to form them into a distinct variety, of which we shall speak hereafter. We only doubt whether the Incas, "the *golden-haired* children of the sun," can be considered as belonging to to it; but our information respecting them is far too limited to allow of even a probability being attained on this point: Dr. Prichard suggests that they may have been a family of the original Asiatic immigration, who, from some peculiarity of custom or situation, preserved their ancient manners and civilization, by means of which they were enabled to become the legislators of the rest, who, spreading more widely through immense uncultivated tracts, soon degenerated into all the habits of barbarous life.

2. The second great variety of the human species, termed Mongolian, extends over all the eastern and northern parts of Asia, the north of America, and embraces those European tribes, the Laplanders, Hungarians, &c., excluded from the first. In all these the head presents a square and flattened appearance, as though the globular Caucasian head had been depressed, and the face widened and dilated. The general complexion is yellow or olive, "a middle tint," as Mr. Lawrence says, "between ripe wheat and boiled quince, or dried lemon-peel." In many of them it is by no means darker than in several of the foregoing race, particularly when embrowned by exposure, yet it effectually conceals the rush of blood to

the cheek; the becoming blush seems the peculiar privilege of the Caucasian tribes, though it has been distinguished in a faint degree in young and delicate females of the Tonquinese by Damper, of the Esquimaux by Chappell, of the Otaheiteans by Forster, and even of the Negro race by Goolberry. The hair in the Mongolians is black, straight, thin, and stiff; many of them shave it, leaving a single lock, as may be seen in representations of the Chinese; the beard is scanty, and generally eradicated. The general contour of the face is square, and the features seem, as it were, pressed into it. The forehead is low and slanting, the superciliary ridges scarcely exist, the space between the eyes is wide and flat, the eyes of a black-brown colour, narrow, linear, and drawn upwards towards their outer angle; the cheek-bones project literally; the nose is flattened in, particularly at the root, and the nostrils are very open; the upper jaw is flat and wide, the teeth straggling, the chin short, and not retreating. In general form of body the Mongolian is, at least to our eyes, by no means so graceful as the Caucasian. The trunk is large, square, and massive; the extremities thick, short, and muscular; the whole is constructed rather for strength than agility, and the average height is inferior to ours. Under this head have been assembled the inhabitants of China, Japan, Tonquin, Cochin-China, the Burmese, and other territories east of the Ganges; of Thibet and Boodhtan, the nomad hordes of central and northern Asia, the Finnish races, already alluded to, of the north of Europe, and the Esquimaux of the northern parts of America, extending from Behring's Straits to the extremity of Greenland. Amongst these people, however, innumerable differences are to be found, insomuch that Dr. Prichard quite rejects the idea of uniting them under one common name, and there certainly appears sufficient reason for admitting, at least M. Virey's subdivision, into three principal families, the rude wandering hordes of the elevated ground in central Asia, verging on one side into the more cultivated and civilized nations between the Ganges and the sea, where this variety appears to have reached its utmost perfection, though still far from rivalling the Caucasians, and, on the other, into those stunted and diminutive tribes, the Esquimaux, the Samoiedes, the Ostiacks, the Laplanders, and others surrounding the Arctic Pole.

3. We could suppose a skull, such as we have described the Mongolian, to be formed from a Caucasian by depression; but compression as well as depression would be required to produce our third variety, the Ethiopian, including, we may say, all the African tribes not referred to the first division, and who, from their prevalent complexion, are known by the common appellation of Negroes, or Blacks. In this variety we generally find a predominance of the sensual over the intellectual developement. The senses are all of extreme acuteness, and the face seems to be moulded, so as to afford their organs as much size and prominence as possible. The eyes are brought to the surface of the head, the nostrils enlarged, the mouth protuberant, the teeth strong, the jaws powerful, the temporal muscles by which these are moved enlarged, and occupying a considerable extent on each side of the skull, which seems as if it were flattened and narrowed between them. The hair is short, crisp, and woolly, and, as well as the eye, of a black colour. The cheek-bones are prominent, the jaws projecting, the nose broad, thick, flat, and confused with the surrounding parts, the lips, and particularly the upper one, are thick, the upper front teeth are oblique, the chin retreating. The head is altogether of an elongated form from front to rear, where is placed its principal bulk. The occipital foramen is situated so far back, that there is scarcely any bend in at the neck, which forms almost a straight line from the head to the back. The general figure is less graceful and erect than in the Caucasian, the knees are generally turned in, the calf is small, and situated immediately below the knee, the sole of the foot rests more on its outer edge than in us, the head is elongated, and the leg is not well straightened in progression.

There are, doubtless, many points in which the Negro differs from the Caucasian, and in most of which he more nearly approaches the monkey-tribe. This fact has been seized on by persons who have considered it a reason for either depressing the Negro-race to an affinity with monkeys, or raising those latter to the rank of men. But a moment's consideration would have shown the trifling importance of the fact upon which they build such grave conclusions: if there is to be a variety in the formation of mankind, some *must* resemble monkeys more than others; but this is no proof of anything like an approximation of species; "some pigs," says Mr. Lawrence, "have solid hoofs, and in so far approach the structure of the horse, but do we on that account suppose that the nature of the animal in general is less porcine, or more like that of the horse, than that of other pigs?" The Negroes are in fact, "children of a larger growth;" we perceive in them the same volatility, the same restlessness, the same impatience of restraint, the same attention to objects which strike their senses, the same fickleness of will, the same want of determinate aim or purpose. The reflecting powers seem dormant or little exercised, the moral sense is weak and obscure, the animal propensities alone seem to have reached maturity; and under their unchained influence, the Negro is capable of the warmest attachments, the bitterest enmities, and the most horrible revenge. A nation of civilized Negroes is a phænomenon unknown; in vain will you search amongst them for elevated flights of imagination, profound investigations of the laws of nature, or just views of human responsibility; no woolly-headed race has ever produced even a great conqueror—perhaps the least honourable path that leads to human distinction. Blumenbach has taken pains to collect some examples of natural talent amongst Negroes, and instances some who have succeeded as painters, poets, musicians, and divines. These are, however, only individual cases, the general character accords with that we have sketched—and may be applied, with but few exceptions, to the African nations living along the coasts of Guinea, Benin, Angola, Loango, &c., or generally, to all south of the Atlas mountains.

