TREATISES

ON

PHYSIOLOGY

AND

PHRENOLOGY:

FROM THE SEVENTH EDITION OF

THE ENCYCLOPÆDIA BRITANNICA.

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EDINBURGH:
ADAM AND CHARLES BLACK, NORTH BRIDGE,
BOOKSELLERS TO HER MAJESTY FOR SCOTLAND.
1838.

EDINBURGH:
Printed by Balfour and Jack, Niddry Street.

PREFACE.

So great and so numerous are the improvements which Physiology, in all its departments, has received since the period of the publication of the former edition of the Encyclopædia Britannica, that it was deemed necessary by the Editor to give, in the present edition, an entirely new Treatise on that subject. When I engaged, at his request, to write this Treatise, I was far from sufficiently estimating either the magnitude of the undertaking, or the space to which, in endeavouring to comprehend all its branches, the subject would extend. The limited time which was assigned me for its completion, and my distance from the place of publication, will, I trust, be admitted in extenuation of whatever errors may be discovered to be still uncorrected.

In revising the article CRANIOSCOPY, which had been published in the Supplement to the last edition of the Encyclopædia, and which the Editor purposed introducing in the present edition under the title of PHREN-

OLOGY, making such additions to it as I might think were requisite, I have availed myself of this permission to reply to some of the criticisms which had been made upon it by Mr. G. Combe and Dr. A. Combe: it was, accordingly, thought desirable to reprint the former essay, with no other alterations than a few verbal corrections, and the introduction of a few sentences descriptive of some modifiations and additions to the system of Gall and Spurzheim contained in Mr. Combe's System of Phrenology.[1] In the remarks which I have subjoined to that essay, the reader will perceive that I have refrained from entering into the discussion of the numerous objections that might be urged against the metaphysical part of the modern system of Phrenology, having neither the leisure nor the inclination to engage in controversies of this nature.

P. M. R.

LONDON, *Oct.* 20, 1838.

[1] In the quotation from that work relative to the organ of *Eventuality*, the sense has been seriously affected by a mistake of the press, consisting in the omission of two lines in the MSS.; it occurs in the last sentence of the paragraph, which should have been as follows: "An author in whom Individuality is large and Eventuality small, will treat his subjects by description chiefly; and one in whom Eventuality is large and Individuality small, will narrate actions, but deal little in physical description."

NOTICE TO THE READER.

In consequence of the Treatise on Phrenology preceding that upon Physiology in the alphabetical progress of the Encyclopædia Britannica, the same arrangement has been observed in the publication of these Treatises in their present form. According to the natural order of the subjects this arrangement ought to have been inverted, and Phrenology subjoined as an Appendix to the larger Treatise. The reader is therefore recommended to adopt this order in his perusal of the work, as Phrenology being, strictly speaking, a branch of Physiology, will be read with more advantage after, than before that Treatise.

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PHRENOLOGY.

Phrenology, derived from φρην, *the mind*, and λογος, *discourse*, is a term which has been recently applied to denote a new doctrine of mental philosophy, founded on a presumed knowledge of the functions of different portions of the brain, obtained by comparing their relative forms and magnitudes in different individuals, with the propensities and intellectual powers which these individuals are found respectively to possess. This term has of late years totally superseded the more unpretending titles of Craniology and Cranioscopy, by which this doctrine, in its earlier periods, and before it had aspired at effecting a revolution in psychology, was designated, and which simply implied the study of the external forms of the skull, both in men and animals, with a view to determine the size of the subjacent parts of the brain, and thence to derive indications as to the mental and moral qualities of each individual.

The original propounder of the doctrine which is the basis of phrenology was Dr. Gall, a physician of Vienna, whose system, matured in conjunction with Dr. Spurzheim, has attracted so much attention, and been so keenly discussed, both here and on the Continent, that we think it our duty to present our readers with a general outline of this pretended science.

Of the several parts which compose the human body, the mechanism of which has been so thoroughly unfolded by the diligence of modern anatomists, there are few whose use in the economy is wholly unknown. The intention and operation of every part of our frame subservient to the mechanical purposes of connexion, of locomotion, and of strength, such as the bones, muscles, and ligaments, are, in general, sufficiently apparent; the functions performed by the abdominal and thoracic viscera are, for the most part, well ascertained; and we are able, in like manner, to discern the adaptation of the organs of sense to receive appropriate impressions from surrounding objects. One organ alone, and an organ of vast importance in the system, connected with every other, and essentially interwoven with our sensitive existence, has baffled all investigation, and still presents a wide blank in this rich and cultivated field of knowledge. The brain, that large mass of pulpy substance, which fills the cavity of the cranium, is, even at the present day, as incomprehensible in its functions, as it is subtle and complex in its anatomy. It appears, indeed, to be sufficiently established, that the brain is, in some unknown way, subservient to sensation and voluntary motion, and is thereby the immediate agent by which the soul and body mutually exert an influence over each other: and it has also been very generally supposed, that this organ is immediately concerned in all our mental operations, besides being the instrument by which we feel and act. But the phenomena comprehended under the operations of the mind are exceedingly various and complicated, and are also of very different kinds; so that before we can reason concerning them, it is necessary that they should be properly distinguished and arranged. Metaphysicians have, accordingly, classed them as referable to our sentient, our intellectual, our active, and our moral powers. Further subdivision again is required; and the intellectual phenomena, for instance, are arranged according as they relate to the faculties of conception, association, memory, abstraction, judgment, imagination, invention, &c. Other phenomena are distributed under the heads of the different active principles, such as the propensities, the instincts, the affections, and the passions, which belong to our nature. Whilst we thus discover a great diversity in the functions of the mind, we observe also as great a complexity of structure in the organs by which they are performed. Shall we rest satisfied with an acquiescence in the general proposition, that the brain is the organ of thought? May we not rather regard it as a congeries of distinct organs, corresponding to the different faculties into which the mind may be analyzed; each organ having its appropriate office, and being immediately subservient to some particular function of the mind? The question has, indeed, presented itself to many physiologists; but few have ventured farther in attempting its solution, than to throw out some vague and general conjectures as to the uses of certain parts, or as to the supposed habitation of the sentient principle. Thus, for a long period it was held, that the cerebrum was the organ of perception, and the cerebellum the organ of memory. The cavities which are met with in the interior of the brain have often been considered as the scene of the intellectual operations. Nemesius, the first bishop of Emesa, under the reign of Theodosius, taught that the sensations had their seat in the anterior ventricles, memory in the middle, and understanding in the posterior ventricles. Albertus Magnus, in the thirteenth century, went so far as actually to delineate upon a head the supposed seat of the different faculties of the mind. He placed common sense in the forehead, or in the first ventricle of the brain, cogitation and judgment in the second, memory and moving power in the third. Peter de Montagnana, in 1491, published the figure of a head, on which were indicated the seat of the *sensus communis*, the *cellula imaginativa*, *cellula æstimativa seu cogitativa*, *cellula memorativa*, and *cellula rationalis*. Ludovico Dolci, Servito, and a great number of other writers, have hazarded similar hypotheses as to the locality of the different faculties. Both Haller and Van Swieten fancied that the internal senses occupy different places in the brain ; but they considered its whole organization as too complicated, too intricate, and too difficult, to allow of any hope that the seat of memory, of judgment, or of imagination, could ever be detected.

In the pursuit of this speculation, no one has engaged with more ardour and perseverance than Dr. Gall, who, after many years of patient labour, and much fruitless wandering in search of the truth, conceived that he had at last discovered the clue which was to conduct us through the mazes of this labyrinth, and enable us to arrive at a more accurate knowledge of human nature, and of the means which may conduce to its perfection. The account which he gave of the circumstances that gradually drew his attention to the subject, and of his progress in this new path of discovery, is as follows : Brought up in the midst of a numerous family, and naturally gifted with the talent for observation, he was struck, even when a boy, with the diversities of disposition and of character amongst his brothers and sisters, and the companions with whom he was educated. He remarked, that each excelled in a particular study, or was distinguished by a peculiar turn of mind. One was noted for the beauty of his handwriting; another for his quickness at arithmetic; a third for his aptitude in learning languages; a fourth for remembering everything that he read in history. This diversity was apparent in all that they did; thus the style of composition of the one was remarkable for its flowing and elegant periods; of another for its baldness and dryness; of a third for its condensation and vigour. Many displayed talents for arts which had never been taught them; they excelled, perhaps, in drawing, or in the execution of works of mechanism; some sought for amusement in noisy sports, others preferred cultivating their gardens; a few placed their chief delight in rambling through fields and forests, and in collecting birds, insects, and flowers. One was of a social and affectionate disposition, another was selfish and reserved; a third was fickle, and not to be depended upon. The great facility with which some of his school-fellows could commit their tasks to memory, which to him was a work of immense labour, although in matters of reasoning and judgment he felt himself their superior, often proved a grievous source of mortification, and excited in him a strong desire to know the cause of this difference. He at length remarked, that all the boys gifted with this kind of memory had large and prominent eyes. He afterwards went to the university; and directing his attention to all those among his fellow-students, who presented the same peculiarity of feature, he learned that they were all distinguished by the tenacity of their memories; as, indeed, he soon found to his cost, for they were sure to leave possessed most courage, and thence drew inferences as to the organ which prompted that sentiment. In order to obtain more precise data for his conclusions, he endeavoured to procure models of the more remarkable heads that he met with, and generally got permission from the individuals themselves to take a cast of their heads in plaster of Paris. The Count of Sauran, then minister of police at Vienna, gave him material assistance in effecting these objects; and he was thus in no long time in possession of a very large collection of casts, all bearing more or less upon the several points of his theory. If he happened to hear of the death of any one whose head he had already moulded, he was at great pains to procure his skull, that he might compare the form of its different parts with the shape of the head during life. As it was soon known that the doctor aimed chiefly at those who possessed some remarkable talent, a very general alarm spread itself amongst the inhabitants of Vienna; and not a few were pursued with the terror of being selected as the subjects of cranioscopical investigation, and of their skulls being destined to make a figure in his anatomical cabinet. The aged Mr. Denis, librarian to the emperor, is said to have inserted an express clause in his will, to protect his head from the keen scalpel of Dr. Gall. Notwithstanding these fears and precautions, he contrived to amass an extensive collection of skulls, as well as of heads, in illustration of his doctrines. He next availed himself of the aid of comparative anatomy; and having no family to provide for, spared no expense in procuring skulls of all sorts of animals, with a view of tracing the form and size of corresponding organs throughout the whole series. Being physician to the establishment for the *deaf and dumb* at Vienna, he had opportunities of observing the natural features of uncultivated minds, and the various degrees in which they were susceptible of education. With the same view, he used to call together into his house persons of the lowest class, such as coachmen, and beggars in the street, and excite them to display their characters before him. His professional practice made him acquainted with a great number of families, and afforded him many opportunities of making valuable observations. He neglected no means of instruction that could be derived from the inspection of the heads of patients labouring under different forms of insanity. He was physician to the director of establishments for education, and was allowed to examine every child who excelled, or showed any remarkable disposition. He visited the prisons and houses of correction, as well as the hospitals for idiots and lunatics. He took casts of the heads of criminals, inquired into the offences for which they were confined, and collected the history of their lives; and thus derived from every quarter materials for bringing his theory to perfection.

As his observations multiplied, he became sensible that he had fallen into many errors in the earlier periods of his inquiries, and was forced to give up many of his favourite opinions, which he found had been too hastily adopted, with regard to the general form of the head, as connected with the character of the individual. He felt the necessity of being in future more on his guard, and resolved to institute a separate examination of the different regions of the skull; and although he was here, also, frequently obliged to shift his ground in assigning the function of each part, his researches were, on the whole, attended with more uniform success. By degrees he acquired greater confidence in the stability of his conclusions, and at length ventured to announce them to the public, by the delivery of lectures on his new science. His doctrines were eagerly received, and much canvassed at Vienna; but their fame had no sooner reached the Austrian court, than a violent outcry was raised against them by the bigoted priests, who controlled all the operations of that weak and misguided government, and who represented these doctrines as tending to materialism and atheism. The consequence of this senseless clamour was, that Gall was interdicted from lecturing. But the number of those to whom he had communicated the principles of his art, and in whom he had infused a strong desire to continue to profit by his instructions, was by this time very considerable, especially among the strangers who happened to be at Vienna. They formed a strong party in his favour, and made such interest at court, principally through the medium of the foreign ambassadors, that the doctor was again permitted to resume his prelections, on condition that he delivered them to foreigners only; as it was wisely considered that their being exposed to the dangers of knowledge, would not be of any material consequence to the state, as long as care was taken that the infection did not spread farther; the emperor kindly preserving the bliss of ignorance for the exclusive enjoyment of his Austrian subjects.

It was long before Gall committed himself by writing on the subject that had procured him so much celebrity. He merely announced, in 1798, in a letter addressed to Baron Retzer, which appeared in the *Deutsche Merkur* of Wieland, his design of publishing a large work on the new theory, of which he affords his readers only an imperfect glimpse. A detailed account was afterwards given by M. Froreiss, one of his pupils, in the second volume of Voight's *Magazin*

Physique; and an amusing outline appeared from the pen of M. Charles Villers, in a letter addressed to Cuvier. Various surreptitious copies of his lectures were also circulated throughout the protestant states of Germany, where they excited so much curiosity, that Dr. Gall was at length induced to make a tour for the purpose of delivering them himself at the principal universities in the north of Germany. With this view he visited Dresden, Berlin, Hallé, Jena, Weimar, Göttingen, Hamburgh, &c. and every where met with the most flattering reception, being invited to the several courts of the states through which he passed, and treated with the honours due to a distinguished literary character. By frequenting the first societies, and conversing with the best informed persons, he had ample opportunities of extending his observations, and he was attentive to improve these opportunities to the utmost of his power. Dr. Spurzheim, who had at an early period been associated with him in these inquiries, and who had devoted himself particularly to the anatomical researches they comprised, accompanied him in this tour, and participated in all his labours. Dr. Gall at length settled in Paris, where he continued his pursuits and lectures, and united with them the practice of his profession.

In 1810 Drs. Gall and Spurzheim published, in conjunction, the first volume, in quarto, of the work they had announced, and which was to contain a full account of their doctrines, under the title of *Anatomie et Physiologie du système nerveux en général, et du cerveau en particulier, avec des observations sur la possibilité de reconnoitre plusieurs dispositions intellectuelles et morales de l'homme et des animaux, par la configuration de leurs têtes.* The first part of the second volume appeared in 1812. This work, together with the one published in 1815, by Dr. Spurzheim, entitled *The Physiognomical System of Drs. Gall and Spurzheim, founded on an anatomical and physiological examination of the nervous system in general, and of the brain in particular, and indicating the dispositions and manifestations of the mind,* contain the most authentic account of their system. Information on the subject may, however, be derived from the following books, besides those of Froreiss and Villers, already mentioned. The best of the foreign works is that of Professor Bischoff, entitled *Darstellung der Gall' schen Gehirnund Schädellehre, nebst Bemerkungen über diese Lehre,* von D. W. Hufeland, Berlin, 1805. At Dresden, in 1806, Bloede published a similar work, viz. *Galls Lehre über die Verrichtungen des Gehirns, nach dessen zu Dresden gehaltenen Vorlesungen;* and at Paris, in the same year, we have, from the pen of Démangeon, *Physiologie intellectuelle, ou dévelopement de la doctrine du Professeur Gall.* A small tract in English, entitled *Some Account of Dr. Gall's new Theory of Physiognomy, founded upon the Anatomy and Physiology of the Brain, and the Form of the Skull,* appeared in London in 1807, and is chiefly taken from Dr. Bischoff's work, including the critical strictures of Dr. Hufeland. Soon after the publication of Dr. Spurzheim's book, a small volume, principally reprinted from a short tract in the *Pamphleteer,* was given to the public by Mr. Thomas Forster, under the title of *Sketch of the New Anatomy and Physiology of the Brain and Nervous System of Drs. Gall and Spurzheim, considered as comprehending a complete system of Zoonomy, with observations on its tendency to the improvement of education, of punishment, and of the treatment of insanity.* Two pamphlets in opposition to these doctrines were published by Professor Walter of Berlin, in

1805. of which, as well as of Bischoff's work, a short account is given in the *Edinburgh Medical and Surgical Journal* for July 1806. Dr. Spurzheim having conceived that he was unfairly attacked in some of the Reviews, thought proper to publish a reply, in a pamphlet which made its appearance at Edinburgh in 1817, entitled *Examination of the Objections made in Britain against the Doctrines of Gall and Spurzheim.* These, together with the lectures delivered in London by Dr. Spurzheim, are the sources which have supplied the materials for the following summary.

It is laid down both by Gall and Spurzheim as the foundation of their doctrines, that the nature of man, like that of all other created beings, is determinate, and that the faculties with which he is endowed are *innate;* that is, that they are implanted in him at his first formation, and are not the result merely of the external circumstances in which he may afterwards happen to be placed, nor of the wants and necessities to which these circumstances may have given rise. They warn us that this opinion is by no means at variance with that of Locke, who argues only against the innateness of ideas, and not of the faculties or capacities of receiving ideas. Education, doubtless, has a powerful influence in modifying and giving certain directions to these faculties; but the faculties themselves, that is, the capacities of feeling, of intellect, and of action, must have already pre-existed before they could be called into play, and thus produce the various phenomena which diversify the scene of human life. Savages have at different times been found in woods destitute of all the ordinary faculties of rational beings. Their resemblance to brutes has been supposed to be the consequence of their total want of education; but, when we come to examine into their real condition, we shall find that they are wretched beings, with great bodily defects; for the most part deeply tainted with scrofula, and almost always complete idiots. In general, they appear to have been abandoned in their childhood by their parents, to whom they were burdensome. The pretended savage of Aveyron, who was kept in the Institution for the Deaf and Dumb at Paris, was almost completely idiotical. He was quite deaf, and his head and body were incessantly in motion from side to side, even when he was sitting.

In estimating the causes of that diversity which we see prevailing in the characters and faculties of individuals, much has been ascribed to the influence of diet, mode of living, and the impressions received in early infancy, while the organs are yet tender, and highly susceptible of every kind of external influence. But the operation of these causes, as well as the power of education in general, is much too limited to explain the immense differences we observe among different men, and even among different children of the same family. Helvetius and other bold metaphysicians have maintained the paradox, that all men are born originally the same, and are moulded into what they afterwards become solely by the force of external circumstances. Genius, according to this doctrine, is a mere creature of the fancy, and originally belongs no more to one man than to another. Train all men alike, and their powers, their attainments, and their actions, will all be similar. Accident, more than design or premeditation, has fixed the destinies of great men, as well as disposed of those who are unknown to fame. "Demosthenes," say these philosophers, "became eloquent, because he heard an oration of Callistratus, whose eloquence made so deep an impression on his mind, that he aspired only to acquire this talent. Vaucanson excelled in mathematics, because, being obliged, when a child, to stay alone in the waiting room of his mother's confessor, he found there a clock, examined its wheels, and endeavoured, with the help of a bad knife, to make a similar machine of wood. He succeeded; and one step leading on to another, he arrived at the construction of his wonderful automatons. Milton would not have composed his *Paradise Lost*, had he not been deprived of his place of secretary to Cromwell. Shakspeare composed his tragedies because he was an actor, and he became an actor because he was forced to leave his native place on account of some juvenile errors. Corneille fell in love, made verses for the object of his passion, and thence became a great poet. An apple fell from a tree at the feet of Newton, while he was in a contemplative mood: this event, so trivial in itself, led him to the theory of gravitation." Reflections of a similar kind are often met with in the writings of poets and moralists. Those contained in Gray's *Elegy* must be familiar to all our readers. Dr. Johnson considered talents or genius as a thing that, when once existing, might be directed any way. Newton, he thought, might have become a Shakspeare, for, said he, a man who can run fifty miles to the south, can run fifty miles to the north.

Yet these are but the ingenious speculations of the theorist, more calculated to dazzle than to convince, and obviously in contradiction with the daily experience of mankind. Original differences in the constitution of the mind exist as certainly as in that of the body; and doubtless are dependent upon differences in organization. Children often show, from their earliest infancy, the germs of those peculiarities of character which adhere to them through life, which hardly any education can alter, and which no condition of life or variation of circumstances can afterwards affect. It is needless to expatiate on the subject of the diversities of intellectual powers exhibited by different individuals under the very same circumstances of birth and education; diversities which, as we have already seen, first directed the mind of Dr. Gall to his physiognomical researches. Many of these peculiarities are unquestionably derived from the parent, and are observed to prevail in certain families, and to descend through several successive generations.

That no sensation, or other affection of the mind, and that no operation of intellect can take place without a certain condition of the nervous system, is a position established by so many direct proofs, that its truth must be generally admitted. The question becomes more difficult when we come to inquire what part of the system it is that exercises these functions. It is quite clear that the sentient principle does not reside in the nerves, or in the part which receives the first impression from the external cause of sensation. The opinion which has been embraced by many physiologists, and particularly Bichât, that while the brain is the organ of the intellectual faculties, the nerves of the great viscera of the abdomen and thorax are the seat of the moral sentiments, is at variance with a multitude of facts in comparative anatomy. There are animals endowed with the faculties ascribed to these nervous plexuses, or ganglions of the great sympathetic nerves, distributed to certain viscera, which have not the viscera in question. On the other hand, most quadrupeds have viscera analogous in their whole structure to those in man, without having the faculties of which in man it is pretended they are the seat. We have a complete series of proofs that the nerves, of themselves, and without an uninterrupted continuity with the brain, can produce neither sensation nor voluntary motion. Compression of the brain, by any cause, produces an entire suspension of all sensation and consciousness, and puts a complete stop to every operation of intellect. All the other parts of the body, on the other hand, may be wounded or destroyed, and even the nervous mass of the spinal marrow may be compressed or injured, at a certain distance from the brain, without the immediate destruction of the feelings and intellectual faculties. In tetanus, produced by a cause remote from the brain, the other nervous systems are affected in the most violent manner, while the functions of the mind continue unimpaired.

In children, Dr. Spurzheim observes, the brain is yet pulpy, and the faculties imperfect; its growth accompanies their improvement; its maturity marks their greatest degree of vigour. If its developement has been considerable, the manifestations of these powers are energetic; if small, they are comparatively weak. In proportion as the organization of the brain decreases, the strength of the moral sentiments and intellectual faculties decreases also. If the developement of the brain take place too early or too late, the faculties exhibit corresponding variations. Certain faculties are more active in men, and others in women, according to the difference of their cerebral organization; and peculiarities of character are hereditary, according as the corresponding organization of the brain, on which they depend, is propagated from parents to their children.

Although many facts show that considerable injuries may be sustained by the brain without detriment to the mental faculties, yet as a general principle, it is contended by Dr. Spurzheim, that these faculties are weakened or destroyed in proportion as the brain is mechanically altered. It is, however, certain, that physiologists are by no means agreed as to this point; and that innumerable cases might be quoted in direct contradiction to this principle. These are attempted to be explained away by the general supposition, that most of them are the result of very inaccurate observations, in which the statement of the facts has been distorted and vitiated by ignorance, prejudice, or credulity; and that the rest are inconclusive as to the general question, from the observers not being aware of the real functions of the injured parts, and being inattentive to the circumstance, that almost all the parts of the brain being double, the loss of those on one side would scarcely be felt, as long as the corresponding organs on the other side remained entire. On the other hand, it should be recollected, that a derangement in an organ may occur of such a nature as that our senses cannot enable us to discover it. How often is this exemplified in fatal diseases of the nervous system, such as hydrophobia, tetanus, and atonic gout. Analogy shows us other parts where apparently no proportion is preserved between the injury and the derangement of function. Sometimes large abscesses are met with in the lungs without much disturbance of the function of respiration; and ossification of the heart, without any sensible affection of the circulation. In persons possessed of great irritability, very slight wounds of the brain may produce serious effects, while considerable wounds in others, who are less irritable, shall be attended with no bad consequences. This consideration will go a great way towards explaining the fact, that in many cases of insanity, instead of our discovering any change in the brain, a diseased state has been observed in the liver, the bowels, and other viscera; and may serve as an answer to the assertions and objections of Pinel, who states that the most accurate dissections have not taught us any thing with regard to the seat of mental alienation, and that we have no sufficient data to conclude, from diseases of the brain, that it is exclusively the organ of the intellectual faculties.

Those who have opposed the theory of the subserviency of the brain to the operations of mind, have laid great stress upon an argument derived from the phenomena of hydrocephalus. In patients afflicted with this disease, the brain appears to be destroyed and replaced by water; and yet the intellectual and moral faculties have remained perfect to the last. Drs. Gall and Spurzheim conceive, that the facts have been very erroneously represented; and that the only alteration which the brain sustains in these cases, is a displacement of its parts, and not an absorption of its substance. The effused fluid, by accumulating in the ventricles, gradually unfolds the convolutions of the hemispheres of the brain, and expands them to such a degree, that they are reduced to a thin stratum of substance, constituting a sort of bag, within which the fluid is still contained. This stratum of brain is sometimes not more than a line in thickness, and is generally lacerated in attempting the dissection; in which case the water rushes out, the real structure escapes notice, and the fluid is erroneously supposed to have been accumulated between the brain and its membranes.

It has been advanced, as another objection to the same theory, that monsters are sometimes born without any brain, who yet suck and perform various movements. Actions of this kind, however, are purely automatic, and appear to be unattended with consciousness; with such actions the brain has no concern whatever. Some have founded their opposition to the theory, on the result of some experiments of Duverney on pigeons, which, it is alleged, continued to perform all their animal functions after the whole of the brain had been removed from the skull. But Dr. Spurzheim, on repeating these experiments on birds and rabbits, found, indeed, that the destruction of the superior parts of the brain does not destroy the functions of the five senses and of voluntary motion, but that it is impossible to take out all the cerebral mass without killing the animal. As soon as the *corpora striata* and optic *thalami* are wounded, convulsions and death ensue; consequently he does not hesitate to pronounce the account given by Duverney to be entirely false. He, in like manner, wholly discredits the stories related by Morgagni, Zacutus, Lusitanus, Bartholine, Haller, Vallisneri, Moreschi, Giro, Dr. Simson, Soëmmerring, and others, concerning petrified or ossified brains being found in individuals, without prejudice to the exercise of their intellectual faculties. He admits it to be doubtful, how far, in perfect animals, the brain may be necessary to the passive consciousness of the external senses; but deems it certain, that the exertions of the will, including voluntary motion and reflection, depend entirely upon the brain; no phenomenon of this kind ever taking place without that organ.

Concluding, therefore, that the brain is the organ of the sensitive, the intellectual, and the moral faculties, we have next to inquire, whether these faculties are exercised in common by the whole, or any particular portion of the brain, or whether, on the other hand, they are more especially the offices of different parts of that organ. Dr. Gall adopts the latter of these opinions, and upon this view of the subject is the whole of his system founded. The following is the reasoning on which be builds it.

Physiologists, influenced by the metaphysical tenets of the schools, have often maintained, that the soul, being simple, its material residence must be simple also, and that all the nerves must end in one point; or, which amounts to the same, that they can have but one common origin, because each individual has but one soul. Bonnet, Haller, and others, who had extended its seat to the whole substance of the brain, were opposed by these metaphysicians, who did not reflect that a little more or less room could not enable them to explain any better the nature of the soul; nor that, as Van Swieten and Tiedemann remark, a material point, in which all ideas and sensations should centre, is inconceivable, in consequence of the confusion and disorder that would result from such an arrangement. It appears ridiculous, indeed, that the physiologist, to whom all nature is open, should direct his researches and inductions by the guidance of such frivolous speculations. Great pains were, however, taken to determine this central point, or *sensorium commune*; but it is enough to enumerate the various and contradictory opinions that have been held with regard to it, in order to be satisfied of the utter futility of this research. Descartes, in his treatise on the *Passions*, labours to prove that the soul is concentrated in the pineal gland. This hypothesis continued in fashion for some time, till it found an enemy in a follower of Descartes, the Dutch physician Boutekoe, who dislodged the soul from its narrow watch-tower in the pineal gland, and confined it in the more spacious prison of the *corpus callosum*. Lancisi, Maria, and La Peyronie, successively declared themselves in favour of this new opinion; and the latter of these anatomists wrote a memoir in support of it, which was printed by the Academy of Sciences in 1741, and which has since been republished separately. Digby next transferred the soul to the *septum lucidum* in place of the *corpus callosum*. Vieussens allowed it greater latitude, assigning for its boundaries those of the *centrum ovale* of the medullary substance. Willis, again, restricted it to the *corpora striata*; Serveto, to the aqueduct of Sylvius. Wharton and Schellhammer placed it in the commencement of the spinal marrow; Molinetti and Wrisberg in the *pons Varolii*; Crusius and Meig in the origin of the *medulla oblongata*; whilst Drelincourt and others lodged it altogether in the cerebellum. Lastly, Soëmmerring imagined the soul to reside in the serosity which moistens the inner surface of the ventricles, to which he had traced the extremities of many nerves from the organs of sense; and conceives that the different motions or oscillations of this fluid are the immediate material cause of our sensations.

Discarding the notion that the functions of sense and intellect are concentrated in any particular point or portion of the brain, let us next examine the opinion that all the faculties are exercised by the whole mass of brain considered as one organ. We may, in the first place, remark, that the analogy of other parts of the system is adverse to this hypothesis. Every different secretion has its appropriate gland, the offices of which are never interchanged. The liver never secrets urine, nor the kidneys bile. The five external senses are distinct and independent of one another. Every where do we observe that nature, in order to produce various effects, has varied the material organs. The structure of the brain in its different parts, is far from being simple and uniform; it is composed of two substances; the one soft, pulpy, and ash-coloured; the other white, opaque, and fibrous in its texture. The fibres of the latter run parallel to each other, having, at the same time, various collateral connexions, but by no means uniting in any one central part which can be considered as their common origin or termination. The parts of the brain are numerous, and distinct from one another, bearing evidence of a very complex and artificial construction. They are constant in their general arrangement in different subjects, shewing in this respect a striking contrast with the distribution of blood-vessels, or even the disposition of the muscles and viscera, in which it is so common to meet with variations. Comparative, as well as human anatomy, furnishes strong analogical arguments in favour of a plurality of the cerebral organs, corresponding to the plurality of faculties. However defective may be our knowledge of the structure of these organs in the lower animals, still a general comparison of their faculties, as we ascend in the scale of being, shows us that the number of these faculties increases in proportion as the cerebral parts are multiplied. The immense augmentation of the powers of intellect which we behold in man, when compared with the limited instincts of animals, is neither in proportion to the increased size of the five external senses, nor of any other part of the body, but to the increase of the cerebral organs only. It is the great size of the hemispheres of the brain, more especially, that characterizes this organ in man, and establishes its superiority, as an instrument of intellect, over that of all other animals. Man unites in himself all the organs which are variously scattered and distributed among the brute creation ; but he has also organs in his brain, which no other animal besides himself possesses ; and these are the seats of faculties of a higher order, peculiar to him alone.

Considerations arising from the differences in the proportional energy with which the faculties manifest themselves in different individuals, are also in favour of the plurality and independence of the organs. If the brain were one simple organ of mind, and alike instrumental in all its faculties and operations, wherever we met with any one faculty in a state of high energy, we must suppose the whole organ adapted to produce this degree of energy, and ought to expect its other operations to be equally energetic. Yet we may find the same individual remarkably deficient in other faculties, which are equally dependent on this organ. One person shall excel in verbal memory, while he cannot combine two ideas philosophically; another is a great painter, but a bad musician, or a wretched poet; another is a good poet, but a bad general. If the brain be a single instrument, it cannot be at once both weak and strong; it cannot exhibit one faculty in its perfection, and another in a very limited extent. But all difficulty vanishes if we admit it to be an assemblage of many organs; for the combinations of these organs may be as infinitely diversified as the actions and powers of man. The argument derives additional force from the readiness with which this theory may be applied to explain the diversity of character we meet with in the brute creation, and especially to the varieties of disposition observable among some of our domestic animals, which, under the same circumstances of education, exhibit such different qualities. In like manner, the diversity of character in the same individual, at different periods of his life, are most readily explicable on the supposition of distinct organs, which have their respective periods of growth, maturity, and decline. The analogy of the external senses is also strongly in favour of the same doctrine. Thus the taste and smell appear earlier than the senses of seeing and hearing, because their respective organs are earlier developed. This reasoning will be confirmed when it is found, as will afterwards be shown, that the proportional size of the different parts of the brain is very different in different individuals. Is it not, therefore, reasonable to suppose, that the different energies of the several functions of the mind are connected with these differences in the structure of the organs which respectively produce them?

The faculties of animal life are incapable of long continued exertion; rest is necessary for the renovation of their powers. Fatigue is the consequence of the prolonged action of the muscles of voluntary motion; but when one set of muscles are fatigued, the power of others is still unimpaired, and they are ready to be employed in a different action, without any additional fatigue. When we have been long sitting, we are relieved by standing; and even the bed-ridden find ease from a change of posture. Our eyes, in like manner, may be fatigued by looking at pictures; but we can then listen to music, because there is one organ for seeing, and another for hearing. It is well known that study, long protracted, produces fatigue; but we can continue to study, provided we change the object of attention. If the brain were a single organ, the whole of which is employed in performing all the functions of mind, a new form of study should increase instead of relieving the sense of fatigue. Thus the analogy is complete between the phenomena of mental and bodily exertion. Are we not, then, justified in extending it to the instruments by which these operations of mind and body are effected?

The phenomena of sleep are also readily accounted for on this hypothesis. During this state all the organs do not remain inactive; but sometimes a particular organ enters into action, and this constitutes dreaming. The state of vigilance is that in which the will can put in action the organs of intellectual faculties, of the five senses, and of voluntary motion; but it is incorrect to define it as the state in which all these organs are active, for it is impossible that all the faculties should be active at the same moment. Somnambulism may be regarded as a state of still more incomplete sleep, or one in which several organs are watching. If, during sleep, the action of the brain is partial and is propagated to the muscles, locomotion takes place; if to the vocal organs, the sleeping person speaks. All this may take place in different degrees. Some persons dream and speak in their sleep; others dream, speak, hear, and answer; others, besides dreaming, rise, walk, and do various things. This latter state is called somnambulism; that is, the state of walking during sleep. Now as the ear can hear, so the eyes may see, while the other organs sleep; and there are undoubted facts which prove that several persons in the state of somnambulism have seen; but it has always been with the eyes open. There are also convulsive fits in which the patients see without hearing, or *vice versa*. Some somnambulists do things of which they are not capable in a state of watching; and dreaming persons reason sometimes better than they do when awake. This phenomenon is not astonishing. If we wish to reflect upon any subject, we avoid noise, and all external impressions; we cover the eyes with our hands, and we put to rest a great number of organs, in order to concentrate all vital power in one, or in a few. In the state of dreaming and somnambulism this naturally happens; consequently the manifestations of the active organs are then more perfect and more energetic; the sensations are more lively, and the reflections deeper than in a state of watching.

States of disease are also adduced as proving the plurality of the cerebral organs. In many cases of insanity we find only one faculty deranged, whilst all the rest are in a perfectly sound state. Lunatics, on the other hand, are met with, who are reasonable only while pursuing some particular train of thought. There was a chemist, for instance, who was insane on every subject except chemistry. An embroiderer, during her paroxyms of insanity, while uttering the greatest absurdities, calculated correctly how much stuff was necessary to such or such a piece of work. The effects of blows, or other injuries on the head, supply facts of a similar kind, which afford still more convincing proofs that the brain is susceptible of being very partially affected. Some persons lose from this cause the memory of proper names, while they preserve the memory of words which indicate the qualities of objects. One Lereard of Marseilles, after having received a blow from a foil in the orbit, lost entirely the memory of names; sometimes he did not recollect those of his intimate friends, or even of his father. Cuvier, in his historical eulogium on Broussonet, states that this celebrated botanist, after having recovered from an apoplectic fit, never could recollect proper names nor substantives, though he had recovered his prodigious memory with respect to other objects. He knew plants, their figure, leaves, and colours; he recollected the adjectives, but could never recover the generic substantives by which they were designated. These and similar instances of partial affections of the faculties support the supposition of their being owing to different conditions of various parts of the brain subservient to these faculties.

Lastly, the doctrine that different portions of the brain exercise different mental functions, is countenanced by numerous authorities in former as well as in modern times. It is expressly stated in the writings of Boerhaave, Van Swieten, Haller, Prochaska, Soëmmerring, &c.; and the Academy of Dijon long ago proposed it as a prize-question, to determine the situation of these different cerebral organs. Charles Bonnet, indeed, went the length of maintaining that each fibre of the brain is a particular organ of the soul.