These are the three* principal varieties of the human kind, and with them Cuvier declares himself satisfied; though he allows it is difficult to reduce the Malays or the Americans to any one of these precisely. Still he suggests they may be sorts of transition Varieties,—the Malays between the Mongolian Chinese on the one side, and the Caucasian Hindoos on the other; the Papuans, a cross on some Negroes who had found their way to the Indian seas; while for the Americans, related to the Mongolians by their black hair and scanty beard, and to us by the distinctness and prominence of their features, he declares he can find no character sufficiently decided and important to warrant him in constituting them "distinct varieties."

We shall, however, for the sake of more clearly stating the prominent difference observable in mankind, retain the remaining varieties, as established by Blumenbach, under the names of American and Malay.

4. Through the entire of the new world, if we except the regions bordering on the Arctic circle, there exists a wonderful uniformity of personal appearance. "The Indians of New Spain," says Baron Humboldt, "bear a general resemblance to those who inhabit Canada, Florida, Peru, and Brazil. They have the same swarthy and copper-colour, *straight and smooth hair*, *small beard*, squat body, *long eye*, *with the corner directed upwards towards the temples*, *prominent cheek-bones*, thick lips, expression of gentleness in the mouth, strongly contrasted with a gloomy and severe look." "Over a million and a half of square leagues," adds M. Volney, "from Tierra del Fuego to the river St. Lawrence, and Behring's Straits, we are struck at the first glance with the general resemblance in the features of the inhabitants; we think that

* Descended, it has been supposed, from the three sons of Noah; Japheth being the progenitor of the Caucasian or European tribes; Shem, of the Mongolian or Asiatic; and Ham, of the Negro or African. The original affinities of the various languages spoken amongst these great subdivisions have been brought in support of this idea. Much curious information, tending to throw light on the question, may be found in Adelung, Vater, and Prichard.

we perceive them all to be descended from the same stock, notwithstanding the prodigious diversity of languages which separates them one from another." The traits mentioned above, particularly those marked in italics, can leave little doubt as to that stock being the Mongolian, to which, if we add the consideration of their relative geographical situations, of the narrow strait which separates north Asia from the shores of the new world, of the evidence that in former times, this distance was still less, or perhaps that an actual junction existed, or at least, that islands* studded the strait, the passage from one to the other of which, even in the rudest canoe or raft, must have been perfectly easy; if, further, we take into account the analogies which American languages furnish with those spoken in northern Asia, the similarity even in certain habits and shades of character noticed by travellers, particularly by Humboldt, Spix, and Martius; and finally, add the singular but well-established fact, that the dog found with the natives, was a rough-haired, prick-eared, savage animal, agreeing identically with the *Canis Sibiricus*, the faithful attendant of the northern Mongolian nomad hordes; we think the supposition of a separate creation of autochthones for the new world will be given up as gratuitous and unnecessary, and its inhabitants will be allowed to offer no exception to the theory which looks on mankind as one, and derived from a single origin.

The characteristics of the American tribes, however, are, like all others we have noted, subject to considerable variation. The tint of the skin, generally of a red or copper colour, may become of a deep brown, while others are nearly white, as Cook observed of the natives at Nootka Sound, and Molina of some who inhabited a high situation in the Chilian Andes. In stature, they present all degrees, from the great height of

* Dr. Mitchell, of New York, has confirmed the fact, that the islands placed between Kamtschatka and the coasts of America, such as the Aleutian, the Kurile, &c., are inhabited by the descendants of Siberian tribes, retaining all their manners, habits, and appearance.

the Patagonian to the dwindled bodies of the Chaymas, whom Humboldt describes as seldom exceeding four feet. The depression of the forehead also varies considerably, and, it is said, is in many cases assisted by artificial means. Blumenbach represents the skull of a Carib, in which pressure had been evidently used for this purpose, and the forehead slants off so suddenly from immediately above the eyes, that we can almost suppose the individual must have been able to see above him without turning up his head.

Civilization would appear never to have made much way amongst our red brethren. When the Spaniards entered America, there existed two powerful nations, the Peruvians and the Mexicans, respecting which the Spanish historians entertain us with wonderful accounts of their power, wealth, intelligence, and advancement; but it is evident they had as yet made few steps from barbarism, as they had no current coin, no written alphabet, no manufactures, or commerce, no clothes, except some painted feather girdles and other ornaments, and a few hardy adventurers proved sufficient to overthrow these two mighty empires. Yet courage is by no means that quality in which the American Indian is deficient; he will face the most appalling dangers, will undergo the severest tortures without a groan, and will march to his funeral-pile with a proud disdain of life, chanting his war-song, and bidding defiance to his enemies by whom he is surrounded. Neither are some of the more generous feelings of our nature wanting. Though they are said to kill all their children born after a certain number—a habit consequent on the difficulty, or almost impossibility, of providing food for a numerous family in their wild mode of life, they yet exhibit occasional instances of very strong attachment even to strangers whom they may have spared and adopted. The proud constancy with which they have refused to bend their necks to the yoke of slavery, but have rather preferred to suffer extermination, is well known, and the difference between their character and that of the Negroes in this respect, gave rise to the proverb long current amongst the French colonists of the Antilles isles, "Que regarder un sauvage de travers, c'est le battre; le battre, c'est le tuer: mais frapper un Nègre, c'est le nourrir."

A slowness to adopt improvements, or modify their habits to circumstances, seems, however, a constituent part of American nature. These men who exhibit such surprising instances of sagacity in their native forests, develope such traits of ingenuity, patience, and skill in pursuing or avoiding a foe, in securing the objects of their chace, or in rescuing themselves from situations of danger and difficulty, have never learned anything from an approximation to civilized life, further than to participate in its vices. "The native Americans," says Ulloa, "are so stupid, that all the Negroes generally evince more aptitude at learning what it is attempted to teach them, and of which they never can attain a conception; for this reason the Negroes, though slaves, believe themselves of a superior nature to the Indians, whom they look on with contempt, as incapable of discernment and reason*." Their early conquerors, the Spaniards, readily fell in with a doctrine so favourable to the violence and cruelty with which they were inclined to treat the unfortunate Americans, who were, however, rescued from this nominal degradation, by the celebrated bull of Pope Paul III., declaring them to be "real men, and not, as was commonly asserted, a race of animals."

The habitation of these "real men" is daily becoming more and more confined; they have shrunk from the proximity of their Caucasian brethren, whose superior power and intellect have served so much oftener to destroy than to improve. Driven from almost the whole of their Atlantic coasts, they have retired to the interior of the country, where they still may tread the pathless forest, and wander by their mighty streams; in such haunts they still retain their distinctive marks, their characteristic traits; of these, we are convinced,

* This contempt the Indians are not slow to return, and their ideas respecting the relative places held by each, in the animal scale, are pithily expressed in their usual classification:—"God make white man first, then red man, then dog, *and then nigger*."

much yet remains to be learned; and observations respecting them we should regard as amongst the most valuable additions to anthropological science.

5. The Malay variety is, we think, by many degrees the most imperfect of those which Blumenbach has proposed; in fact, it contains all that he could not put into his other varieties, forced together in this one, though often exhibiting great dissimilarity of character, and the variety, as it at present stands, includes almost every possible shape of skull and form of body, from the noble-looking Otaheitean, "erect and fair," whom we scarcely can distinguish from a Caucasian, to the black and woolly-headed Papuan, the near neighbour of the Negro, or the underlimbed Mallicollese, whom Dr. Forster describes as a small, nimble, ill-favoured set of beings, who, of all men that he ever saw, bordered the nearest upon a tribe of monkeys. Yet some of the three exhibit much resemblance to the inhabitants of the peninsula of Malacca, from whom they all derive the common name, and who are described as of a chestnut-colour, varying to yellowish on one side, and deep-brown on the other; with the forehead retiring, yet rounded, the nose large and thick at the extremity (a *bottle nose*); the eyes of a black colour, elongated, half closed, and raised towards the temples; the cheek-bones moderately prominent; the mouth large, the upper jaw much advanced; the hair thick, curled, long, and soft, of a colour always black; and the general figure good, and calculated for active exertion. Such is the description of the chief inhabitants of the Malaccan peninsula, and it certainly rather favours M. Virey's opinion, that the Malays are a sort of bastard race, between the Chinese Mongolians, and the Papuans, whom he looks on as nearly allied to the Negroes. The gradation certainly is extremely gentle, and by steps almost imperceptible, whether we ascend or descend, and we consider this race, if taken in connexion with the consideration of its various, yet similar, dialects, of its analogous habits, and of the traces which can be found of its divergence from a common point, to be that which goes furthest

towards determining the identity of the human species, under its several varieties of form, and showing the possibility of members of a common stock presenting, in their physical formation, characters so widely different. "These varieties," says Dr. Prichard, "are here so blended, and they appear under circumstances so clearly identifying the race, that we are prevented from falling into a suspicion, which would otherwise arise, that these different kinds of people are of distinct families. If their mutual separation were somewhat more broadly marked, this hypothesis would have been forced on us. As the case is, it would be scarcely more absurd to assert, that the natives of London and Edinburgh are distinct species of men, than to maintain a similar pretence with respect to the New Zealander and Otaheitean."

We come now briefly to consider the principal differences we have pointed out as existing between men and men, and to inquire whether they are of such magnitude, and of a character so unalterable, as to render it impossible that all mankind should have descended from a common stock. It might be supposed that the quality by which men are most surely distinguished from other animals, would, by its gradations, afford no bad standard for ascertaining differences of origin and breed amongst themselves, did any such exist; and, accordingly, the obvious *general* inferiority of the Negro to the Caucasian has been much insisted on, as a proof that they could not have sprung from common parents. But it is evident that the character, to be specific, must be invariable; and will any one pretend to say, that every white is superior in intellectual powers to every black? The assertion would be ridiculous: we have a sufficiency of individuals, endowed with about as much sense as Pope's lord, who was "far too wise to walk into a well;" while on the other hand, individuals amongst Negro tribes, have been found to exhibit a clear and comprehensive intellect, and to attain a distinguished proficiency in the arts, and even in abstruse science. H. Grégoire has written a work, "De la Littérature des Nègres. Paris, 1808," in which he collects numerous such examples, and Blumenbach possesses pecimens of English, Dutch, and Latin poetry, written by Negro authors. That skill and talent, together with some of the higher moral feelings, were called into display during the revolt, which freed the Haytian republic from the French yoke, admits of no question; nor has there been any lack of political sagacity in the mode in which it has been subsequently governed. Lislet, a Negro of the Isle of France, was named corresponding member of the French Institute, on account of his meteorological observations; Hannibal distinguished himself as a colonel of artillery, in the Russian service; and Fuller, of Maryland, was an extraordinary example of quickness in reckoning. Being asked, in a company, for the purpose of trying his powers, how many seconds a person had lived, who was twenty-seven years and some months old, he gave the answer in a minute and a half. On reckoning it up after him, a different result was obtained: "Have you not forgotten the leap years?" said the Negro. The omission was supplied, and the number then agreed with his answer.