It seems hardly necessary to expose the absurdity of the accusation that these doctrines tend particularly to materialism, although the dread of such a consequence has been sanctioned by royal edicts. There are two opinions only, which, in respect to this question, stand opposed to each other; namely, that which asserts perception to take place by the intervention of a material organ, and that which asserts it to take place immediately by the energies of the mind itself, or at least without the intervention of the body. The doctrines of Gall are unquestionably incompatible with this last opinion, that is, with pure immaterialism, which may in fact be regarded as denying the existence of matter altogether. This sceptical spiritualism can be avoided only by the admission of the necessity of a material organ; and if this be admitted, any modification of such opinion, that does not exclude mind as the ultimate percipient, must be equally remote from absolute materialism. The immaterialist believes that it is the soul which sees and the soul which hears, as much as that it is the soul which judges and the soul which imagines; and since he does not condemn, as impious, the allotment of different organs of sight and hearing, what greater heresy is there in the allotment of different parts of the sensorium, as the organs of judgment and imagination? If, indeed, any one were to say, that the affections of these parts are themselves judgment and imagination, he would be a materialist; but he would be as much a materialist, if he should say, that the affections of the organs of sight and hearing are themselves the ideas of colour and sound.

Supposing it, then, established that each function of the mind is exercised by a separate portion of the brain, let us next inquire whether observation can furnish us with any means of determining the precise nature of the function, to which each particular organ is subservient. Although it is clear that the adaptation of each organ to the performance of its office, must be wholly dependent on its particular organization, yet it is equally evident that no consideration of its general structure as shewn to us by anatomy, can teach us *a priori* what such function really is, and still less what may be its degree of energy, or its peculiar quality and modifications. The energy of the function must in all cases depend on certain conditions of the organ, such as the perfection of its original constitution, its elaborate texture, its relative size, and the degree of exercise it has received; and will also be regulated by the influence which other faculties may exert on its operations. The only one among these conditions, which is open to observation, is the relative size of the organ. In general, we find that the properties of bodies act with an energy proportionate to their size. A large loadstone attracts a greater mass of iron than a small loadstone. A large muscle, in like manner, is stronger than a small one. If the nerves of the external senses be larger on one side of the body, the functions on that side are also stronger. Comparative physiology shews us that the olfactory, optic, and auditory nerves of those animals which are distinguished for the excellence of their smell, sight, or hearing, are marked by being numerous and large, evincing a more elaborate developement. The coincidence is so uniform as to justify the general inference, that wherever any organ is met with in a higher state of developement, we may there expect to find the power dependent on it increased in energy in the same proportion. May not this analogy be fairly extended to the organs which compose the brain? Our present object, it must be recollected, is not to determine every degree of activity existing in a cerebral part, but merely the *nature* of its function; and for this purpose the indication afforded by its comparative size, in different cases, will suffice.

We may observe in different individuals a considerable variation in the proportional developement of different parts of the brain. It is reasonable to suppose, that the functions which are more developed in one person than in others, will be more active, and manifest themselves with more energy, than those which are less developed. Those which are comparatively small we may expect to be less active, and their powers more feebly exerted. Let us then select as the subjects of observation such persons as are marked by strong peculiarities of mind or character, and especially such as are endowed with a partial genius, as it is called; that is, who manifest in a very high degree any particular faculty of mind: let us note the peculiarities in the form of their heads, and observe what organs in them are of an unusually large size. By repeated comparisons we shall arrive at the knowledge of the particular organ in which that faculty resides. The converse method, on the other hand, must be pursued with those who betray a singular deficiency of power in any faculty. With such persons we must endeavour to discover what particular part of the brain exhibits an imperfect developement. The results of both these modes of determining the functions of each organ, when compared together, will correct, and, if just, will ultimately corroborate each other. Experience, multiplied and extended, will finally confirm and establish our conclusions, and complete the system in all its parts.

But the living brain can never be exposed to observation, and, from the nature of its substance, loses much of its form and texture soon after death. It may appear impossible to discover the form or size of particular parts of the brain during life, since the whole mass is inclosed in the bony case of the skull, of which the thickness varies in different parts; and since the skull itself cannot be immediately inspected, being covered by muscles and integuments, which, by contributing to smooth all the inequalities of its surface, must preclude us from forming an exact estimate of its real shape. This obvious objection to the proposed inquiry, Drs. Gall and Spurzheim labour to remove by the following considerations. If we attend to the successive stages of the growth of the skull, we find that its ossification begins at different points; and the bony processes extend in divergent lines, adapting themselves exactly to the form and size of the cerebral parts they are destined to inclose and protect. Whatever violence may be done to the bones of the skull during birth, they soon return to their natural state, partly from their elasticity, and partly from the inherent powers of the brain, which tend constantly to restore its original shape. The compression of the brain is besides of too transient a nature to produce any permanent change in the primitive forms either of the skull or of the brain. If it ever amounted to what could irrecoverably derange the organization, and hinder its future developement, the necessary consequence of such a degree of violence would be death or idiocy.

In the progress of its growth, the increasing dimensions of the skull keep pace with those of the brain. All the cerebral parts do not increase simultaneously; and this partial developement is equally observable in the skull. The forehead, for instance, which at birth is narrow and flat, grows wider and more prominent from the age of three months to that of eight or ten years. After this period, the middle part of the forehead is less developed in proportion to the other parts. The neck of the child is very small, because the cerebellum, which is situated at the inferior occipital *fossæ*, is not yet developed; but in proportion as this organ increases in size, the skull grows prominent at that part. The same happens with all the other cerebral parts which increase progressively. The shape of the skull cannot be in any degree influenced by external causes, such as occasional pressure in one direction, as happens in carrying burdens on the head, or artificial modelling of the heads of infants, as is asserted to be practised among the Caribs and other savage nations. In other parts of the body we may remark, that whatever soft parts are inclosed in bones, the shape of the latter is adapted to the dimensions of the former, and is regulated by the changes they undergo; the ribs, and even the spine, yield to the pressure of an abscess, or the enlargement of an aneurism; and the bones of the face, in like manner, make way for the increase of tumours, and adapt themselves to the new form these render necessary. By experience in feeling the living head, we may readily learn to distinguish the form of the bones which lie beneath the integuments. The observation of the shape of the skull, or of the head, is therefore capable of giving us exact information as to the relative size and shape of the different parts of the brain, and on the knowledge thus obtained is founded the art of CRANIOSCOPY.

In practising this method, however, it is necessary to guard against several sources of error. We must take into account several protuberances, which belong to the natural state of the skull, and which had some particular destinations foreign to the immediate functions of the brain; such as the mastoid processes behind the ears, the crucial spine of the occiput, the zygomatic processes, and the frontal sinuses. The cerebral parts, situated behind the orbits, indeed, require some exercise on the part of the organoscope, in order to be exactly determined. The developement may be perceived by the configuration and position of the eyes, and by the circumference of the orbits. It is therefore necessary to examine whether the eyeball is prominent or hidden in the orbit, whether it is depressed or pushed sideward, inward, or outward. According to this position of the eyeball, we may judge that such or such parts of the brain, which is situated against such or such part of the orbit, is more or less developed. The functions of those organs, which lie wholly at the basis of the brain, can be ascertained only by examination after death.

It may be objected, that the organs are not confined to the surface, or convolutions of the brain; but although this be the case, and although they really extend from the surface to the basis of the brain, or *medulla oblongata*, yet the degree in which they are expanded at the surface, where they form the convolutions, will indicate, in general, the relative magnitude of the whole organ. The analogy of the five senses, of which the peripheric expansions indicate the developement of their respective nerves, shews the reasonableness of this supposition. From a large eye, implying a large retina, or peripheric expansion of the optic nerve, we naturally infer that the nerve itself is of considerable magnitude: may we not draw the same conclusion with regard to the organs of the moral sentiments and intellectual faculties, whenever we find that the convolutions, which are their peripheric expansions, are much developed?

In feeling for the organ, Dr. Gall recommends the use, not of the fingers, but of the middle of the palm of the hand; and declares that habit, as well as a certain natural delicacy of tact, is necessary to qualify a person to make these observations with certainty of success. We are warned, also, to confine our observations to young and grown-up persons in the flower of their age; for at an advanced period of life the brain diminishing by degrees, and retiring from the skull, leads to the recession of its inner table, and consequent inequality in its thickness, which renders it impossible to judge exactly of the size or shape of brain from that of the head. Analogous changes occur in the skulls of some lunatics, and occasion similar difficulties in applying the rules of cranioscopy. It is also to be considered, that our aim is to distinguish the size, and not the mere prominence of each organ. If one organ be much developed and the neighbouring organ very little, the developed organ presents an elevation or protuberance, but if the neighbouring organs be developed in proportion, no protuberance can be perceived, and the surface is smooth.

We have already stated the mode in which Dr. Gall proceeded to apply and to verify these principles; it is now time that we should present our readers with the result of his labours.

He arranges the faculties of the mind, with their corresponding organs, according as they relate to the feelings and to the intellect: the first class comprehending the *propensities*, all which are common to men and animals, and the *sentiments*, which constitute what the French denominate *l'ame*, and the Germans *gemüth;* and the second class comprising the faculties by which we acquire knowledge, or the *knowing faculties*, as he terms them; and also the *reflecting faculties*, which last compose what the French call *l'esprit*, the Germans *gheist*, and what we should generally understand by the term *intellect*. He finds that the organs of those faculties which men possess in common with animals, are situated towards the basis and back part of the brain; while those of the superior faculties, which are peculiar to man, are placed somewhat higher; and the organs subservient to the intellectual faculties occupy exclusively the forehead. The total number of special faculties is thirty-three, as may be seen by the following enumeration.

1. Of the faculties common to men and animals, the first is that physical propensity which has for its final purpose the continuance of the species. The cerebellum, a part which occupies the lowest situation in the encephalon, is affirmed to be the organ, the actions of which give rise to this propensity. Accident led Dr. Gall to this discovery, by his noticing the size of the back of the neck in a lady

whose character, in respect to this passion, was not equivocal: and subsequent observation on an extensive scale, both in the human subject and in the lower animals, have abundantly confirmed him in his opinion. The following are the leading arguments on which he has rested it. First, the great size of the organ indicates the importance of the function to which it is subservient, and there is no cause, except the existence of such an organ in the brain, that is adequate to account for this propensity. The function of copulation takes place only in those animals which have a nervous mass or cerebellum. Throughout the whole class of quadrupeds, the neck of the male is thicker than that of the female, as may be observed particularly in the bull, the ram, and the stallion. It is also remarked that vigorous pigeons are distinguished by the size of their necks. The developement of the cerebellum is simultaneous with that of the genital organs at the period of puberty, and early castration prevents its developement, as well as that of the beard, and the organs of the voice. Wounds of the neck have been observed by Hippocrates to be sometimes followed by impotency. In other cases, however, they produce erotic excitement. Apollonius Rhodius, in speaking of the love of Medea, represents her as suffering a violent pain in the back of her neck. A case occurred to Professor Reinhold, at Leipsig, in which an excitement of the genital organs succeeded the introduction of a seton in the neck, in a boy who laboured under ophthalmia. Spirituous frictions on the neck in hysterical fits are very useful. Lastly, the position of the cerebellum is supposed to prove its destination. After hunger and thirst, no function is more necessary than that of propagating the species. This function is the most common in animals after nutrition, and the cerebellum is in the inferior part of the head. Hence it is probable, that it is destined to the propensity of propagating, or that it is, as Dr. Spurzheim expresses it, the organ of *amativeness*.

2. *Philoprogenitiveness*, or the love of progeny, the στοργη of the Greeks, has its seat in those convolutions of the brain situated immediately above the hind part of the tentorium, and corresponding, therefore, on the outside of the skull with the crucial spine of the occiput. Dr. Gall had observed a distinct protuberance on this part of the head in women, and comparing the skulls in his collection, found a similar elevation on the skulls of children, and on those of monkies. During five years he was in search of a faculty that was common to all the subjects of those observations, and was in the habit of suggesting this difficulty to his auditors. At length a clergyman who attended, observed that monkies have much attachment to their progeny. The Doctor pursued this idea, and found that it applied perfectly to the observed appearances, as the developement of this part coincided always with the energy of this propensity. In animals it is generally larger in the females than in the males of the same species. This rule holds good in the human subject, although it is liable to occasional exceptions; for there are men who manifest the strongest propensity to associate with children, and in whom we accordingly find this organ larger than in the generality of women. In negroes we find this organ more prominent than in Europeans. In the cuckoo, the crocodile, and other animals to whom nature has not appointed the office of rearing their progeny, this organ is extremely defective. The crime of infanticide is more likely to be perpetrated by mothers in whom this organ is deficient in size; and accordingly out of 29 women who were guilty of this crime, Dr. Gall found 25 who had

this organ extremely small. On the other hand, a female, who, being seized with delirium during child-birth, imagined that she was pregnant with five children, was found to have this organ unusually large. It must, no doubt, have been of gigantic dimensions in the lady, who, stricken by the curse of the gipsey whom she had refused to relieve, was impressed with the belief that she was about to give birth to as many children as there are days in the year.

3. The organ of *Inhabitiveness*, or the propensity which some animals, such as the chamois and the wild-goat, have to inhabit high situations, is placed still higher in the occiput than the former, in a line proceeding towards the top of the head. In animals of the same species which live in low countries, we do not meet with an equal degree of protuberance in this part of the brain, as is observable in those which prefer living in elevated and mountainous districts. This is seen even in the rat, some varieties of which choose for their dwelling corn-lofts or the higher parts of a house, while others prefer living in the cellars. This faculty is not very active in man; but Dr. Gall conceived that it was in him allied to pride and haughtiness. Dr. Spurzheim, however, disclaims this doctrine; as he thinks it impossible to confound the "instinct of physical height" with the moral sentiment of self-love and pride. Mr. Combe, conceiving that this organ has a more extensive sphere of action, and that it confers the power of being conscious of every thing going on in the mind, and of concentrating the attention, terms this power *Concentrativeness*.

4. The organ of *Adhesiveness*, or the propensity to attach ourselves to persons, animals, or other objects, is situated on each side of the former, immediately under the *lambdoidal suture*, and gives a fullness to the lateral and posterior part

of the head. This organ is the source of friendship, moral love, society, marriage, and attachment of all kinds. Dogs have it in an eminent degree, especially those races whose fidelity and constancy are characteristic, as the terrier, spaniel, and lap-dog. It is less prominent in the butcher's dog, greyhound, and mastiff. It was very large in a notorious highwayman at Vienna, distinguished equally as a robber and a friend, and who chose rather to die than to betray his confederates.

5. *Combativeness*, or the propensity to fight, results from the operation of an organ, situated immediately behind the ears on each side, at a part corresponding to the posterior inferior angle of the parietal bone, and behind the mastoid process. It is the seat of anger, as well as of pugnacity; and its locality is fully established, in Dr. Gall's estimation, by an extensive series of facts. His first discovery of the seat of this faculty, was from his observation of the head of the Austrian General Wurmser; and it was subsequently confirmed by the experiments we have already mentioned which he made on boys he had collected from the street. The breadth of the occiput is a criterion of the spirit and courage of horses, dogs, &c. The bull-dog and pug-dog are in this respect superior to the mastiff. The hyæna is strongly contrasted with the hare, and the guinea-hen with the robin red-breast.

6. *Destructiveness*, or the propensity to destroy in general, but more especially to destroy life, has its seat just above the ears; the prominence of which part will account for the strange pleasure which some people take in killing or tormenting animals, in seeing executions, and for their inclination to commit murder. Among animals, this instinct for blood is strongly marked in the carnivorous tribes, especial-

ly in the lion, tiger, and others of the feline tribe; and the breadth of their skulls in this part shows us the great size of this organ, compared with that of their victims, the sheep, the goat, or the hare. The heads of murderers have in general been found to possess a visible prominence at this place. When the band of ferocious robbers and assassins, who so long infested the left banks of the Rhine, under Schinderhanns, had been caught, and a number of them executed, Dr. Gall found this organ strikingly developed in the heads of these banditti. This propensity is frequently strong in children, in idiots, and in madmen. Its object, in the lower animals, is evidently to procure the food on which nature destined they should live; yet some animals kill more than is necessary for their nourishment. In man this propensity presents different degrees of activity, from a mere indifference to the pain of animals, to the pleasure of seeing them killed or tortured, or even the most imperious desire to kill. Dr. Gall called this faculty *murder;* but Dr. Spurzheim thinks it produces the propensity to destroy in general, without determining the object to be destroyed, or the manner of destroying it. "It gives," says he, "the propensity to pinch, scratch, bite, cut, break, pierce, devastate, demolish, ravage, burn, massacre, strangle, butcher, suffocate, drown, kill, poison, murder, and assassinate." It would seem, therefore, that this organ has a great deal to answer for.

7. *Constructiveness*, the propensity to build, or the disposition to the mechanical arts, is indicated by the developement of the brain at the temples. Dr. Gall found this to be the case in great mechanicians, architects, sculptors, and designers; and also in the skulls of the beaver, marmot, field-mouse, and rabbit, which construct habitations. Hares, on the contrary, which lie in the fields, have this or-

gan defective, although in general they resemble rabbits. He possesses the skull of a milliner of Vienna, who had a good taste, and understood perfectly the art of changing the forms of her merchandises ; in this skull the organ in question is prominent. It is by means of this faculty that birds build nests, savages huts, and kings palaces. It produces also fortifications, ships, engines of war, manufactures of all kinds, furniture, clothes, toys, &c. There was a lady at Paris, who, every time she was pregnant, felt the greatest propensity to build. The excessive size of this organ may lead a man to ruin his family by building, or to coin false money.

8. *Covetiveness*, or the propensity to covet, gather, and acquire, without determining the object to be acquired, or the manner of acquiring it, has its organ situated at the temples, on the anterior inferior angle of the parietal bone. This faculty gives a desire for all that pleases; money, property, animals, servants, land, cattle, or any thing upon earth. It produces egotism and selfishness, and may, when abused, lead to usury, plagiarism, fraud, or theft. The instinct of stealing, it is asserted, is not always the effect of bad education, of poverty, idleness, or the want of religion and moral sentiment. This truth, says Dr. Spurzheim, is so generally felt, that every one winks at a little theft committed by rich persons, who in other respects conduct themselves well. Mr. Combe terms this faculty *Acquisitiveness.*

9. The organ of *Secretiveness*, or the propensity to conceal, or to be clandestine in general, is situated in the middle of the side of the head, above the organ of the propensity to destroy. Dr. Gall first observed this organ in a person who had many debts, but who had the address to conceal his real situation, so that the creditors could have no knowledge of each other. He ascribes to this faculty cunning,

prudence, the *savoir faire*, the capacity of finding means necessary to succeed, hypocrisy, lies, intrigues, dissimulation, duplicity, falsehood; in poets, the talent of finding out interesting plots for romances and dramatic pieces; and finally, the quality of slyness in animals, as in the fox and the cat, who conceal their intentions, and are clever in hiding themselves.