As connected with intellectual developement, the form of the brain and skull has been much insisted on as showing a diversity of species. It is true the Negro exhibits a most remarkable difference in this respect, from the Caucasian, and were we merely to confine our view to these extreme cases, we should have little hesitation in inferring original distinctness.

"Having filled," says M. Virey, "with water, the cranium of an European, and having poured this water into the skull of a Negro (both adults), I found, in a first experiment, that the head of the European contained four ounces and a half more liquid than that of the Negro. Another experiment, on other skulls, gave me nine ounces more capacity in the white than the black. I have also observed that the head of a man, whether black or white, contains two or three ounces more water than the head of their respective females."

This difference in capacity is attended, as a reference to our descriptions will show, by a no less striking difference of form, but neither of these is permanent: our Pole, already mentioned, with his rapidly-retreating forehead, of course, lost sadly in capacity; while, on the other hand, the celebrated Abbas Gregorius, to the black complexion and crisp hair of the Ethiopian, added a perpendicular forehead, and well-developed brain, that would have done honour to any Caucasian. But when we come to consider the connecting links, and take into account the conformation of intermediate tribes, the difference totally disappears through each progressive step, and we find an assemblage of skulls, diverging, as it were, from the Caucasian in the centre, on the one side towards breadth and squareness, terminating through the American in the Mongolian, or on the other side, towards narrowness, depression, and contraction, already incipient in some of the Caucasian race, more observable in the Otaheitean form, increasing through the various Polynesian and Papuan tribes, until we arrive at the savage inhabitants of New Guinea, Louisiana, or New Caledonia, in whom the projecting muzzle, the retiring forehead, the narrow skull, the black skin, the hair all but woolly, and the nose all but flattened, offer such striking proximity to the Negro form, as to defy all attempts at constituting them a separate species.

Our analogical argument conducts exactly to the same conclusion. The skull of the wild boar differs widely from that of the domestic pig, yet they are allowed to be of the same species. The different breeds of horses and dogs present remarkable varieties in the shape of the skull, and, adds Mr. Lawrence, "the very singular form of the skull in the Paduan fowl, is a more remarkable deviation from the natural structure, than any variation which occurs in the human head." Equally little can combinations of features, hair, and complexion, be adduced as decisive marks of original difference. The Tibboos, so accurately depicted and so well described by Captain Lyons, present few peculiarities of the African race, except the black complexion. Their features and form are nearly European, and their hair, though curled, and somewhat frizzled, is not woolly. Some of the Kaffers, on the other hand, have the woolly head and black complexion, but the conformation and general figure still European, while others, of this same tribe, present perfectly the features of the Negro. How is it possible to draw a line here? Again, "Other instances have been mentioned," says Dr. Prichard, "in which the black colour is combined with Negro features, while the hair is more like that of Europeans." In Albinoes the features are Negro, the hair long and soft, and the skin perfectly white: these Albinoes may be the children of Negro parents, and may, in their turn, have Negro children. Yet these are among the races, for which Voltaire would have us establish a distinct original stock! The singular facility with which some men believe everything that *seems* to contradict the Scriptural account, contrasts strangely with their obstinate scepticism regarding anything that may give it support.

The difference of hair is perfectly trivial: every one knows that the same race of sheep bear hair in one country and wool in another. In our own country, a mixture of hair will appear in the fleece of such as are neglected; by breeding from such animals, we should soon get a race entirely hairy, but as this is not our object, we generally adopt the reverse plan, reject those in which hair has appeared, and thus get a race perfectly woolly.

The colour of the hair is equally unimportant. It is generally black in the dark races of men, and it is only amongst Caucasians that it is found fair, auburn, or red. But to this also there are exceptions. The hair is universally black amongst the Hindoos, whom we must look on as nearly allied to the Japhetic race, while Winterbottom found it red in Africans and Mulattoes. Sonnerat reports the same of some Papuans. Forster found individuals with yellowish, brown, or sandy hair, at Otaheite, and Pallas mentions instances of the same kind amongst the Mongolian tribes; though, he remarks, they were very rare. In animals, more particularly such as have come under the influence of domestication, colour is allowed to be of no avail in determining species.

The pigs of Piedmont are all black, and those of Normandy all white, yet no one supposes them of different species; Dr. Buchanan found, in Mysore, three varieties of colour in sheep, red, black, and white, "and these are not distinct breeds;" but further, in the Arctic regions the same animal will be white at one season, and black at another; which puts colour, as a criterion, totally out of the question.

Size cannot for a moment be proposed: we all know what differences, in this respect, may occur, even in members of the same family, and there is not one of the five varieties we have specified, in which certain tribes may not be distinguished from others by their height, without any one having, therefore, thought of assigning them a different origin. The pigs in Cuba have grown to twice the size of their ancestors, imported by the Spaniards; and do any two races of men differ so much, in this respect, as the great dray-horse of Flanders from the little Cingalese ponies, which do not exceed thirty inches in height?

Certain other characters have been mentioned, which appear to us equally inadequate. Of the facial angle, adopted by M. Virey, we have already spoken. Desmoulins asserts the specific difference of the Guanches, because "the fossa at the end of the humerus for the reception of the olecranal process of the ulna, which in us is only a deep hollow or pit, is in them a hole, opening quite through the bone." But M. Desmoulins does not condescend to say on how many individuals he has verified this fact: whether his observations are confined to one or two, which is probable, as Guanche skeletons do not abound in Paris, or if more extensive, whether they admitted of any exception. Until he mentions these facts, we can by no means allow his character to be of the highest value, as he must well know the transformation of a notch into a foramen, or the opening a foramen into a notch, or the closing a furrow by a bony sheath, so as to change it into a channel, are among the very most ordinary varieties met with in the skeleton; and no man has made a dozen dissections, who has not found the frontal branch of the ophthalmic nerve passing at one time through a hole, at another through a notch, or seen at the bottom of the orbit, another branch of the fifth pair, now running in a groove, and again arched over with a thin plate of bone: nay, who has not seen a canal on one side, and a furrow at the other, of the very same skeleton. How M. Desmoulins, for whose anatomical talents we have all proper respect, could have attached any importance to a point so utterly trivial, is truly astonishing; we can only account for it by the poet's rule, "Sua dira cupido fit Deus cuique." Sœmmering had observed a difference in form between the stomach of the Negro and that of the European, but had not thought this of sufficient weight to be quoted as a proof of specific difference. What he, however, left undone, another, assuming the fact without acknowledgment, has attempted for him. "I had frequently observed," says Mr. Madden, in his *Travels in Turkey*, &c., "that the exhibition of an emetic to the Negro soldiers, was often attended with convulsions, and even death: on further inquiry, I found that these remedies invariably produce distressing effects on all the black people of Dongola and Sennaar; on examining the body, I found the stomach different from that organ in white people, both in size and structure. As the difference has not been noticed hitherto, I am free to acknowledge that the appearance I observed might be the consequence of disease, and not its natural state; but, as I remarked the same especial difference in *three* cases, I think I am warranted in the supposition that the *smallness* of the Negro's stomach, and the *peculiar corrugation* of their folds, are no less distinct marks of that race than their thick cranium, and prominent cheek-bones." The number of Mr. Madden's observations is truly astonishing; but without resorting to the supposition of a distinct race, we do not find it very strange, that when people have died after severe vomiting, their stomachs should be small and corrugated: were size of stomach to be admitted as a standard of species, there is little doubt the London aldermen might claim an Adam for themselves.

Mr. Madden, however, has another proof: "I discovered, likewise, a difference in the skeleton in *two* of these cases, each having six vertebræ of the loins, instead of five; and upon examining the spines of many living Negroes, I find the occurrence of six lumbar vertebræ *very frequent*. This accounts for the extraordinary length of the lumbar part of the back in so many Negroes. That they are a distinct race, I think, is evident from these and other peculiarities." It is equally evident, if this standard be of any avail, that two of the Negroes above mentioned, were of a different race from the third, and that as the occurrence is only *very frequent*, it is not universal. But further, six lumbar vertebræ may be found in a long-backed white, as well as in a long-backed Negro; and a skeleton of a man seven feet three inches high, in the Museum of the late Professor Rudolphi, is expressly stated by him to exhibit this perfectly accidental variety *.

The fact is, all our differences are superficial, and of that kind which Cuvier has shown to be most easily produced by accidental variations in external influences, in nutrition, and generation. And this is honestly admitted by our most determined, (we regret to say, in many instances, our most unnecessarily profane,) opponent, Colonel Bory de Saint Vincent.

"Before commencing the examination of each of these species," he says, "we must confess, that to establish their characters in an unquestionable manner, many anatomical details are still wanting. We have been obliged to stop too often at simple external differences, though at the same time we feel convinced that it is necessary to descend deeply into the organization of beings, to distinguish them invariably from

* The fact may, indeed, be found stated even in elementary anatomical works; thus, in the edition of Cloquet's *Anatomie Descriptive*, by Dr. Knox, we read, "It not unfrequently happens that the number of ribs is found to vary. There are never, however, more than thirteen or less than eleven. When the number of ribs is thus increased or diminished, *the same phenomenon is observed with respect to the dorsal vertebræ.*"

one another. In certain cases, we have found ourselves reduced to seek rather in the accumulation than in the real value of differences, the bases of our labour. But *an instinctive conviction* tells us that future observations will confirm the arrangement which we have instituted." (Bory de St. Vincent. *L'Homme.*)

We have too high a respect for instinctive convictions to attempt answering them; meantime, we wish to put it on record that Colonel Bory de St. Vincent's division of the human race into fifteen distinct species, the object of so many independent creations, rests on an *instinctive conviction* that its truth will be established by future observers.

We may add, that those who most earnestly contend for the formation of many Adams, can by no means agree amongst themselves as to the necessary number. M. Virey is content with two; M. Desmoulins at first was satisfied with eleven, but in his last work, cannot do with less than sixteen; fifteen we have seen suffice for Colonel Bory de St. Vincent, while Rudolphi gives up the question as incapable of solution.