To the second genus of the order of feelings, namely, Sentiments, belong the following faculties:—

10. *Self-love, or self-esteem.* Dr. Gall first noticed this organ, which lies in the middle of the upper posterior point of the head, in a beggar, who stated that he was reduced to his present condition by his pride, which made him neglect his business. The animals endowed with this organ are the turkey-cock, peacock, horse, &c. Dr. Gall thought this organ is the same as that of the faculty which makes certain animals dwell upon mountains; but Dr. Spurzheim, as we have already observed, draws a line of distinction between them. The two great activity of this faculty is the cause of various abuses, as pride, haughtiness, disdain, contempt, presumption, arrogance, and insolence. The want of it disposes to humility. It is said to be more active in women than in men, and that its excess is sometimes the cause of madness.

11. *Love of Approbation.* Persons fond of the good opinion of others, have the upper posterior and lateral part of the head much developed. This may be called the organ of ambition or vanity, according to the object, which may be of various kinds. A coachman endowed with this faculty is pleased if his manner of conducting horses be approved; and a general is elated if he be applauded by his nation for leading his army to victory. This faculty is more

active in women than in men, and even in certain nations more than in others. More women become mad from this cause than men.

12. Organ of *Cautiousness.* Two persons at Vienna were known to be remarkable for their extreme irresolution. One day, in a public place, Dr. Gall stood behind them, and observed their heads. He found them extremely large on the upper posterior part of both sides of the head. Hence he derived the first idea of this organ. Circumspect animals also, as the stag, roe, pole-cat, otter and mole, and those which place sentinels to warn them of approaching danger, as the chamois, cranes, starlings, and bustards, have this cerebral part much developed. This faculty produces precaution, doubts, demurs; and, in general, exclaims continually "*take care.*" It considers consequences, and produces all the hesitations expressed by the word *but.* When excessive, it produces uncertainty, irresolution, unquietness, anxiety, fear, melancholy, hypochondriasis, and suicide. Dr. Gall finds this organ more strongly marked in children than in grown persons.

13. The organ of *Benevolence* in man, or of *meekness* in animals, is situated on the superior middle part of the forehead. In most animals it is restrained to a passive goodness; but in man its sphere of activity is very considerable, producing all the social virtues, or in one word, *Christian charity.*

14. The organ of *Veneration,* or of *Theosophy,* occupies the centre of the uppermost part of the *os frontis.* Dr. Gall had observed in churches, that those who prayed with the greatest fervour were bald; and that their heads were much elevated. The pictures of saints show the very configuration which he had thus noticed in pious men; and the head of our Saviour, also, is generally represented of this shape.

It is by this faculty that man adores God, or venerates saints, and persons and things deemed sacred.

15. The organ of *Hope* is situated on the side of that of veneration. Dr. Spurzheim considers the sentiment of hope as proper to man, and as a sentiment necessary in almost every situation; it gives hope in the present, as well as of a future life. In religion it is called faith. Its excessive developement produces *credulity.*

16. *Ideality*, or the poetical disposition. The heads of great poets are enlarged above the temples, in an arched direction. The sentiment inspired by this organ is the opposite of circumspection; it renders us enthusiasts, while circumspection stops our career by saying "take care." If the part of the head above this organ, and a little backward from it, be very much developed, the person is disposed to have visions, to see ghosts, and to believe in astrology, magic, and sorcery.

17. The faculty of *Righteousness*, or *Conscientiousness*, which produces the sentiment of just and unjust, right and wrong, has its organ situated a little more forward than the organ of approbation. It produces the sentiment of duty, and constitutes what is called conscience or remorse. Dr. Spurzheim admits farther an organ of *justice*, which he seeks for on the side of the following organ.

18. *Determinateness*, or *Firmness*. Dr. Gall observed that persons of a firm and constant character have the top of the brain much developed. Lavater had made the same observation. This faculty contributes to maintain the activity of the other faculties by giving constancy and perseverance. Its too great activity produces infatuation, stubbornness, obstinacy, and disobedience. Its deficiency engenders fickleness and inconstancy.

To the order called Intellect, and the first genus of that order, viz. the *knowing faculties*, belong the following species:

19. *Individuality*, or the faculty which procures us the knowledge of external beings, after we have received impressions from them by the external senses, occupies the middle of the lower part of the forehead. Dr. Gall found this part very prominent, indicating a great developement of the anterior and inferior part of the brain, in all persons, who, from their extensive, but superficial knowledge in the arts and sciences, were capable of shining and taking a lead in conversation. It has been not unaptly, though satirically characterized as the *blue-stocking* faculty. Tame animals have the forehead more developed than wild ones, and are more or less tameable in proportion as the forehead is more or less developed; Dr. Gall, therefore, calls this organ that of *educability*. Dr. Spurzheim, however, objects to this term, and has substituted that of individuality; he also remarks that the organ is early developed in children, because they are obliged to acquire a knowledge of the external world.

20. The organ of *Form* leads us to take cognizance of the forms of objects, with the existence of which the preceding faculty had made us acquainted. Persons endowed with it in a high degree, have a great facility of distinguishing and recollecting persons; they are fond of seeing pictures, and if they make collections, they collect portraits. Crystallography is the result of this faculty. The conception of smoothness and roughness also belongs to it. This organ is placed in the internal angle of the orbit, and, if much developed, it pushes the eyeball toward the external angle, that is, a little outward and downward. The Chinese appear to have it in perfection.

21. *Size.* After the existence and figure of any body, the mind considers its dimensions or size, for there is an essential difference between the idea of size and that of form. The organ must therefore be different; it is probably however in the neighbourhood of the former.

22. *Weight.* The ideas of weight and resistance, density, softness and hardness, cannot be attributed to the sense of feeling, and require, therefore, a particular faculty for their conception. Its organ must be situated in the vicinity of the two last.

23. *Colour.* The faculty of conceiving colour is, in like manner, totally distinct from the sense of vision, or the faculty of perceiving light. Its organ is placed in the midst of the arch of the eye-brows, giving them when expanded, a vaulted and rounded arch. This configuration is characteristic of painters, and is strikingly displayed in the Chinese, who are well known to be very fond of colours. This faculty is generally more active in women than in men.

24. *Space,* or *Locality.* The faculty of local memory, by which we recollect localities, and find our way to places where we have been before, is much stronger in some persons than in others. Animals are also endowed with it, and it enables them to return to their dwellings and their progeny, when obliged to leave them in search of food. It is conspicuous in some dogs; while others are very deficient in this respect. The migration of birds is the result of this faculty. The pictures and busts of great astronomers, navigators, and geographers, as of Newton, Cook, Columbus, &c. present a great developement of this organ, which is situated under, but extends a little beyond, the frontal sinuses. The swallow, the stork, and the carrier-pigeon, have all this organ. This faculty conceives the places oc-

cupied by the external bodies, and makes space not only known to us, but inspires a fondness for this kind of knowledge. It makes the traveller, geographer, and landscape painter; it recollects localities, judges of symmetry, measures space and distance, and gives notions of perspective.

25. *Order.* This faculty enables us to conceive order. It gives method and order in arranging objects as they are physically related. Its organ is probably situated outward, but not far from the organs of size and space.

26. *Time.* Ideas of time are the result of a distinct faculty; for they may exist without those of order and number. They seem to be higher in the scale, and their organ, accordingly, occupies a higher place in the brain.

27. *Number.* All the ideas that are concerned about unity or plurality, that is, about number, belong to a faculty whose organ is situated in a part of the brain near the external angle of the orbit. The object of this faculty is calculation in general. When much developed, the arch of the eye-brows is considerably depressed, or is elevated at the outer extremity. This conformation is apparent in the portraits and busts of great calculators, as Newton, Euler, Kaestner, Jedediah Buxton, and Pitt. The heads of negroes are very narrow at this part; and, in general, they do not excel in this faculty.

28. *Tune.* The perception of musical tone is distinct from that of sound, and implies a different faculty from that of hearing. Its organ is placed on the lateral parts of the forehead. Its form varies according to the direction and form of its convolutions. In Gluck and Hadyn, it has a pyramidal form; in Mozart, Viotti, Zumsteg, Dusseck, and Crescentini, the external corners of the forehead are enlarged but rounded.

The heads and skulls of singing birds, especially the males, exhibit this organ fully developed. Monkeys are absolutely destitute of it.

29. *Language.* The organ of the faculty of learning the artificial signs for the operations of the mind, of perceiving their connection with the thing signified, and of remembering them, and judging of their relations, occupies a transverse situation in the midst of the knowing faculties, and presses upon the basis of the orbit of the eye, so as to project the eye forwards when much developed. This produces what is commonly called a goggle-eye, denoting strong verbal memory. Sometimes the eyes are not only prominent, but also depressed downward, so that the under eyelid presents a sort of roll, or appears swollen. Such persons are fond of philology, that is, they like to study the spirit of different languages.

The second genus of the order Intellect, viz. the reflecting faculties, contains the following species:—

30. *Comparison.* This faculty compares the sensations and ideas of all the other faculties; and points out their difference, analogy, similitude, or identity. Dr. Gall observed various persons, who, in every conversation, had recourse to examples, similitudes, and analogies, in order to convince others; and seldom to reasoning and philosophical arguments. In them he found, in the midst of the superior part of the forehead, an elevation which presented the form of a reversed pyramid, and he named this organ, according to its functions, the organ of analogy. Nations who have this faculty in a high degree are fond of figurative language.

31. *Causality.* This faculty examines causes, considers the relations between cause and effect, and always prompts

men to ask, *Why?* Persons fond of metaphysics have the superior part of the forehead much developed and prominent in a hemispherical form, as Mendelsohn, Kant, Fichte, and others. The ancient artists have given to Jupiter Capitolinus a forehead more prominent than to any other antique head.

32. *Wit.* Persons who have this faculty, who write like Sterne, Voltaire, Piron, &c. have the superior external parts of the forehead elevated. The essence of this faculty consists in its peculiar manner of comparing, which always excites gaiety and laughter. Jest, raillery, mockery, ridicule, irony, &c. are its offsprings.

33. *Imitation.* Persons who have a considerable elevation of a semi-globular form at the superior part of the forehead, have the faculty of imitating, with great precision, the gestures, voice, manners, and, in general, all the natural manifestations of men and animals. They have a disposition to be actors, and are prone to gesticulation. This organ is, in general, more developed in children than in adult persons.

To the above catalogue of the organs enumerated by Dr. Spurzheim, Mr. Combe has since added the two following, namely,

34. The organ of *Wonder*, (situated immediately above *Ideality*, in the lateral parts of the anterior regions of the vertex,) which occasions the belief in the reality of ghosts, and other mysterious apparitions and visitations, and inspires a love for all that is marvellous and supernatural, and also a taste for novelty and fashion. When largely developed, it excites young men, born and bred in inland situations, to choose the sea as a profession.[1]

[1] *System of Phrenology*, fourth edition, p. 381.

35. The organ of *Eventuality*, which, when large, gives prominence or a rounded fulness to the middle of the forehead. "The function of this faculty is to take cognizance of changes, events, or active phenomena, indicated by active verbs. In such expressions as the ROCK *falls*, the HORSE *gallops*, the BATTLE is *fought*, the substantive springs from Individuality, and the verb from Eventuality. It prompts to investigation by experiment, while Individuality leads to observation of existing things. Individuality gives the tendency to personify abstract ideas, such as Ignorance and Wisdom; and Eventuality to represent them as acting. An author in whom Individuality is large, and Eventuality small, will narrate actions, but deal little in physical description."[1]

Two other primary faculties are mentioned by Mr. Combe; one, which he terms *Alimentiveness*, or the desire of eating and drinking; and another, which has been called by Spurzheim *Vitativeness*, or the *Love of Life;* but the seat of these powers has not been exactly determined.

Excepting in the case of idiots, all the thirty-five organs above described are possessed by every person, but they exist in greater or less perfection in different individuals. Peculiarity of character is the result of irregularity in the original structure, or inequality in the relative developement of the several organs; circumstances which, according as they are diversified, lay the foundation of every excellence, as well as constitute the fatal sources of vice and depravity. These doctrines should, however, by no means be understood as lending their sanction to the latter; for crimes are considered as flowing from the abuse of certain

[1] *System of Phrenology*, fourth edition, p. 518.

faculties, and as still requiring for their prevention the counteracting influence of morality, and the salutary coercion of law. It must be of importance to every individual to know, if such knowledge be attainable, what is the degree of energy of the propensities and other faculties with which he may have been naturally and originally endowed; because every organ and corresponding faculty may be invigorated by proper exercise. The business of education will accordingly consist in exciting or restraining their developement, according to their natural deficiency or exuberance. Phrenology, by pointing out what are the strongest faculties in a child, will enable us to adopt the best plan of intellectual, as well as moral discipline; will assist us in regulating his passions, and maintaining a due balance between all his moral sentiments; and guide us in the choice of a profession for our pupil, conformable to the particular bent of his genius. "What benefit would arise to society," says Mr. Forster, the zealous advocate of these doctrines, "should we be enabled to make a just election of objects in youth, to be placed in situations capable of ripening their naturally energetic faculties. Phrenology will lead to important considerations regarding criminal punishment, particularly in houses of correction. It will enable us to distinguish, not only between those who have naturally strong evil propensities, from those whom distress or other contingencies may have hurried on to crime, but will point out the particular nature of the evil propensities to be corrected." It will also tend, he conceives, to establish important distinctions between different kinds of insanity, and enable us to discover the treatment appropriate for the cure of each. Lastly, it may prepare the way to a radical improvement of the human race, by pointing out those conformations of the head which it is desirable to eradicate or to perpetuate, and which should therefore be avoided or preferred in the choice of marriages. "It is certainly a pity," says Dr. Spurzheim, "that, in this respect, we take more care of the races of our sheep, pigs, dogs, and horses, than of our own offspring."

Such is the body of doctrines, and such the reasonings in their support, which have emanated from the school of Gall and Spurzheim, and which they have dignified with the appellation of a new science. A host of opponents, as might be expected, have arisen against a system so much at variance with common notions, leading to conclusions so remote from vulgar apprehension, and admitting so easily of being held up to ridicule by partial or exaggerated statements. We have already noticed the objection founded upon its supposed tendency to favour materialism, and shall pass over others of a similar nature, which proceed upon the presumption of a greater knowledge of the laws of the creation than we really possess, or which are derived from imperfect or mistaken views of the theory itself. We shall also refrain from employing the weapons of ridicule against a system so vulnerable to its attacks, and which would have been so capable of affording Swift a new incident for the history of the philosophers of Laputa. The simple exposition of the sandy foundation on which it has been built, of the flimsy materials of which it has been composed, and the loose mode in which they have been put together, will suffice to enable our readers to form their own conclusions as to the soundness and solidity of the edifice.

It is, in the first place, obvious, that nothing like direct proof has been given that the presence of any particular part of the brain is essentially necessary to the carrying on of the operations of the mind. The truth is, 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 has given us a copious collection of cases, which bear upon this point; and a similar catalogue has been made by Dr. Ferriar, who, in a paper in the fourth volume of the *Manchester Transactions*, has selected many of Haller's cases, with considerable additions from other authors. The evidence afforded from this mass of facts, taken conjointly, appears to us to be sufficient to overturn their fundamental proposition. This evidence is not impeached by the feeble attempts of Dr. Spurzheim to evade its force, by a general and vague imputation of inaccuracy against the observers, or by having recourse to the principle of the duplicity of each of the cerebral organs; a principle of very dubious application, on a subject of so much uncertainty as the physiology of the brain. Poor, indeed, must be his resources, when we find him resorting to the following argument, in proof that the brain is the organ of thought, namely, that "every one feels that he thinks by means of his brain." We doubt much if any one has naturally that feeling.

It requires, also, but a slight attention to perceive, that the very ground-work on which the whole of the subsequent reasoning proceeds, namely, that the different faculties of the mind are exercised respectively by different portions of the brain, is in no respect whatever established. The only arguments in its favour which bear the least plausibility, are derived from analogy. Now, analogy, in reasoning concerning the unknown operations of nature, is, at best, but slippery ground; and when unsupported by any other kind of evidence, cannot lead to certain knowledge, far less constitute the basis of an extensive system. The utility of analogical deductions as to what takes place in one department of nature, from our knowledge of what occurs in another, consists chiefly in their affording indications of what may possibly happen, and thus directing and stimulating our inquiries to the discovery of truth by the legitimate road of observation and experiment. But to assume the existence of any such analogy as equivalent to a positive proof, resulting from the evidence of direct observation, is a gross violation of logic. Yet it is upon assumptions of this kind that Drs. Gall and Spurzheim have ventured to found all the leading propositions of their doctrine. In the secretions of the body, they observe, the preparation of different fluids is consigned to different glands, having different appropriate structures; and they consider this analogy as a demonstrative proof of what happens in the operations of thought, and the phenomena of the passions, which, because they differ as much in their nature as milk does from gall, must, accordingly, be the result of actions in different portions of the brain; which portions are, therefore, to be regarded as so many different organs, rather than as parts of one organ. Even in a case where all the analogies are favourable to one side of a question, such a loose mode of reasoning would be entitled to little confidence; but how fallacious must it not prove, when analogies can be pointed out which apply in the opposite direction? It requires no extensive knowledge of the animal economy to perceive, that modifications of functions equally diversified with those of the intellect, are, in many cases, the result of actions taking place in the same organ. Does not the same stomach digest very different and even opposite kinds of aliment? Yet we do not find that one portion of that organ is destined for the digestion of meat, and another for the digestion of vegetable matter; although the operations required for the conversion of such different ingredients into the same chyle, cannot possibly be the same. Nerves perform the double office of volition and sensation; but the different bundles of fibres which convey each impression, the one to the muscles, the other to the sensorium, are wrapped up in the same sheath, and are so intimately intermixed during their course as to constitute a single cord. The same organ serves for the hearing of acute and of grave sounds. The whole retina, and not merely different portions of its surface, receives the impression of different kinds of colour; there is not one organ for the perception of blue and another for the perception of red rays. Guided by such analogies as these, might we not be equally justified in concluding, that the same part of the brain may serve for the memory of words, as for the memory of things; and that the same portion of that organ which enables us to conceive the idea of figure, may also suggest to us that of size?

The same doctrine of the plurality of cerebral organs, is endeavoured to be supported by another analogy, equally vague and loose with the former, namely, that the sense of fatigue from long continued muscular exertion, resembles, in its circumstances, the effects of long continued study on the mind, and is equally relieved, in both cases, by a change of action. To us, however, it appears, that this analogy might, with equal justice, have been adduced, as favouring the opposite view of the subject; for we can just as readily conceive the sense of fatigue to take place from the exercise of the whole organ in a particular mode, as from that of any part of the organ; and relief must equally, in both cases, be experienced from the ceasing of that action, or from the substitution of one of a different kind. The muscles admit only of one kind of action; and the energy which each derives from the nerves, when once exhausted, is not so readily replaced from the general stock belonging to the system. In the finer textures of the body, which approach more to that of the brain, the analogy not only fails of giving support to the doctrine, but has an opposite tendency. The same retina, when fatigued by the continued impression of a particular colour, is still as ready as before to receive the impression of another colour. The circumstance of partial fatigue with regard to one set of actions, may, therefore, exist, without implying the necessity of a separate organ for the performance of these actions. Indeed, if the brain have any laws similar to those of muscular motion, it must have a much greater number peculiar to itself, and all such distant analogies as those we have been considering, must be perfectly inconclusive. Similar observations will apply to the explanation of the phenomena of sleep, of dreams, of somnambulism, of partial losses of memory, and of insanity. It is equally conceivable, that they should result from the imperfect or differently modified actions of one organ, as from the separate activity of different parts of that organ, whilst the other parts are inactive. Analogies may be equally adduced in support of both sides of the question, and can certainly prove nothing on either.

Drs. Gall and Spurzheim appeal with great confidence to anatomy, and particularly to their own anatomical discoveries, as affording a solid support to their doctrines. "We never," say they, "separate anatomy from physiology, for physiology without anatomy is unfounded; while anatomy without physiology is useless. A physiological system of the brain would necessarily be false, were it in contradiction with its anatomical structure." This conclusion, which at best is but a negative one, is totally inapplicable to the theories in question. The anatomy of the brain is so complex, and so void of apparent adaptation to any purpose we can understand, that it will suit any physiological system nearly equally well; at least it can never be adduced in contradiction of any hypothesis, however wild, that can be framed as to the mutual operation of soul and body. All that these anatomists have done, in this respect, is to show that there is no appearance of a common centre of departure or of a collection of nervous filaments. The separation of the parts of the brain and their diversity of shape, can no more be evidence of a diversity in their functions, than the multitude of distinct and separate lobules which compose the kidneys of birds, and of a great number of quadrupeds, are indications that each part performs a different office. Comparative anatomy, indeed upon which so much is made to hinge, is of all guides the most fallible in questions of this nature; since we behold, in numberless instances, a great variety of ways in which nature accomplishes the same function and the same purpose, in different departments of the animal creation. But on a comparison of animals with each other, it may even be doubted, whether there is any connexion or proportion observable between their intellect or inclinations and the number of parts in their brains.

The possibility of discovering the size and the shape of the different parts of the brain from the external examination of the head, is also discountenanced by anatomy. There are often considerable impressions on the interior of the skull, where the corresponding exterior surface does not exhibit the slightest appearance of projection, and is sometimes even depressed; and there are frequently large prominences without, where there are no corresponding concavities within; so that when the outer surface of the bony case is compared with a mould in plaster or wax of the cavity itself, they exhibit considerable differences, and, from the great variation which may take place in the thickness of the bones, this difference is not the same in degree in any two skulls.

Hollow as are the foundations of this theory, the materials which compose the superstructure will prove, on examination, to be still more frail and unsound. The whole fabric rests upon the validity of a single proposition, which in itself is extremely questionable, namely, that the size of an organ is in general a criterion of the energy with which its function is performed. If any doubt should remain as to its truth, the whole of the pretended discoveries relative to the functions of the several parts of the brain are shaken, and the fantastical edifice has no auxiliary prop to arrest its fall. So essentially, indeed, does the whole of this system depend upon the truth of a number of independent propositions, that if any one of them should turn out to be incorrect, the whole fabric must give way. The evidence in its favour, instead of being cumulative, is disjunctive. Where each proposition must be sustained by a separate series of proofs, as is the case here, it is evident that the chances of error must be multiplied in proportion to the number of steps we must ascend before we can arrive at the last conclusions. Let us, for example, examine the logic by which the above fundamental principle is deduced. "A large muscle," say they, "is stronger than a small one; and a large loadstone is more powerful in its attraction than a smaller one. Why should it not be the same with regard to the brain?" Thus again do they confide in a loose analogy, derived from another and a totally different part of the economy; and as if the organization and functions of the animal body were not sufficiently remote from the nature and operations of the human mind, the inanimate world is ransacked for the shadows of an analogy, which, when viewed through such a distance of intervening mist, may wear the semblance of reality. But the phantom must immediately vanish upon a near inspection. For the perfection of a refined and delicate instrument, such as must be that which is subservient to the operations of the intellect, innumerable conditions must concur; amongst which that of size, it is reasonable to suppose, is the least important. Delicacy of texture, fineness of organization, and harmony of adjustment between the several parts of its complex structure, must contribute infinitely more towards rendering it capable of performing its office, than superior magnitude; a circumstance which in itself is quite as likely to prove a source of imperfection, as to impart additional facility. Increase of size in the viscera of the body is often the indication of a diseased, instead of a healthy state. Small eyes, Professor Hufeland observes, see with more strength, and last longer than large eyes. Why may not this be also the case with the organs of the brain? But really, in our present state of ignorance as to the mode of operation by which they are subservient to the processes of intellect and sensation, all such reasonings *a priori* on their functions, as connected with their size, must be completely illusory.

Even were we to admit so questionable a doctrine as that the energies of the parts of the brain are proportional to their magnitude, insuperable difficulties would still be opposed to the determination of their relative size in the living head; crowded as all these organs are in a narrow compass, and completely hid from our view by an irregular bony case which protects them from injury, and which is itself covered by a thick and variable layer of muscle and integument. Let us, however, for the sake of argument, suppose that the form of each organ within the skull can really be ascertained by external examination of the head; shall we allow it to be an easy task to determine the real character of the individual who is the subject of observation? Are we always able to discriminate between real and affected sentiment; or to mark with certainty the operation of all the various motives which constitute the springs of action? Is the transient glance of a passing observer sufficient for unravelling the complex web of our affections, or unveiling the secret and tortuous recesses of the human heart, so as to assign to each principle its precise sphere of agency? Can the most profound moralist, or acute metaphysician, pronounce with confidence what are the natural dispositions of any human being, knowing as we do, that these dispositions must have been changed or modified, exalted or subdued, perverted or refined, by the force of habit, education, example, and a multitude of other powerful causes, which, in his progress through life, have moulded his intellectual and moral constitution? Can he trace them through the guise of falsehood, artifice, and dissimulation, which so commonly hide his real character from the world, and which occasionally deceive the eye of the closest and most vigilant observer? Is it to the behaviour of a person who knows that he is watched; is it to the partial report of his friends; is it to the testimony of the individual himself, the most fallible of all, that the phrenologist is to trust for his knowledge of human character? Such, however, is the kind of *experience*, from which it appears that all the doctrines relative to the functions of the different parts of the brain have been derived; and it is in this experience, as in an impregnable fortress, that the adherents of the system make their last and most resolute stand. Quitting the airy region of theory, they fancy themselves posted upon a rock, secure against the insidious minings of scepticism, and bidding defiance to the rude assaults of argument. The appeal to the evidence of induction, as to the supreme authority in the court of philosophy, is made with confidence; and all the wild effusions of a bewildered fancy are presumed to be sanctioned by a supposed conformity with experience. You may speculate or reason, they exclaim, as you please; observation shows that such and such forms of the head, are the invariable concomitants of such and such predominant dispositions and faculties. Who will dare to set up his opinion in opposition to ascertained facts? We venture only to express strong doubts as to the reality of these facts, on which so much is made to depend, possessing the character of *general facts*, that is, of being the results of legitimate induction; and to suggest the expediency, previously to any admission of their truth, of inquiring not only into the manner in which the knowledge of these pretended facts has been obtained, and in which inductions from them have been made, but also into the talents and qualifications of the observer upon whose testimony we receive them for the exercise of this philosophical process. We should know in what spirit he conducted the inquiry; with what previous dispositions he examined the objects of his contemplation; what motives led him to these researches; and what interest he may have in the event. Experience, we should recollect, leads to very different results, according to the sagacity and good faith of the person who acquires it. Minds already prejudiced collect from it only a confirmation of their errors, and become, by its means, only the more obstinately wedded to their opinions. The sailor, steadfast in his belief that his whistling to the sea will raise a wind, or conjure up a storm, instead of being undeceived by experience, is only the more strengthened in his faith by the observations which it furnishes to him. In what a multitude of instances do we not find men deceiving themselves as grossly, when they draw inferences from what they see, if prepossessed with the expectation of meeting with a certain coincidence, or succession of events. How disposed are we all to disregard the exceptions to a preconceived rule, and to allow undue weight to every example that conforms to it. How willingly we repel the evidence that opposes, and how eagerly we catch at whatever corroborates our previous notions, especially when those notions have originated with ourselves, and are viewed as the darling offsprings of our own lucubrations.

The discerning reader may already have perceived strong indications of this bias in the framers of the phrenological system, from the account we have already given of its origin and history, and of the kind of evidence on which they pretend to establish its doctrines. In order, however, to enable him to form a correct idea of the species of logic which they have been in the habit of employing and which they deem conclusive, and of the tone of mind with which they prosecute the investigation of subjects where nothing but the exercise of consummate prudence can secure from error, we shall conclude by offering one or two specimens of their mode of reasoning. We shall pass over the numerous stories, each more ridiculous than the preceding, of irresistible natural inclinations to wander from place to place, to commit murder, theft, infanticide, and other crimes, without any assignable object. We shall refrain from criticising the wonderful accounts of people who were insane on one side of the head only, and observed their insanity with the other side, and of others who heard angels sing, and devils roar, only on one side; nor shall we stop to investigate the curious case of the woman who declared in a court of justice, when accused of having destroyed her infant, that her sole motive for becoming pregnant was that she might enjoy the exquisite pleasure of killing her own child. Neither shall we venture to involve ourselves in that metaphysical labyrinth of the *thirty-five special faculties* into which they pretend to have analyzed the human soul; but content ourselves with examining, what in fact alone deserves examination, the sort of evidence brought forward to establish the relation between each faculty and a particular defined portion of the brain. We shall take, for this purpose, the following passage, which may be esteemed a fair specimen of the whole.

"Dr. Gall examined the head of a woman at Vienna who was known as a model of friendship. She suffered different changes of fortune; she became alternately rich and poor; but was attached to her former friends. Gall found the part of her head situated upward and outward from the organ of philoprogenitiveness, very prominent, and called it the organ of friendship. Our observations are not multiplied enough to enable us to decide positively on this organ; yet its seat appears to be more than probable. It *must* be inferiorly, because this faculty exists in the lower animals, and is a propensity. *For this reason* it belongs to their region of the head; and according to its mimical signs, and the motions of the head when it is active, it lies laterally and backward." Dr. Spurzheim, it is obvious, here reasons in a circle; for he assumes as true the thing to be proved, namely, that faculties of a certain class reside in a certain department of the head, and then applies it to establish the very proof on which the proposition itself ought to have rested. In order to render intelligible the latter part of his argument, the reader should be informed that Drs. Gall and Spurzheim believe, that, when any faculty of the mind is strongly excited, the action of the corresponding organ in the brain tends to raise that part of the head in which it is situated; so that the person has a propensity to lay his finger upon the nearest external part of the head, or sometimes to apply his hand to it, either to cool it when too hot, or to warm it when too cold, and that he is occasionally prompted to rub it in order to excite it when too sluggish. Thus, when we endeavour to recollect a name or a word, we unconsciously slap our foreheads, or rub the skin a little above the eyes, or perhaps higher still, just where the appropriate organ of memory is situated, that it may awake and exercise its peculiar faculty. When embarrassed by any difficulty, we gently stimulate in like manner, the organ of contrivance, by scratching the head at the part under which is the seat of *constructiveness.* The timid man scratches his head on the organ of courage behind his ear, as if he tried to rouse the feeble organ into activity. A proud man holds his head erect upon his shoulders, and raises himself upon his toes, for no other reason than because the organ of the sentiment lies at the very top of the head, and is therefore elevated by the action. A sense of danger, or the necessity of *circumspection,* leads all animals, man not excepted, to stretch their necks forwards horizontally, thus presenting the broad extent of that organ, as it were, in front. Devotion raises the head gently; and our adorations are all directed upwards, not because we regard the Deity as above, but because the organ of adoration is situated in the centre of the upper part of the head. When busied in deep contemplation, we cover the whole forehead with our hands, as it is there that the reflecting faculties are lodged; and, accordingly, when we reproach any one for his want of reflection, we put our hand to this part of the head; and exclaim, "he wants it here." If we try to recollect a date, we put into action the organ of time, which being situated over the eyebrows, and a little to one side, occasions an involuntary movement of the eyes upwards and towards the temples. In beating time to a musical air, we make the head oscillate from side to side, because the organs of tone as well as of time, being situated on each side, and being alternately in action, occasion these gesticulations. Sterne excelled in wit: and we find him represented in all his portraits with his head leaning on his hand, the fore-finger of which is placed on a particular part of the forehead. Dr. Spurzheim considers this as one of the proofs that the organ of wit occupies that very spot.

With minds capable of allowing any weight to such observations and imbued with such notions of the nature of philosophical induction, as are implied by the grave admission of such frivolous arguments as these, the investigation of the laws of nature must be an easy and a delightful task. With the abundant and all-powerful resources, which their indulgent method of reasoning is ever ready to supply, all difficulties may be smoothed away, all chasms immediately filled up, and all obstacles made to vanish the moment they arise. We need not be under any embarrassment at meeting with a skull exhibiting a particular prominence, although the faculty which should correspond to it be deficient. Doubtless the individual must have been strongly gifted by nature with this faculty, but education has long ago taught him to disguise or suppress its manifestations. It exists, perhaps, unknown to the person himself, and wants only a proper occasion for its being exhibited; or more probably the other faculties, having received a greater proportional developement, have overpowered and prevented it from appearing. If we find, on the contrary, a strongly marked faculty, without the corresponding shape of the head, we may still conclude that the organ exists notwithstanding; for the neighbouring organs, having received a greater extension, may have pushed it from its true place, or have grown up around it, and have concealed it from vulgar observation. Its not having been recognised is only a proof of want of skill in the observer; no doubt, it would easily have been discovered by the eye or hand of a true believer, and experienced cranioscopist; for it should be recollected that the differences are often very minute, and require the *tactus eruditus* for their detection. Besides, how can we be certain that the excellence of the faculty in question is not of an artificial or relative kind, and that it results from education, or the weakness of opposite faculties, rather than from nature? If all these expedients should fail us, we have nothing to do but to plunge into the depths of metaphysics, to refine and make subtle distinctions, or loosen the signification of a few words, till we have entangled ourselves in a wood, and lost sight of the real difficulty that had perplexed us. Thus will the theory be freed from all exceptions, and the induction be rendered complete. With such a convenient logic, and accommodating principles of philosophizing, it would be easy to prove any thing. We suspect, however, that on that very account, they will be rejected as having proved nothing.

We have here re-printed the Essay on this subject which originally appeared under the head of CRANIOSCOPY, in the Supplement to the Sixth Edition of the Encylopædia Britannica. We have done so because we have not seen any reason to alter our views. Since the year 1818, when that essay was written, replies have been attempted to some of our strictures; particularly by Mr. George Combe, in his "*Essays on Phrenology, and on the objections made against it*," Edinburgh, 1819; and by Dr. Andrew Combe, in the *Phrenological Journal*. Although the conductors of this Journal have admitted that our Article was "regarded in the South as the most formidable attack Phrenology ever had to sustain,"[1] and have in so far paid us a compliment, we deem it unnecessary to answer, otherwise than very generally, their comments on the reasonings contained in it; because most of those comments are founded on a misconception of the scope of our arguments. When, for instance, we attempted to show, that, in establishing a philosophical principle, mere analogies ought not to be esteemed as equivalent to proofs, and when we maintained that they are still less to be relied on, when other analogies, of a contrary tendency, can be adduced on the other side of the question, we are represented by Dr. Combe as building our arguments on analogy, the very principle of which we were

[1] *Phrenological Journal*, i. 166.

pointing out the fallacy, and repudiating the authority; and we are even charged with being guilty of the strange inconsistency of endeavouring to "refute direct inductive evidence, by that drawn from analogy."[1] Any reader who had paid the least attention to the train of reasoning we employed, must have perceived that our reasoning was diametrically the reverse of that which is imputed to us; and that we had even guarded against the possibility of mistake by the sentence concluding with the words, "all such reasonings *a priori* ...... must be completely illusory."

By the help of a mis-quotation, in which the qualifying adverb "nearly" is omitted, we are represented as having asserted, that the anatomy of the brain "will suit any physiological system equally well."[2] All the notions we can form of the nature of mental operations are so completely and essentially different from any of the affections of which we can conceive matter to be capable, that it is utterly impossible for us to understand the mode in which a connexion has been established between them; or to imagine any physical structure whatsoever, which shall, in the remotest manner, correspond with the metaphysical constitution of the soul. This, however, we may confidently assert, that amongst all the hypotheses which have been propounded respecting the correspondence between the corporeal instruments of the mind, and the mental faculties themselves, the one which is the least in accordance with the actual structure of the brain, is that devised by the phrenologists. Let a person, unacquainted with the anatomy of that organ, be shown the phrenological map of the cerebral regions, and let him be told, that to each corresponding subjacent portion of the brain is ascribed, as

[1] *Phrenological Journal*, i. 168, 169. [2] *Ib*. i. 166.

to a separate organ, a certain special mental function; one set of these organs being appropriated to the establishment of certain definite propensities, whilst another set gives rise respectively to various sentiments, and a third confers each its peculiar intellectual power; with what immeasurable surprise, on lifting up the bony covering which had concealed this expected assemblage of well defined organs, would he behold a uniform mass of pulpy substance, divided by furrows only, into serpentine but continuous convolutions, bearing no conformity or even similitude to the notions which his previous instructions had led him to form of distinct masses, divided from each other in accordance with their phrenological functions. Each of these pretended organs, far from being isolated in its structure, as its alleged isolated functions would imply, from the neighbouring parts, is seen to pass on, without visible boundary, to the next, by a continuity of cerebral substance. Turning round upon his instructor, would he not complain of being misled by him; and would he not require him to explain what intermediate function he can ascribe to those portions of the same convolution which occupy an intermediate place between two organs, to which he has already assigned functions utterly heterogeneous with one another? What lucid ideas can he convey of a function intermediate between *benevolence* and *imitation*, between *ideality* and *acquisitiveness*, between *cautiousness* and *adhesiveness*, or between *self-esteem* and *concentrativeness* or *inhabitiveness*, of which the respective organs are not merely contiguous, but pass insensibly into one another; and what is the curious and hitherto nondescript office that he will assign to those portions of the brain which occupy the central space at the junction of quintuple groups of organs, such as those of *ideality*, *acquisitive-*

ness, *constructiveness*, *tune*, and *wit*, all of which, though separated by the fancy of the phrenologist, have been by nature amalgamated into one continuous mass, undistinguishable by any visible lines of demarcation?