We shall, as regards this point, make but one more observation. Animals are all subject to variation in a greater or lesser degree,—this degree may be estimated by the extent to which they have been made the companions and servants of man,—*and varieties originating in this way, become permanent by descent.* From circumstances of this kind, cats exhibit a long and silky hair; oxen become long-horned or without horns, or display a peculiar colour, or develope a fatty hump on the back, which they preserve even when transported to a different climate; sheep become hairy or woolly, or have spiral horns or fat tails; the domestic hog loses its tusks, becomes short-legged in one place, and long-legged in another, exhibits a solid hoof, or three toes, or two of monstrous appearance, half a span in length; while the varieties of the dog are almost endless, and even run so far as the developement of an additional toe on the hind foot, with a tarsal bone to correspond, as we see occasionally six-fingered families among the human kind. Shall it then be said, that all these animals are to be subject to variation and alteration, and that in the direct ratio in which they are brought within the influence of domestication and cultivation, but that man alone, who far beyond them all, is subject to these influences, must remain "unchanged and unchangeable," or that every deviation from an ideal standard must be set down to an original specific difference instituted at the creation, and since handed down? The supposition is enormous:—we have closed this part of our subject.

Respecting the causes of variety, we shall speak briefly, as they are known imperfectly. Dr. Prichard has laid down and confirmed by very numerous examples, the principle that changes produced by external causes in the appearance or constitution of the individual, are temporary, terminate with the individual, and are not propagated to his posterity: such, therefore, can never produce a permanent variety. But, peculiarities born with the individual, and thus forming part of his original constitution, are transmitted by descent, and if his posterity were by any circumstances so isolated, as that intermarriages amongst themselves became necessary, the new peculiarity would in a few generations become permanent, and in this way a variety be produced.

The first of these propositions is in direct opposition to the common opinion that climate is the cause of variety. Nothing can be more erroneous, and scarce anything more universally spread, than this belief. We find it in authors ancient and modern; we find it in Herodotus, in Strabo, and Pliny; we find it in Smith, in Blumenbach, and Buffon, assigned by turns as the cause of the dark complexion or the woolly hair; nay, Volney has even gone so far as to suppose it will account for the form of the features. "J'observe," says the last, "que la figure des Nègres représente précisément cet état de contraction que prend notre visage lorsqu'il est frappé par la lumiere et une forte reverbération de chaleur. Alors le sourcil se ferme; la pomme des joues s'élève, la paupière se serre; la bouche fait la moue. Cette contraction, qui a lieu perpétuellement dans la peau nud et chaud des Nègres, n'a-t-elle pas dû devenir le caractère propre de leur figure?" The reasoning of a gentleman whose observations on Egypt have only just seen the light, complete M. Volney's picture in the only part which he left unfinished. "The effect," says Mr. St. John, "of the climate of Egypt upon the hair, is remarkable. My own beard, which in Europe was soft and silky, and almost straight, began immediately on my arrival at Alexandria to curl, to grow crisp, strong and coarse, and before I had reached Es-Souan resembled horse-hair to the touch, and was all disposed in ringlets about the chin. This is no doubt to be accounted for, by the extreme dryness of the air, which, operating through several thousand years, has in the interior changed the hair of the Negro into a kind of coarse wool."

But however numerous the names by which such theories are supported, we feel not the least hesitation in pronouncing them erroneous, when we find them contradicted by undoubted facts. The tropical regions of Asia and America are to the full as hot as the regions of southern Africa, yet their inhabitants have hair as smooth and flowing as ours. It is true, that in a general way, it may be asserted, that colour deepens as we approach the Line, and Buffon has taken care to make the most of this fact: "The heat of the climate," he says, "is the principal cause of colour; when the heat is excessive, as in Senegal and Guinea, then men are altogether black; when it is a little less intense, as on the northern coasts of Africa, men are less black; when it commences to become more temperate, as in Barbary, Mongolia, Arabia, men are only brown; and finally, when it is quite temperate, as in Europe and Asia, men are white." Had he pursued his subject a little further, he would soon have found how untenable was his idea.

The Esquimaux, the Greenlanders, the Samoiedes, and other tribes surrounding the pole, are of a deep tawny colour, though their very moderate portion of sun should have left them delicately fair; and the inhabitants of New Guinea, New

Britain, New Ireland, &c., present much deeper shades of black, than could be at all accounted for by their situation relative to the Equator. Madagascar is inhabited by two races of men, one black, the other only olive, yet they certainly undergo the same degrees of temperature; but the theory is at once upset by a reference to the new world, in which all the inhabitants exhibit the most remarkable uniformity in their red or copper-coloured tint, always excepting the Esquimaux and tribes farthest north, who show the darkest complexion. It is true, indeed, as every one knows, that exposure to sun and air deepens the colour of the individual; but it remained for Dr. Prichard to observe, that the effect ceased with the individual, and was not propagated to his offspring. Of this there can be no doubt. The children of the Moors and their women, who are constantly confined to the house, are as delicately fair as any Europeans; the same may be said of the children of the English in the West Indies, where, nevertheless, they have been settled so long a time; and Dr. Buchanan found at Cochin, on the Malabar coast, Jews whose documents proved them to have been located there more than fourteen hundred years, and yet, having kept themselves distinct, they resembled in every respect, both of feature and complexion, their European brethren. Were any further proof required, of how little the sun has to do in producing intensity of national colour, it might be found in the fact noticed at the Sandwich Islands by M. Charis, "that the most delicate young girl, the least exposed to the effects of climate, is black; while the men constantly obliged to work under the rays of the sun, are almost *an orange colour;*" to which we may add Dr. Prichard's testimony, that the domestic Negroes who are protected from the heat of the sun by more clothing, and who pass their time in sheltered houses, are of a darker complexion than the slaves who labour half-naked in the fields.