Not content with expressing his dissatisfaction at our failing to perceive the accordance between the structure of the human brain and the doctrines of phrenology, Dr. Combe extends his censure to our objection as to the evidence which observations on lower animals are supposed to afford in their favour; and to our assertion, that in the construction of their system "much was made to hinge" on facts derived from comparative anatomy. That the founders of the system placed great reliance on this kind of evidence, is a proposition sufficiently borne out by the testimony of Sir George Mackenzie, who, when speaking of inhabitiveness, remarks, "it is chiefly from observation on the lower animals that Dr. Spurzheim seems *to consider it as certain*, that there is such a faculty in man."[1] The fallacy of the reasoning by which comparative anatomy has been pressed into the service of phrenology, has been so ably exposed by Dr. Prichard, in his Treatise on Insanity, that we shall beg leave to borrow from that work the following judicious remarks. "The chief peculiarity," observes Dr. Prichard, "of Dr. Gall's psychological theory, was the attempt to draw a parallel between the animal qualities displayed by the lower animals and the individual varieties discovered among men." He proceeded "on the principle, that the innate or original faculties are common to man and the lower tribes of animals, to those at least which bear to man a general analogy in their organization, and especially in the structure of their nervous system; and sought for

[1] *Illustrations of Phrenology*, p. 92.

analogies in physical phenomena between the brute tribes, tracing in them the rudiments of those properties which, taken collectively, and in their highest degree of developement, form the human character, and which, in lower degrees and various relations, constitute the distinctive nature of each of the inferior kinds. The attempt was ingenious, and seemed to hold out the prospect of discovering curious and interesting relations; but it is necessary, before embarking in the inquiry, to determine whether the analogies are real or apparent; for it has been tacitly assumed that the supposed distinction between instinct and reason is unreal, and that the active principles are of the same kind in the higher and lower beings of the creation." "Perhaps metaphysical writers have been mistaken in laying down so broad a line of difference as they have established. We must, then, either elevate the brutes, or lower the superiority of mankind. Shall we say, after tracing the operations of a constructive instinct so wonderfully displayed by the beaver, or in the cells in which the bee lays up his honey, that an impulse to action precisely similar gave origin to the pyramids of Egypt, or to the building of Constantinople? Shall we venture to affirm that the tunnel under the Thames owes its existence to a burrowing propensity resembling that of the rabbit or the mole? Shall we conclude that Parry and Franklin sought the regions of the north, impelled by the instinct of the migratory rat; and that Magellan and De Gama traversed the Southern Oceans directed by an influence analogous to that which moves the flight of swallows? Or may we, with greater probability, determine that the lower tribes act under the guidance, not of blind instinct, but of enlightened reason; that metaphysicians were mistaken when they laid down the principle, 'Deus est anima brutorum,' that the birds of passage have some acquaintance with physical geography, and know the quarter where tropical warmth exists and genial breezes blow; that the bee has studied the exact sciences, and knows by calculation the form most advisable for its cells? In short, that there is a real analogy and correspondence between the mental faculties of man and the physical endowments of those creatures whom he conceitedly regards as his inferiors? If either of these positions can be maintained, there will be a sound foundation for the comparative pyschology of Dr. Gall and his followers; but if they should be rejected as improbable, we must admit that the analogies pointed out are remote, the things compared are different in kind, they agree only in external appearances; and we shall be brought to the conclusion that it has pleased the Author of nature to bring about corresponding results in the rational and irrational departments of the creation, by very different means."

"If the evidence," continues Dr. Prichard, "brought in support of the organological system depends so entirely on universal coincidence between psychical properties and corresponding varieties in the structure of the nervous fabric, it must be important to determine whether there are any departments of the animal kingdom in which instincts and motive habitudes, and an entire psychical nature are displayed analogous to those of vertebrated animals, while yet in these departments there is no structure which can be said to bear resemblance to the complicated cerebral system of the so termed higher animals. In all the vertebrated kinds, the organization of the nervous fabric is in one principle, and the same fundamental type, with different degrees of developement, is traced in man and all other mammifers, in birds, reptiles, and fishes; but here the resemblance terminates, and the nervous system of molluscous animals and insects presented but few and remote analogies to that which belongs to the first great branch of the animal creation. It is, indeed, to be presumed that the nervous system, taken as a whole, fulfils, in the tribes last mentioned, the same offices as in those animals who have it enclosed in a bony case. Still, nothing exists at all resembling the complicated formation of a brain, with its lobes and convolutions. It is so much the more surprising to find the higher instincts, which had almost disappeared in fishes, display themselves with new splendour and variety in the brainless insects; creatures which, in the wonderful imitations of intelligence that govern their motive habits, rival, if they do not even exceed, the sagacity of the animals which most approximate to man."

"Now, if it should be established, that all those properties of animal life, approximating to intelligence, or bearing analogies so striking to the manifestations of mind, which, in one great division of the animal kingdom are assumed to be essentially connected with, and depending on, a particular system of organization, exist in another department, and display themselves in all the same various profusion, while the creatures belonging to this latter department are yet destitute of that system of organization, and of any thing that bears the resemblance to it, the advocates of Phrenology will be obliged to abandon that broad ground on which they have attempted to fortify their position. Within the more confined field which the vertebrated tribes alone present, it will be more easy to maintain such an assumed connexion of physical properties with a peculiar structure; or, rather, it is more difficult to disprove it when assumed. The general analogy which prevails throughout these tribes in the organization of their cerebral and nervous system, affords no room for so decisive a contradiction to the relation which the phrenologists would establish. Yet even within this field great and striking facts display themselves which are adverse to the hypothesis. Birds and reptiles, as Jacobi has observed, are nearly, if not wholly destitute of many cerebral parts, which in mammifers are held as of high importance for the manifestation of psychical properties, and yet they display psychical phenomena similar to those of mammifers. Whenever an undoubted and tangible fact can be laid hold of in the different proportional developement of cerebral parts, which can be brought into comparison with the relative differences of animal instinct, or of psychical properties in general, there is, if I am not mistaken, a manifest failure of correspondence between the two series of observations. This has been shown by Rudolphi in a striking manner, with respect to the cerebellum. The cerebellum, as this writer has observed, is found to lessen in its proportional developement as we descend in the scale of organized beings, without any corresponding diminution, and even with an increase of the propensity which Gall connects with it. How remarkably powerful is this instinct in birds; and yet how small is the cerebellum in the feathered tribes compared with its size in mammifers, and even in the latter, when we consider the magnitude which it attains in the human species? We observe those tribes in which the cerebellum nearly or entirely ceases to exist, obeying, nevertheless, the impulsion of instinct as blindly or devotedly as other kinds which have the organ in question remarkably developed. When we consider the great amplitude which the cerebellum attains in man, in comparison with its size in lower animals, we are obliged, if we really attach any importance to such a system of correspondence, to acknowledge some relation between this circumstance and the transcendant superiority of the human intellect, compared with the psychical powers of brutes."

"The facts which suggest themselves as we follow these trains of reflection, are scarcely to be reconciled with the phrenological theory: they seem, in the first place, to show, that the relations which in it are assumed to prevail through all nature are subject to vast exceptions; and as one great proof of the doctrine is the assumed universality of such relations, or the endowment of psychical properties in coextension with certain peculiarities of structure in cerebral parts, the exceptions endanger at least the outworks of the whole doctrine. When, in a more limited survey, we confine our observation to the sphere of vertebrated animals, and discover that variations in psychical phenomena take place without any evidence of corresponding changes in the structure of cerebral parts, and that these changes, on the other hand, occur without such alterations as we are led to anticipate in psychical properties, the system of organology seems to be shaken to its very centre."[1]

Whilst the defenders of phrenology have, on the one hand, misrepresented the minor points of our argument, they have, on the other, disguised from their readers that it is on the insufficiency of the evidence adduced in support of their doctrine, that we rest our main objection to its credibility. We maintain, that they have taken only a one-sided view of what nature presents to our observation; that they have paid attention to those facts alone, which are confirmatory of phrenology, and shut their eyes to those which oppose it. In order to establish what they consider as the

[1] *Treatise on Insanity*, p. 465 to 474.

rule, they have collected together all the instances in its favour, and have passed over or suppressed all the exceptions. What we assert is, that more enlarged inquiry, conducted with a more entire devotion to the cause of truth, anda scrupulous rejection of error, would have shewn the latter to be at least equal, if not superior in number to the former. Our own observations, as far as we have pursued them, have led us to this conclusion; and it was on the result of these observations that our scepticism was principally founded. So frequent, indeed, are the exceptions, that even the founders of the system, Drs. Gall and Spurzheim themselves, on applying it practically, committed, as is well known, very glaring mistakes; giving frequently the most false judgments of the characters of various individuals. Have these mistakes, we may ask, been any where recorded by the phrenologists, and candidly set off against the instances in confirmation of their sagacity? What avails their collections of thousands of examples of coincidences, when the perhaps equally numerous instances of discordance are excluded from the catalogue? The fact, that the brain of Cuvier was of unusual magnitude, has been triumphantly proclaimed in all the publications on phrenology; but we are not aware that any phrenologist has brought forward the equally well-certified fact, that the brain of Sir Walter Scott was found on examination to be "not large."[1]

In like manner, a long catalogue of persons avowing their belief in phrenology, including many men of eminent talents and extensive knowledge, has been paraded before the public; but we have not yet seen any counter list of unbelievers prepared with the view of ascertaining, in a science pro-

[1] *Life of Sir Walter Scott*, by Lockhart, vol. vii. p. 395, note.

fessedly of pure observation, on which side the weight of authorities preponderates. The class of men who, from the nature of their pursuits, are perhaps best qualified to form a correct judgment in matters of this nature, are the members of the medical profession; yet how inconsiderable, compared with the total number, is the proportion of those belonging to that profession who, according to Mr. Combe's catalogue, have given in their adhesion. Sculptors, again, compose another class of men whose studies lead them more especially to the most minute and accurate knowledge of the external form of the human head; yet amongst the many who are at present engaged in the active exercise of their noble art, Mr. Combe has been able to bring forward the name of only one solitary individual as lending a countenance to phrenology.

"It is not enough," as Dr. Prichard very justly observes, "to have a few chosen coincidences brought forward by zealous partizans, who go about in search of facts to support their doctrine, and pass by, or really cannot perceive the evidence that ought to be placed in the opposite scale. The principles of the system ought to be applicable in every instance. The phrenologists, however, aware of numerous and striking exceptions, elude their evidence by asserting, that when a certain portion of the cranium and of the brain is greatly developed, while the faculty there lodged has never been remarkably distinguished, it nevertheless existed naturally, though the innate talent, for want of proper cultivation, has never been displayed; the predominant organic power was never discovered by the owner, though, according to the principles of the doctrine, with this organic power a proportional impulse to exertion, or an instinctive energy is combined, which communicates of itself a strong and irresistible tendency to particular pursuits. When, again, a strongly marked propensity, or a decided talent has been manifested without any corresponding amplitude of structure, it is in like manner pleaded, that by sedulous exercise and culture, a natural deficiency has been overcome. Thus the phrenologist avails himself of a double method of elusion; his position, like the cave of Philoctetes, affords him an escape on either side; and in one direction or another he contrives to baffle all the address of his opponents.

"If, however, the testimony of facts in a great scale should be found adverse to the alleged coincidences, or to the correspondence of given mental equalities with certain conditions of the brain, phrenology will not continue to make proselytes, and it will be ultimately discarded as an hypothesis without foundation. At present, most inquisitive persons seem to be in doubt on this subject, and to be looking out for evidence. I have taken every opportunity that has occurred to me for many years of making inquiries of persons who had a great field of observation within their reach, what had been the result of their experience on this subject. Many of the persons have been physicians, who were superintendants of extensive lunatic establishments. Some of them had been men who had addicted themselves to the study of phrenology, and were predisposed to imbibe the opinions of its authors; some have been persons distinguished by their researches in the anatomy and physiology of the brain and nervous system. Among these I do not remember to have found one who could say that his own observation had afforded any evidence favourable to the doctrine. Yet we should imagine, that a man who lives amidst hundreds of monomaniacs must have constantly before his eyes facts so obvious that he could not be mistaken in their bearing. Some hundreds, and even thousands of such persons have passed a part of their lives under the inspection of M. Esquirol, who possesses most extensive resources for elucidating almost every subject connected with the history of mental diseases, and has neglected no inquiry which could further the attainment of that object. The result of his observations will be allowed to be of some weight on the decision of this question, in which the appeal is principally to facts of the precise description of those with which he has been chiefly conversant. At his establishment at Ivry he has a large assemblage of crania and casts from the heads of lunatics, collected by him during the long course of his attendance at the Salpêtrière, and at the Royal Hospital at Charenton, which is under his superintendance. While inspecting this collection, I was assured by M. Esquirol, that the testimony of his experience is entirely adverse to the doctrine of the phrenologists; it has convinced him that there is no foundation whatever in facts for the system of correspondences which they lay down between given measurements of the head and the existence of particular mental endowments. This observation of M. Esquirol was made in the presence of M. Mitivié, physician to the Salpêtrière, and received his assent and confirmation. M. Foville, physician to the extensive lunatic asylum at St. Yon, gave me a similar assurance. There are few individuals in Europe whose sphere of observation has been so extensive as that of M. Esquirol and M. Foville, and certainly there are none whose science and habits of observation better qualify them to be witnesses in such a subject of inquiry; but testimonies to the same result may be collected from unbiassed witnesses, whose evidence taken collectively may have nearly equal weight. Among these there are men unscientific, though capable of correct and unprejudiced observation, as well as anatomists and physiologists. In the number of the latter is Rudolphi, who declares that he has examined many hundreds of brains without finding any thing that appeared to him favourable to the phrenological theory."[1]

The mode in which Dr. Combe evades the force of the strong testimony here adduced, is quite characteristic of the disposition to be found amongst confirmed phrenologists, of resolutely rejecting all evidence that militates against the system they have adopted. Thus, he says, in reference to the passage we have just quoted, "If Dr. Prichard believes that the intelligent and benevolent Esquirol, is that person," (namely, one "competent to form a judgment on the subject,") and if his collection of crania and casts be the hostile evidence which is relied on, this only proves, in a forcible manner, that Dr. Prichard is himself not competent to judge, or that he has not taken time either to examine the collection of crania, or to ascertain the competency of Esquirol and Metivié, to decide on the merits of the question on which they volunteered an opinion."[2] We cannot help remarking here, that, on another occasion, when criticising the suggestion we threw out, in the Essay on Cranioscopy, of the propriety of inquiring into the talents and qualifications of observers before admitting the truth of the facts received on their testimony, a very different language was held. "When they" (the advocates of phrenology) "affirm that the subjects of observation are patent to the whole world, who have eyes to see, and understandings to comprehend; and when they say, compare manifestations with cerebral developement, and

[1] *Treatise on Insanity*, pp. 476, 477.
[2] *Phrenological Journal*, viii. p. 654.

you are at the bottom of the problem yourself; what need for inquiry into their talents and qualifications to observe?" "When Gay Lussac hears that Sir Humphry Davy has made a discovery in chemistry, and reads Sir Humphry's statement of the way in which it was made, does he begin by inquiring first, whether it be possible to make the discovery at all, seeing natural substances are 'so changed and modified, exalted and subdued' by a multitude of powerful causes? And, after settling this point, does he, in the second place, proceed to inquire into Sir Humphry Davy's talents and qualifications as a chemist, and into his capacity to make the discovery, and then believe it, or not, according to the result of this investigation? No man who knows the first rudiments of philosophy would follow so absurd and preposterous a course. What should we think of Gay Lussac's refutation of Sir Humphry's discovery, founded on a metaphysical inquiry into the possibility of making it, and into the 'talents and qualifications' of the discoverer? We should pity him for his ignorance of the rudiments of philosophy."[1]

This happy talent, possessed by the champions of phrenology, of shaping their course either one way or the opposite, according as it may suit the convenience of the occasion, enables them, at one time, to proclaim, that the evidences of their science are palpable and demonstrative, that the field of nature is open to all inquirers, that "every one who has eyes may see" and judge for himself; and at another, when such judgment is against them, they can turn round, and allege that in order to arrive at the truth a peculiar discretion and tact, acquired by long experience and careful appreciation of minute and hair-breadth differences

[1] *Essays on Phrenology*, p. 71.

of size is necessary. They can then declare that the observer who has not arrived at the same conclusions as themselves, is doubtless incompetent to the task he has attempted; and that his testimony, being of no value, ought to be wholly set aside.

Let it be borne in mind, then, by the practical inquirer into the truth of phrenology, that he will not be esteemed qualified to verify its doctrines, unless he be previously deeply versed in the new system of psychology, can assign to each of the thirty-five special and primary faculties of the soul its sphere of operation, and has acquired a readiness in unravelling their multifarious combinations, so as to analyze, by this subtile metaphysical chemistry, all human qualities into their proximate and ultimate elements, refer all actions to their proper innate impulses, and assign the proportions of the various ingredients which are mixed up in the formation of the character of each individual. No one is competent to excel in this new branch of philosophy who doubts the possibility of appreciating the intensities of moral or intellectual qualities by geometrical measurements, on scales divided into tenths and hundredths of inches. The young and ardent phrenologist, who after having applied his callipers to the skull subjected to his examination, and taken a note of the dimensions of each of the thirty-five organs, proceeds to verify his observations by comparing them with the character of the possessor of those organs, will never fail to meet with *wonderful coincidences*, sufficient to give him the greatest satisfaction, and confirm him in the persuasion that he possesses the real key to the secrets of nature in the hitherto recondite science of mental philosophy. A moderate share of dexterity in reconciling apparent discrepancies will suffice to ensure a preponderance of favourable evidence; since, fortunately, there have been provided in the brain different organs, sometimes of similar and sometimes of opposite properties, capable, by a little adjustment of *plus* or *minus* on either side of the equation, of furnishing the requisite degrees of the mental quality sought for, and of thus solving every psychological problem. We shall suppose, for instance, that he is inspecting the head of a person known to have given credit to the prophecies of a weather almanack; he finds, on reference to the "system of phrenology," that a belief in astrology is the offspring of No. 16, that is, *ideality;* so that if this organ happen to be sufficiently large, the phenomenon is at once accounted for. But if it be not, our phrenologist will have another chance; for he will probably discover it to arise from the dimensions of No. 15, which inspires *hope*, the source of the *propensity to credulity*. Habitual *irresolution* may result either from the magnitude of No. 12, or the diminutiveness of No. 18; thus affording very great convenience for making our observations of the character square with those of the dimensions of the organs, and *vice versa*. If, again, the magnitude of the organ of *combativeness* accord with the manifestations of pugnacity given by the individual, it is well, and we need inquire no farther, but set it down at once as an irrefragable proof of the accuracy of phrenological determinations. Should the correspondence, however, not prove satisfactory, the organ being large for instance, and the manifestation small, we have then further to examine the dimensions of the organ of *caution*, the influence of which is to moderate and check the operation of the former; and we shall perhaps find this organ sufficiently large to account for the phenomenon. Both these organs may be large, or both small, or the first may be small and the second large, or the converse; and other modifications of action may result if either one or both be only of moderate size, allowing great latitude of choice in the assignment of motives. Should we be so unfortunate as to exhaust all the combinations without meeting with the success we desire, there is still an abundance of auxiliary faculties of which we may avail ourselves with advantage. If we were to explain the fact of the individual in question having accepted a challenge, he might have been inspired by *combativeness*, whose voice was "still for war," or goaded on by *destructiveness*, to fight that he might destroy; *firmness* may have urged him to persevere by the consideration that he had previously resolved it, and *concentrativeness*, by rivetting his attention to the subject, may have screwed his courage to the sticking place; or he may have been prompted by *imitation* to follow the example, or by *approbation* to gain the applause of his friends. We have also to take into the account the countervailing influence of faculties which are pulling in the opposite direction, and qualifying the combined powers of the former incentives: And should *cautiousness* not be in sufficient force, we are to consider the power of *conscientiousness*, which preaches forbearance, meekness, and forgiveness; of *veneration* which appeals to the high authority of religion and of law; of *benevolence* restraining the hand from inflicting pain and death; of *approbation*, who qualifies her sanction by raising other voices condemnatory of the deed; and last, though not least, the *love of life* which recoils with instinctive dread from the possible catastrophe. Drawing, then, a diagram of all these component moral forces, in their proper directions, and suitable proportions, it will not be very difficult to obtain by this artificial dynamico-phrenological process, the exact result-ant which corresponds with the actual fact to be explained.

Lest it should be imagined that the above description is a caricature of the new method of philosophizing, so admirably calculated to establish the truths of phrenology, we shall beg to quote the following passage from Sir George Mackenzie's *Illustrations* as an example of this satisfactory process of ratiocinatien.

"In discussing the conjectured faculty of inhabitiveness with Mr. Combe, he had the goodness to make us acquainted with a case, in which *locality* and *inhabitiveness* were both very moderate in developement, but the *propensity to wander*, as he informed us, very powerful. Dr. Spurzheim mentions this propensity as belonging to *locality*, and he states several remarkable cases in which the organ was much developed, and the propensity strong. The case referred to by Mr. Combe was, on this account, interesting; and we will state the result of our inquiries into the particulars, for the purpose of giving an example of the caution with which we ought to receive the description of any case brought in opposition, since it sometimes appears to be necessary even among friends.

"The young man to whose case we refer, had a very strong desire to adopt a seafaring life, contrary to the wishes of his friends. It occurred to them, that a voyage up the Baltic, during the stormy months of October and November, might have the effect of giving him a disgust to the profession for which he showed so ardent a desire. He suffered so many privations and hardships, that he yielded to the wishes of his friends, although the desire to go to sea continued as strong as ever. On proposing a few questions, we found that the propensity was confined to *being at sea;* that this propensity did not originate in a desire to wander;

for neither travelling on land, nor mere change of place, would have gratified the propensity. At the same time, the person referred to declared, that regular voyages to the same place would not have satisfied him. The propensity had haunted him as long as he could remember any thing. Being anxious himself to contribute to the unravelling of what appeared mysterious and irreconcilable to the system, he stated that he used to go once or twice a-day to examine the mechanism and rigging of ships in Leith harbour, an employment of which he was passionately fond; and long before he commenced his trial voyage, he had become familiar with the names and uses of every part of a ship, and of the rigging. He was fond of machinery, and has often amused himself by making models of ships; and his mechanical turn was so strong, that he had constructed a model of machinery, by which a ship's motion may be applied to work the pumps. This mechanical propensity, and his early attachment to naval machines, together with *firmness*, appear to us to have given rise to his desire for a sea-faring life. *Courage* might also have prompted his wish to enter the navy. Thus the supposed propensity to wander appeared not to exist; and it was found that a mechanical genius, an early attachment[1] to the mechanism of a ship, *perseverance*, *courage*, and probably also love of *approbation*, or ambition, and *ideality*, all of which were well developed in the individual referred to, combined to inspire the desire to enter the navy." (*Illustrations of Phrenology*, p. 170.)

It is to be lamented that, at the period when this elaborate investigation was undertaken, the organ of *wonder* had not yet been made; for as one of the functions of this or-

[1] "Dr. Spurzheim has shown, that the faculty of attachment extends its influence to inanimate things, as well as to animate beings."

gan, according to Mr. Combe, is to " incite young men to chuse the sea as a profession," much light would have been thrown upon the object of the inquiry by a critical examination of its dimensions compared with those of all the other organs which were taken into consideration as combining their influence in producing the result.

There is this very remarkable peculiarity in the pursuit of phrenology, that the student is perplexed, not with the difficulties, but with the facilities it affords for explaining every phenomenon. The pliability of its doctrines is exemplified, not merely in the analysis of motives, but likewise in the influence which we are allowed to ascribe to the habitual exercise, or education of the faculties. The observed magnitudes of the respective organs indicate, not the acquired, but the natural powers, sentiments, and propensities. Now, the character of the individual is the joint result of the force of natural endowments, and of the amount of moral and intellectual cultivation which has been bestowed upon them. But can we ever know enough of the minute history of the progress of the mind of any individual to enable us to form a correct estimate of the relative power of these two elements, which have, in the formation of each respective faculty, combined their operations? If it be true that an organ may be the seat of a faculty varying in its activity according to the occasions which call it forth, by what physical criterion can we distinguish the active from the dormant conditions of that organ? Unless we can draw, with precision, these distinctions, it is evident that the ground of all cranioscopical observation is cut from under us.

It may be indeed alleged, that at all periods of life, and even after the bones of the skull are consolidated, the organs increase or diminish in size according to the exercise or disuse of the faculty associated with it, whether such change may have been brought about by voluntary training, or by the discipline of circumstances; and certainly, if such were the fact, our experience would repose on a much surer basis, than if the form of the organs merely retained the stamp originally impressed upon them by nature. But the hypothesis that the cerebral organs acquire additional size by the exercise of their powers was positively rejected as untenable by Dr. Spurzheim, as we have heard him publicly declare; and it is, we believe, repudiated by the generality of phrenologists.

We do not think it difficult to account for the progress which phrenology has made amongst the very numerous class of persons who find in it a source of agreeable occupation, giving exercise to their ingenuity in discovering striking coincidences, and gratifying their self-complacency by inspiring them with the fancy that they are penetrating far into the mystic regions of psychology. For the last twenty or thirty years, various popular writers, and lecturers without number, have been displaying their powers of elocution, exercising their skill in the critical examination of developements, and expounding the doctrines of the new philosophy to wondering and admiring audiences. With all these advantages and appliances to boot, the wonder seems to be, not that phrenology has met with the success of which so much boast is made, but that it has not speedily gained the universal assent; for had it been a real science, like that of Chemistry and other branches of Natural Philosophy, founded on uniform and unquestionable evidence, it could not have failed, by this time, of being generally recognised as true.

When we consider that the present age is not one in which there is any lack of credulity, or in which a doctrine is likely to be repudiated on the score of its novelty or its extravagance, we cannot but smile at the complaints of persecution uttered by the votaries of the system of Dr. Gall, and at the attempts they make to set up a parallel between its reception in this country, in these times, and that which, two centuries ago, attended the speculations of Galileo, and subjected him to the tyrannous cognisance of the Inquisition; or to establish an analogy between the dogmas of phrenology and the discoveries of the circulation of the blood, and of the analysis of light, which have immortalized the names of Harvey and of Newton.

PHYSIOLOGY.

PHYSIOLOGY.

CHAPTER I.

GENERAL VIEWS OF PHYSIOLOGY.

(1.) PHYSIOLOGY, or the science of animal life, has been variously defined by different writers. If the term were interpreted strictly according to its etymology, it would carry a meaning much more extensive than is warranted by common usage; for, being derived from φυσις, *nature*, and λογος, *discourse*, its proper signification should be, the *science of nature*. It might accordingly be understood to comprehend inquiries in every department of nature, both animate and inanimate; and might indeed be regarded as synonymous with *physics*, or *natural philosophy*, which are other expressions of corresponding import, but which at present are themselves restricted in their meaning to a special department of nature. There can be no doubt, indeed, that such must originally have been the real signification of these terms; but it is needless now to inquire by what gradual transitions they have at length come to bear such different, and even in some respects, opposite significations. If we were desirous of substituting a term which would accurately express the idea now associated with the word physiology, we should adopt that of *biology*, from βιος, life, first introduced by Treviranus, who has written a German work on this subject, which bears that title.

(2.) Natural philosophy, or physics, is now understood as designating that class of sciences, which have for their object the examination of the properties of lifeless matter; whilst physiology, in its modern acceptation, is in like manner limited to the consideration of the properties which are peculiar to organized and living bodies. The former is conversant only with nature in her dead or inanimate condition; the latter with nature endowed with life, and in all its various forms and modifications.

Thus mechanics, hydrostatics, and pneumatics, wholly relate to the general phenomena exhibited by matter in its solid, liquid, and gaseous forms; optics, which relates to the phenomena of light, together with electricity, magnetism, and the science of heat, which regard other classes of phenomena produced by peculiar agents, are all considered as branches of natural philosophy. Chemistry, which is concerned with the changes of composition in bodies, resulting from the mutual action of their particles at insensible distances, ranks also with the sciences relating to the properties of inorganic matter, and of which the assemblage constitutes what are more correctly termed in the present day, *the physical sciences.*

(3.) On the other hand, the study of animated nature does not admit of the same extent of subdivision. Nature has indeed traced a broad and obvious line of demarcation between the *vegetable* and the *animal* kingdoms; the first being the province of *botany*, the second of *zoology*; both of which departments offer us a wide field of inquiry, and inexhaustible subjects of speculation. But it is in the animal world, more especially, that the busy and ever-changing scene is calculated to awaken the most lively curiosity, and inspire the deepest interest. The multiplied relations which connect us with the lower animals, the obvious analogies which subsist between them and our own species, and the striking evidences of power, intelligence, and benevolent design displayed in all the phenomena they present to our observation, confer on the study of animal life a degree of importance which belongs to scarcely any other study.

(4.) But the foundations of all science must be laid by drawing accurate distinctions among the objects which come within its cognizance; by making a strict analysis of the ideas it comprehends, and by establishing precise definitions of the terms it employs. As in all the other departments of human knowledge, we can arrive at general facts, or comprehensive laws, only by submitting to the previous task of ascertaining and collecting individual facts; so in natural history we find it necessary to subdivide our labours into that which takes cognizance of individual objects only, and that which inquires into their more general relations with one another. The first is properly the *history*, the second the *philosophy* of nature; and this distinction we may observe to run through all the branches into which the subject is divisible. It applies even to astronomy, in which the mere physical history of the phenomena forms a preliminary body of knowledge, yet subordinate to that higher range of inquiry which establishes connections between these phenomena, and unites them into comprehensive laws or theories. Mineralogy, again, must be studied as the foundation of geology; the former being the history of the actual appearances; the latter, the theory of the series of changes which have led to these observed phenomena. Thus, also, the external forms, and more obvious habitudes of plants, and their classifications in conformity with these forms and properties, constitute the subjects of *botany*, properly so called; whilst the study of their internal structure and economy, with relation to the more general phenomena of vegetation, is comprised under the head of *phytology*, or the physiology of vegetables.

(5.) In like manner, the proper objects of *Zoology* are to trace the external forms of animals, to distribute and arrange them in systematic order, and to record the particular facts relating to their history; that is, to the more obvious phenomena which they present to our observation. *Physiology* embraces a wider field of research, inquires into the connexions between the phenomena, and investigates the causes from which they spring, and the laws by which they are governed. The zoologist is content with collecting observations on the visible actions of animals, on their peculiar habits, modes of life, and the manifestation of those faculties with which they are respectively endowed by the Author of nature; a pursuit which affords inexhaustible sources of amusement, and furnishes abundant matter of admiration and of wonder. But the physiologist aims at far higher objects; and considering the external phenomena presented by animals as lying merely at the surface, seeks for information relative to the causes of all the facts which are furnished to him by zoology, by examining the interior structure of their bodies, by inquiring into the movements of that interior mechanism, and the sources of those various actions which give rise to all the complicated phenomena of life. An extensive and even boundless region of knowledge opens to his view in these highly curious and interesting subjects of research, constituting one vast science, which, although considerable progress has been made in it by the labours of our predecessors, is yet destined to occupy, for an incalculable period of time, the unremitting efforts of succeeding generations.

(6.) The phenomena of living beings have a totally different character from the changes which take place in inanimate matter; and are with more difficulty subjected to the severe analysis required by inductive philosophy. The properties of inorganic bodies are of a simpler and more definite nature, and however variously they may be combined in their effects, admit, in general, of a reduction to general laws. This is most effectually accomplished by means of experiments, varied in such a manner as to reduce each class of phenomena to its simplest conditions, and afterwards combined in such a way as to allow of a comparison of their results with the appearances presented by nature, and of thus verifying their identity.

But it is hardly possible to pursue the same process of investigation to any extent in the diversified phenomena of organization. So complicated is the mechanism, and so fine the minuter structure of animal and vegetable bodies, that they elude the cognizance of our senses, even when assisted by the utmost refinement of optical and mechanical art. All that chemistry has yet achieved in disclosing to us the properties of different species of matter, and of their various combinations, falls infinitely short of that knowledge which could enable us to follow and to understand the curious and elaborate series of chemical changes which take place in the interior of the living body. Far less are we competent to trace the operation of those more subtle and mysterious principles, which are the springs of motion, and which regulate the actions of the machine, and connect the whole of its movements into one harmonious system. Judging from their more obvious effects, indeed, these principles appear to be quite of a different nature from those which produce the phenomena of the inorganic world. The series of changes which are exhibited by an animal or a vegetable, from the first moment of its separate existence, through all the stages of its growth, maturity, and decline, to the period of its death, are far too complicated and multifarious to admit of being reduced to one single principle, in the same way as the movements of the heavenly bodies, for instance, are reducible to the simple law of gravitation.

(7.) Physiologists, indeed, not deterred by these difficulties, which are inherent in the subject of their researches, have in all ages attempted generalizations of this kind. They have considered all the actions and phenomena which are peculiar to living beings, and which differ from those exhibited by the same bodies after death, as resulting from the operation of a single principle of life. Different designations have been given to this power by different theorists; thus, some have called it the *vital principle*, others the *spirit of animation*, the *archæus*, the *organic force*; and many other appellations have been given to it, according to the particular taste or fancy of the writer. Nothing, indeed, can be more specious than this reference to unknown facts, which have a manifest connexion with one another, to a common principle of action, or in other words, to a vital power. The only idea we can form of life appears to imply the unity of such a principle. This idea, as is well remarked by Cuvier, is suggested by the observation of a certain class of phenomena, succeeding each other in an invariable order, and having certain mutual relations with one another; yet it is but a vague and indistinct idea. We are ignorant of the nature of that link which unites the whole of these phenomena; but the existence of some such link forces itself upon our belief, and we are compelled to give it a particular designation, and speak of it as if it were something more than a mere fiction of the intellect.

(8.) Those who are unaccustomed to philosophical reasonings, may be, indeed, and often are, deceived by the employment of these abstract terms, and regard them as the expressions of a simple law of nature, of the same comprehensive, yet definite character, as those of gravitation, cohesion, heat, and electricity. A more careful and profound analysis, however, will convince us that the power inherent in organization, upon which its infinitely diversified actions depend, is not a simple agency, but a combination of several powers, not only different from the physical agents which actuate the inorganic world, but differing also very widely amongst each other. In order to arrive at this conclusion, however, it will be necessary to take a review of the phenomena themselves, and we shall therefore defer the consideration of this subject to a future chapter.

(9.) Although the peculiar nature of the phenomena which physiology embraces has hitherto baffled all our endeavours to obtain results of the same general and comprehensive nature as those which have rewarded our efforts in the purely physical sciences, yet other resources are open to us, capable of conducting us to a still more ample and inviting field of inquiry. Living nature is impressed with a character, which at once raises it to a higher order among the objects of human intellect, and invests the science which regards it with a more lofty and ennobling sentiment. Life is peculiarly characterised by the manifestation of INTENTION. Adaptation of means to an end is visible throughout the whole of this animated scene. Express design is palpably discernible in every formation, in every arrangement, in every series of changes which this vast theatre of nature displays. Utility is the governing principle of all; intelligence and power far exceeding the utmost stretch of our imagination, are revealed to us in language not to be mistaken, and carrying with it irresistible conviction. Thus, while the sciences of inorganic matter are founded on the relations of cause and effect, physiology takes cognizance more especially of the relations of means to ends, which the phenomena present to our view. Hence we obtain a new principle of arrangement among these phenomena; hence also arises a new source of interest, of a kind very superior to that which mere physical relations can ever inspire.

(10.) The purposes to which, pursuing this new principle of arrangement, we can perceive the different structures which compose an animal body, are subservient, are termed, in the language of physiology, the *functions* of those parts. Life results from the exercise of these functions, and consists in the continued accomplishment of their respective objects. The principal object of physiology, then, is the study of the functions of life; that is, the investigation of the changes occurring in the living system with reference to their respective objects, and in their subservience to the maintenance of life, and the various purposes for which life was bestowed. We shall now proceed to take a general review of these functions, in order to establish a foundation for the divisions of the science we are now treating.

(11.) The most cursory view that we can take of the phenomena of life will be sufficient to shew that the functions to which they are referable are of different degrees of importance with relation to the objects of life. Some are so closely connected with these objects, that their continued exercise is indispensable to the very existence of life, which would cease if they were for a moment interrupted. Others which are less immediately concerned in the actual maintenance of the vital actions, are yet essential to its preservation, and cannot, with safety, be suspended but for a very short interval. Some are only occasionally called into play, and others are so remotely useful, as to admit of lying dormant for a considerable period, or even of being dispensed with altogether. Some functions require for their performance the concurrence of others, and these, again, imply the exercise of many more. Some are of a more isolated nature, and have less connexion with the general system of functions. By studying these relations, we are enabled to trace a certain plan in the designs of nature, and a certain subordination of functions sufficient to guide us in our studies, and to enable us to trace out a tolerably connected order of subjects.