This point being settled, we turn to the second proposition, namely, that, "All original or connate peculiarities of body are hereditary," and of this we have the most ample proof in the propagation of peculiar *breeds* of animals. Every one knows that from a hornless bull and cow you will get a calf which never shall have horns; that an Arab horse and mare will breed an Arab colt; that your short-legged Chinese pigs will not give you a farrow of the long-legged Norman kind; nor your pricked-eared, rough-haired cur, a degenerate dwindled lap-dog, with its pendant flaps and silky coat. In the human species, also, proofs are abundant. Each peculiar variety propagates itself with all its peculiarities, and in every circumstance of climate, food, soil, or other external influence. Negroes are born in Europe, Caucasians in India, white races in warm climates, and dark races in cold. Innumerable instances of the tendency of the child to resemble the parents are well known and authenticated. The thick upper-lip has been in the Austrian family for centuries; a nose, as Washington Irving pleasantly observes, may be found to repeat itself through a whole long gallery of family pictures; six-fingered families have been known to preserve their distinctive mark for several generations; and there is this moment in London, a man whose skin is beset by numerous warty and horny excrescences, and who is the fourth in descent from the person originally marked with this unpleasant distinction, and known to every one under the name of "the Porcupine Man."

In short, it seems a general law, that all animals shall be born with a resemblance to the *original* state of their parents; a butterfly must first be a grub, because the parent butterfly was so; and the young frog must first be a fish, before it rises to the rank of a reptile. Occasional deviations from this law occur; when they are great they constitute monstrosities; when slight, varieties; but in each case they are the result of some impression or change wrought on the ovarium during conception, or its subsequent fœtal existence; and the imperfection of our knowledge of the mysteries of generation and growth is the true cause why we are unable fully to appreciate the nature of these changes, and, therefore, the true origin or varieties. As the subject, however, is of extreme interest, we shall venture a few words respecting it, premising that they cannot be looked on as at all interfering with the former parts of our argument, which must depend on the proofs there adduced, but must be considered merely as an attempt to show how certain of these varieties *might* have arisen from certain natural causes, and thus the different conditions of men have been produced.

In observing the growth of the fœtus, we find that all formation takes place from the circumference towards the centre; that the former, being laid down at a time when the contents of the uterus are most mobile, most susceptible, of impression, are therefore the most liable to aberrations from the normal standard*. This rule is exactly exemplified in monstrous births, in whom we find the irregularities more frequent at the surface than in the interior, at the extremities of any system than towards its centre. Thus, in the nervous system *microcephalia*, *anencephalia*, or *spina bifida*, affections of the top and bottom of the cerebro-spinal axis, are much more common than any affection of its centre: in the digestive system imperforate anus, or imperfections in the mouth, the palatine vault, &c., are much more common than deformities of the stomach.

The case is the same in varieties. We have shown that men differ most in the form of the brain and the extremities, and at the surface.

To simplify the question, let us take one of these points, and we shall choose the most important, that which has been chiefly relied on in the attempt to prove *specific* differences,—the various forms of the brain.

One of the commonest causes of monstrosity, as laid down by Haller, and since illustrated by Meckel, is *arrest of develope-*

[* This is an open question. M. Serres, who proposed the doctrine of eccentric or centripetal developement, as well as Geoffroy St. Hilaire and his son, the warmest supporters of the same, assert, that those organs which are the latest formed are the least constant; that the large trunks are more frequently irregular in their course and distribution than the superficial branches of an artery, or a nerve; and they advance these, and similar facts, as proofs of the soundness of their theory.]

ment, that is, the cessation of growth in any particular organ, while the rest advance towards their usual standard: this, it is evident, may be caused by accidental pressure on the vessels leading to that organ.

We owe to M. Serres the very interesting remark, that the brain of the Caucasian, in arriving at its full developement, represents transitorily the forms which in the Negro and Mongolian are permanent.

Now let us suppose that when the brain was in either of those *phases*, arrest of developement had taken place, a man would have been born with either the Negro or Mongolian cerebral formation.

It will be remembered that we stated the Caucasian, the Mongolian, and the Negro, to be the three primary, or best-marked varieties, and that this opinion was also held by Cuvier.

Having shown how one individual may have been produced, the next question is, as to the probability that his peculiarities would be continued.

The most satisfactory reply to this question is afforded by the facts connected with the origin of a new variety, or *breed* of sheep, as detailed by Colonel Humphreys in the *Philosophical Transactions* for 1813.

In the year 1791, one of the ewes on the farm of Seth Wright, in the State of Massachusetts, produced a male lamb, which, from the singular length of its body, and shortness of its legs, received the name of *otter*-breed. From the curvature of its fore-legs, which caused them to appear like elbows when the animal was walking, Dr. Shuttack termed it *ancon**.

This physical conformation, incapacitating the animal from leaping fences, appeared to the farmers about so desirable, that they wished it continued. Wright determined on breeding from this ram, and the first year obtained only two, with the same peculiarities. The following years he obtained greater numbers, and when they became capable of breeding with one

* From Ἀγκων, an elbow.

another, *a new and strongly marked variety, before unknown to the world, was established.*

In this case we see a variety, originating by accident, perpetuated by cultivation, that is, by constantly uniting individuals marked with the same peculiarities.

This could not be arbitrarily done for the human-kind, but it might be brought about by the force of circumstances. Dr. Prichard has shown that there is a tendency* to the repetition of a variety which has once occurred; thus, there are generally more Albinoes than one in the same family.

Were, then, a family, in which any of the above peculiarities had a tendency to occur, isolated from the general stock, so as to necessitate frequent intermarriages of its members, their peculiarities would be repeated, propagated, and, in a few generations, rendered permanent.

But this isolation could only take place when the world was thinly inhabited, and a wide space intervened between family and family.

Any peculiarity occurring now-a-days speedily merges by intermixture, and returns to the common standard.

Reverting, then, to the objection started at the beginning of our article, it is perfectly clear that the circumstances there alluded to are not the true cause of the propagation of a peculiarity, though they might have some influence on its production; on the contrary, that this propagation into permanent varieties *could* only have occurred at the time to which it is referred.

One word more: the varieties, as we have shown, are of the simplest kind, and obey the simplest law, that of arrest of developement. Had a six-fingered family then originated, they would, with equal certainty, have been propagated, and we should now have a six-fingered race, whom those reasoners, would, doubtless, set down at once as a clearly distinct species, and the

* The existence of this tendency was strongly exemplified in the mare, which having once conceived by a quagga, had afterwards no less than three or four foals begotten by different horses, yet all exhibiting more or less of the quagga form.

grounds for so doing would be infinitely stronger than any that now exist. For every anatomist will admit, that the developement of an additional finger, with its additional phalanges and metacarpal bones, its additional arteries and muscles, and nerves, and integuments, is a far greater deviation from the normal standard, than a simple deficiency in the developement of any part, a want of its arriving at its full growth. But, such varieties as the former *do* appear amongst us even now, though, from the causes already mentioned, they have not become permanent, therefore, *à fortiori*, such varieties as the latter *may* have appeared, and, not being subjected to the same causes, would, as we have shown, have become permanent.

It is, therefore, contrary to anatomy, physiology, and analogy, the surest tests which we can apply, to consider the existing varieties of the human-kind as different species.

Therefore, according to the best grounds upon which we can reason, *all men are descended from one common stock.*

A BRIEF CHRONOLOGICAL TABLE OF PHYSIOLOGICAL DISCOVERIES.

A.D.

131 *Galen* born. He obtained an indefinite idea of the difference between nerves of sensation and nerves of motion, and was the first who proved that the arteries contain blood during life.

1563 *Fallopio* died. He restored our knowledge of the uterine tubes, which, after him, are named Fallopian.

1574 *Fabricius* demonstrated the valves in the veins.

—— *Eustachius* died. He described the capsules of the kidneys, the thoracic duct, and the Eustachian tube.

1605 *Aldrovandus* died: gave an account of the internal structure and physiology of several classes of animals, especially of fishes.

1616 *Harvey* first taught the true theory of the circulation of the blood.

1619 *Fabricius* died.

1622 *Asellius*, of Pavia, discovered the lacteals in the mesentery of a live dog.

1628 *Harvey* first published the facts of the circulation of the blood in his *Exercitatio Anatomica de Motu Cordis, et Sanguinis, in Animalibus:* Frankfurt.

1634 *Veslingius* described the lacteals in the human body.

1651 *Rudbec*, a Swedish, and *Bartholine*, a Dutch, anatomist, discovered the lymphatics.

—— *Pecquet* described the true function of the thoracic duct.

1653 *Bartholine* published an account of the lymphatics.

1661 *Malpighi* described the internal structure of the lungs.

1664 *Swammerdam* observed the valves in the absorbent vessels.

1677 *Hooke* alludes to the use of atmospheric air in respiration, and illustrates that function by the phenomena of combustion.

1678 *Leeuwenhoeck* discovered "that the whole tooth is made up of very small, straight, and transparent pipes."

1688 *Perrault* died.

A.D.

1694 *Malpighi* died. By distinguishing the rete mucosum from the cuticle, he discovered the true seat of colour in the body.

1707 *James Douglas* wrote *The Comparative Description of all the Muscles in a Man and in a Quadruped* (a dog)—very correct.

1721 *Lady Mary Wortley Montague* introduced inoculation for the small-pox into England.

1726 *M. Noguez* described the lymphatic system in a work entitled *L'Anatomie du Corp de l'Homme en abrégé.*

1738 *Boerhaave* died.

1744 The first work on comparative anatomy published in England, consisting of manuscript notes taken from the lectures of *Monro Primus.*

1757 *Dominico Cotugno* proved that the labyrinth of the ear contains a certain liquid; and laid the foundation of all our present knowledge of the physiology of that organ.

—— *Haller's* work on physiology published.

1758 *Haller* published his discoveries regarding the developement of the chick in ovo.

1706 *MM. du Hamel* and *Tillet* accidentally discovered that the human body will bear, without injury, a temperature of 288° Fahr.

1761 *Dr. Hales* died.

1767 *Sulzer* described the influence upon taste caused by the contact of different metals with each other, and with the tongue. This is the first fact of galvanism, but Sulzer was unconscious of its importance.

1770 *Albinus* the anatomist died.

1771 *Peter Camper* discovered the air-cells in the bones of birds.

—— *William Hewson* discovered the lymphatic system in birds and fishes.

—— *Priestley* noticed that air, deteriorated by animal respiration, is purified by the respiration of plants.

1773 *Dr. Walsh* discovered animal electricity in the torpedo.

1774 *John Hunter*, independently of Peter Camper, discovered the air-cells in the bones of birds.

1776 *Ellis*, the naturalist, died.

1778 *Linnæus* died.

1785 The great work of *Monro Secundus*, on the structure of fishes, published.

1788 *Buffon* died.

A.D.

1789 *Lyonnet* died.

1790 *Galvani* discovered that the limbs of a dead frog are convulsed when the muscles are connected to a nerve by a metallic conductor. The fact was previously known, but he explained the conditions of galvanism.

1791 *Peter Camper's Treatise on the Facial Angle*, published by his son.

1793 The first volume of *Darwin's Zoonomia* published.

1795 *Frederick Cuvier* began to lecture on comparative anatomy.

[illegible] *Gall* first lectured on phrenology.

[illegible] *Dr. Jenner* introduced vaccination.

—— *Galvani* died.

1800 The publication of *Cuvier's Lectures* commenced.

THE END.

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