(12.) It will be useful, before proceeding to the details of the subject, to present our readers with a general sketch of the system of the animal economy, which may serve, indeed, the same purpose, as a map does to a traveller, imparting a general notion of the bearings and relations of the several objects of interest in the country he is about to traverse. We shall, for this purpose, embrace in one view that assemblage of functions which constitutes animal life in its most complete and perfect form, and in the attainment of its full developement.

(13.) All the functions of the animal economy, all the mechanical dispositions of the system, and all the movements of its parts, are subordinate to two great objects; first, the preservation and welfare of the individual being which they compose; and, secondly, the continuance of the race to which it belongs. It is evident that the first great purpose to be accomplished is the conferring of the powers of *sensation* and *perception*, these being the essential attributes of animal nature, and the characteristics which distinguish it from the mineral or vegetable world. Next to these is the power of *voluntary motion*, by which the animal is enabled to change its place, to procure for itself those objects which are necessary for its subsistence or gratification, and to repel those which are noxious or painful.

(14.) The power of being affected by external objects, or of receiving impressions of which we are conscious, is connected, in the more perfect animals, with a part of the body having a more peculiar organization, and very remarkable properties. It is a soft and pulpy substance, of a whitish colour, with different shades of gray, opaque, and exhibiting slight traces of a fibrous structure. It is termed *medullary* or *nervous substance*. Of this substance are composed the *brain*, which is a large mass of medullary matter; and also the *nerves*, which have the appearance of white cords, extending from the brain to almost every other part of the body. The nerves establish a communication between these parts and the brain, so that impressions made upon the former, are communicated, along the nerves, and by their intermedium, to the brain, where they excite their appropriate sensations, corresponding to the nature of the impression, and to the structure of the organ that originally received it. By what agency, or in what way affections of the brain, thus induced, are instrumental in producing sensation, or how the sentient principle is connected with the physical constitution of the brain, are subjects of which we have no knowledge; nor have we, in our present state, the smallest ground of hope that the mystery in which it is involved, will ever be dispelled. Sufficient let it be for us that such is the fact; and resting on this as an ultimate fact, let us proceed in our inquiries, as to the occasions on which this power, assuming it to exist, is called into action.

(15.) Experience shews that the impressions conveyed by each nerve, or class of nerves, are of different kinds, for they are capable of being readily distinguished from one another by the percipient being whose brain receives them. Hence he acquires a knowledge of the presence, of the situation, and of the different properties of external bodies, which are the source of those impressions. The nature of that power with which the nerves are endowed is such as to convey the impressions from which this knowledge is derived, from the external organ to the brain, with a velocity that exceeds all imagination. This instantaneous transmission is evidently a provision of the highest importance both for the welfare and preservation of the individual.

(16.) The different powers of perception, corresponding to different qualities of external objects, constitute the *external senses*; and each has its appropriate organ, furnished with its separate system of nerves. The skin, which is the organ of *touch*, receives the largest share of nerves, as it is evidently of the greatest consequence that the surface of the body should receive impressions from every substance with which it may happen to come in contact. The nerves of the skin are also susceptible of various impressions, besides those of mere impulse or resistance from solid bodies.

They are affected, for instance, by variations of temperature; and when acted upon in any way that may be injurious to the part impressed, or to the system generally, they give suitable warning to the individual, by exciting a sense of pain. Hence he is admonished of impending evil, and is incited to the prompt adoption of the means of averting it.

(17.) Next in importance to the sense of touch are those of *sight* and of *hearing;* but for the communication of distinct impressions relating to these senses, a much more refined apparatus is requisite than for that of touch. The structure of the eye is calculated to combine, upon a thin expansion of nervous substance, the *retina,* the rays of light proceeding from distant objects, so as to form a picture of these objects, and thus convey to the mind an exact knowledge of the relative situation of all their parts that are within the sphere of vision. Hence are derived the perceptions of their distance and position with respect to the observer.

(18.) In like manner are the sonorous undulations of the air collected into a kind of focus by the structure of the ear, and impressed upon the sensitive expansions of nervous matter in the inner regions of the organ. Thus an important avenue of communication is opened with the external world, highly useful in an infinite variety of ways.

(19.) The existence and properties of various objects at a distance are also recognized by the sense of *Smell,* which enables us to appreciate the presence of the subtle effluvia which they emit, and which affect the atmosphere often to a considerable distance around. The olfactory nerves are adapted to the impressions of this kind, and are situated on the surface of those passages destined for the transmission of the air in subservience to another function hereafter to be noticed, namely, that of respiration.

(20.) The sense of *Taste* is exercised on the substances employed as aliment, and has its seat at the entrance of the passages appropriated to the reception of food, and which are subservient to another class of functions presently to be described.

(21.) The faculty of Sensation consists merely in the excitation of a simple mental change, known to every one, although incapable, in consequence of this very character of simplicity, of either analysis or definition. With reference to its physiology, we know that it is effected through the intermedium of certain nerves, connected, on the one hand, with the organs on which impressions of various kinds are made by the physical action of external objects, and on the other, with those parts of the brain, of which the physical affections are, by some inscrutable link, connected with the affections of the soul, or sentient principle. These simple and preliminary phenomena, composed of both physical and mental changes, are to be carefully distinguished from those subsequent operations that constitute perception, thought, volition, and the whole series of psychical phenomena, which we are in the habit of referring to a distinct branch of human knowledge, and which is generally denominated *Metaphysics*, *Psychology*, or the *Philosophy of Mind*; in contradistinction to *Physics*, *Somatology*, or the *Philosophy of Matter*.

(22.) There can be little doubt that these operations, which we are naturally accustomed to consider as being purely of a mental character, are, in some unknown degree, connected with physical changes taking place in the cerebral substance; but as we are utterly unconscious of these changes, and as we are totally precluded from arriving at any knowledge of their nature, or even of conceiving the manner in which a connexion between mind and matter has been established, we are compelled, in this branch of the inquiry, to direct our attention exclusively to the mental phenomena, to study their laws by the evidence of our own consciousness, and to resort to processes of analysis and methods of inductive investigation, in many respects different from those which are successfully employed in the more arable fields of physical science.

Whenever we are fortunate enough to trace some portions of the mysterious but broken thread which unites the material changes occurring in our bodily organs, with the operations of the intellect, or the affections of the soul, we may then occasionally re-enter the territory of Physiology; and while the two sciences are thus capable of being studied in conjunction, they will derive mutual advantage and illumination.

(23.) Yet, with regard to the mere physiological study of the animal functions, it cannot escape our observation, that a vast variety of phenomena in the economy have a direct reference to the mental constitution of our nature, and are to be studied, with relation to final causes, in immediate connexion with these objects. Thus, although the special purposes served by the multiplicity, the curious arrangement, and intricate structure of the parts of the brain, are as yet wholly unknown, and as we still are, and shall probably ever remain, in utter darkness as to the mode in which they perform their respective offices as instruments of perception, thought, and volition, yet when we return to the observation of the bodily actions consequent on these mental processes, as well as contributing to their performance, we are enabled to resume our physiological inquiries, and trace the continuity of design in the exercise of the faculties of voluntary motion, by which the mind exerts a power of reacting on matter, employs its properties for beneficial ends, and exercises that partial dominion over nature, which has been granted to it by the Divine Author of its being. The possession of voluntary motion is directed, first, to enlarge the sphere of our perceptions, by directing our organs of sense to their respective objects; secondly, to bring the objects themselves within the reach of those organs by which they are to be examined; thirdly, to alter their forms and combinations, and modify them in various ways, so that the mind may, from these different modes of examination, derive accurate and extensive information of their properties, and apply these properties to use; and lastly, to effect the locomotion of the whole body, and thus extend widely the range of its operations, and spread the dominion of man over every kingdom of nature, and over every region of the globe.

(24.) But the relations of man with the external world comprehend a much larger and more important field, since they are not limited to the sphere of the material world, but embrace the intellectual and moral existences of other percipient and sentient beings. Through the intermedium of signs, the results of movements of our bodily organs acting on the senses, communications are established, not merely between mind and matter, but between mind and mind. Mutual interchanges take place, of thoughts, of opinions, of feelings, and of affections; and the value of existence is, to an incalculable degree, augmented by the operations of sympathy, the impulses of benevolence, and all the potent and benign influences of social union. Hence, physiologically considered, the function of the voice, and its modulation into articulate sounds, ranks as an important part of the animal economy.

(25.) The faculty of *Voluntary Motion*, like that of Sensation, is derived from the peculiar properties of the nervous substance. In the instance of sensation impressions are conveyed by means of the nerves from the external organs of sense to the general centre of the sensitive faculty, the brain. A similar power, we find, is exercised, though in a contrary direction, in transmitting the actions arising from the determinations of Volition, and which produce their first effects on the brain, towards those parts which are capable of executing these determinations. Modern discoveries have shewn, that for this latter purpose sets of nervous fibres are employed different from those instrumental in conveying sensitive impressions from the organs of sense to the brain. Hence a distinction is established between the *Nerves of Sensation*, and the nerves of motion, or the *Motor Nerves*.[1] While the nerves of sensation should properly be considered as commencing at the organs of sense, and terminating in the brain, the nerves subservient to volition have their proper origin in the brain, and proceed thence to the organs of motion. Let us next examine in what these organs of motion consist.

(26.) The principal source of motion, in the animal body, resides in the *Muscles*, which taken altogether, usually compose by far the largest part of the bulk of the animal. Muscles consist of a collection of fleshy fibres, proceeding for the most part in parallel directions, and extending from the two points in the limb, or parts of the body, which are de-

[1] We would suggest the propriety of designating these two classes of nerves respectively, by the terms *Sensiferous* and *Voluntiferous*, as more distinctly expressing their proper functions.

signed to be brought nearer to each other. The fibres of which the muscles are composed are endowed with the remarkable property of contracting, under certain circumstances, with prodigious power, so as to move the parts to which they are attached with sudden and enormous force. The impulse given to them by the nerves of volition, by which they are connected with the brain, in every effort of volition, excites them to contraction, and produces those movements of the body which are the objects of that volition.

(27.) The movements required for the purposes of animal life, are of course infinitely diversified in their kind, and scarcely admit of any distinct classification. Amongst the objects of these movements, however, we may notice two, which are of essential importance; the first is that of *Locomotion*, the second that of *Prehension.*

(28.) Locomotion is one of the faculties more particularly distinctive of animal life in opposition to that of vegetable. Plants are more or less rooted to the soil where they originally sprung: animals, destined to a wider sphere of action, are endowed with the power of transporting their bodies from place to place, on the one hand, of pursuing, and on the other, of flying from pursuit; of choosing their habitations, or of changing regions and climes according to their wants or necessities.

(29.) The power of detaining and laying hold of objects, is another mode in which the faculty of voluntary motion may be highly advantageous to the animal possessing it. With these may be associated the various actions requisite for defence or attack, rendered necessary by the conflicts incident to their condition.

(30.) For the performance of all these actions, there is required in the first place, a solid and unyielding structure, capable of sustaining the weight of the body, and of furnishing to the muscles or agents of motion, fixed points of attachment. The *bones*, the union of which constitutes the *skeleton*, are provided for these objects. They are formed into separate pieces, with a view to their being moveable upon one another. Their extremities are connected together by smooth surfaces, which are bound together by firm bands or *ligaments*, bracing them on the sides where they are exposed to the greatest strain. An apparatus of this kind constitutes a *joint*.

(31.) The due performance of these mechanical objects, implies a variety of subsidiary contrivances and adjustments, too diversified in their nature and objects to admit of particular specification. It is evident that the particular texture of each part must be adapted to the actions it has to perform. Flexibility and compressibility are required in one organ; rigidity and hardness in another. Some parts must readily yield to an extending force, others must resist such a force with extraordinary tenacity. Some must exert elastic power, others must be devoid of this quality. Some textures must be permeable to fluids, others must deny them all transmission. Hence, the variety of structures composing the mechanical frame-work of the system.

(32.) But in all the variations of conformation, it would appear that nature has employed the same ultimate structure as the basis of her work. All the solid parts of the animal fabric are formed of fibres, variously united and interwoven; in some cases only loosely connected, so as to constitute a spongy or cellular mass, flexible in every direction, and forming a medium of connexion between adjacent parts of various degrees of cohesion. This substance, which is found universally to pervade the body, is termed the *cellular sub-*

stance or *texture*. It is eminently endowed with elasticity, and thus contributes essentially to preserve the natural figure of every organ, and to restore it to its proper situation, after any displacement by a foreign cause.

(33.) When condensed into a firmer layer or sheet of animal matter, the same substance assumes the form of *membrane*, and is extensively employed as such, to supply organs with external coverings, or to afford them attachments to surrounding parts for the purpose of protection and support. Membranes are also used as barriers, for intercepting the communication of fluid from one cavity to another; and they are also employed to form receptacles for the retention of fluids, and tubes for conveying them from one part of the system to another.

(34.) The fibrous structures, comprehending *ligaments*, *tendons*, and *fasciæ*, are composed of still a denser approximation of fibres, are endowed with a higher degree of toughness and strength, and are capable of exerting great resistance to any stretching force. Hence, they are extensively employed in the construction of parts where these properties are required.

(35.) The organs specially appropriated to touch, are generally also those of prehension: and progressive motion is accomplished by means of limbs, which act either upon the ground, the waters, or the air, according to the element in which the animal resides. But, in order to give proper effect to these movements, the agency of levers is required; and we accordingly find a provision made for this purpose in the construction of the bones, which, as we have before observed, are capable of supplying the fulcra or fixed centres of motion, and allow of the application of the moving powers. It often happens that the actual attachment of muscles to the points required to be moved, would be attended with inconvenience. In this case, an intermediate structure is employed, analogous to that of a ligament, but here denominated a *tendon*, serving as a strap to connect the muscle to a distant bone, or other part on which the action of the muscle is to be exerted.

(36.) All the functions, which have for their object some mechanical effort of the kind we have now described, may be comprehended under the general head of the *mechanical functions.*

(37.) The consideration of the chemical condition of the animal system, introduces us to a class of functions of a totally different nature from any of the preceding, yet equally essential to the maintenance of life. The solids and fluids of which organized structures are composed, differ materially in their chemical constitution from the products of the mineral kingdom. Their elements are combined by a much more complicated arrangement, and united by less powerful affinities; or rather the balance of affinities, by which they are held together, is more easily destroyed, and thus, proneness to decomposition is constantly present. One of the most remarkable and important of the operations of the vital functions, is to repress this tendency to decomposition; for no sooner is life extinct, than we find both the solids and fluids of the body hastening to assume new forms and combinations of their elements; and nothing can now prevent the final disorganisation of that fabric which so lately delighted the eye with its beauty, and in which dwelt the genial warmth of life, and the elastic vigour of youth. If we watch the progress of those changes which take place in the body, we shall find it characterised by a perpetual renovation of materials, continual losses of substance on the one part, being compensated by an equally constant supply on the other. From an atom of imperceptible minuteness we trace its gradual increase of size, by the reception of nutritious matter from without, by the incorporation of this matter with that which had before existed, by the consolidation of the fluid, by the extension of the solid parts. We see all the organs expanding by a slow, but uniform increase, and in regular proportion, till they arrive at a certain limit. Having attained this limit, the body remains stationary for a certain period; that is, the waste of substance is exactly compensated by the supplies furnished by the food received into the body. At length, however, the compensation is less perfectly maintained; the powers which carry on the functions begin to decline, the solids dry up and harden, and a general torpor gradually pervades the system. Life is sooner or later brought to a close by the natural progress of these changes, even if its course be not sooner arrested by causes of an accidental nature.

(38.) The functions of nutrition embrace a class of operations, destined to supply the materials wanted for the growth of the body, and for the supply of those materials which either may have been expended in the natural exercise of the other functions, or lost in various ways, or else employed in the reparation of injuries, which the organs may have accidentally sustained. The nutritive, or as they may also be termed the *chemical functions*, since they relate to the chemical condition of the body, comprehend a long series of processes, which, in order to study them successfully, require many successive subdivisions.

The first division includes all those functions which contribute to the reduction of the food to a substance of similar chemical composition with the materials of which the body already consists; processes which are comprehended under the general term of *Assimilation.*

The second and third divisions relate to the collection of the nutriment thus prepared, or assimilated, into a general reservoir; and its subsequent distribution throughout the body, so as to admit of being applied to use whenever it may be wanted. These objects are attained by the functions of *Absorption* and of *Circulation.*

A fourth division refers to the purification of the general mass of nutritious fluid existing in the great reservoir of the body, by the separation of its superfluous combustible portion, and more especially of its carbon; a change which is effected by the function of *Respiration.*

The last division of this class of functions comprehends the several processes by which certain materials are separated from the blood in a solid or fluid form; some with a view to their final expulsion from the system, some to answer purposes connected with other functions, and the remaining part being expended in repairing the waste which the solids of the body undergo in the exercise of their respective offices. To the former of these functions the term of *Secretion* is applied; whilst the last is more especially regarded as the proper and final process of *Nutrition.* We shall examine each of these divisions more particularly.

(39.) Assimilation is effected by a long series of processes, which are partly of a mechanical and partly of a chemical nature. The food taken into the mouth is first masticated by the action of the teeth and jaws, so as to break down the cohesion of its parts, and prepare it for the chemical action of the fluids to which it is afterwards to be subjected. There is at the same time added to it a quantity of liquid, termed the *saliva*, prepared by a set of glands, to be hereafter specified, and poured out into the mouth in large quantities during the act of mastication. By these means the food is softened in its texture, and reduced to the form of a pulp, in which state it is swallowed, by the organs of deglutition, and conveyed through a tube called the *œsophagus* into the *stomach.* The stomach is a capacious bag, or receptacle, capable of holding a considerable quantity of food, and of retaining it for a certain period. The inner membrane which lines the cavity of the stomach prepares a fluid termed the *gastric juice*, which acts chemically upon the food in that cavity, while this food is at the same time subjected to a degree of pressure from the action of a set of muscular fibres which are interposed between the interior and exterior coats of the stomach. The food is also slowly moved by the successive contractions of these muscles, so that every part of it comes in its turn to be acted upon by the gastric juice, until the whole is converted into a soft and smooth mass of uniform consistence which is termed *chyme;* the operation itself by which this conversion is effected being termed *digestion.*

(40.) The aliment thus digested, or reduced to the state of chyme, passes onwards from an orifice at the farther end of the stomach into a tube of great length, several portions of which have received different names, but which are comprised under the general term of the *intestines.* In the first portion, the *duodenum*, the aliment undergoes still further changes; it is mixed with two fluids, the one called the *bile*, which is prepared by a large glandular organ, termed the *liver;* and the other called the *pancreatic juice*, prepared by another gland, the *pancreas.* Secretions also take place from the inner membrane of the intestines themselves, and the result of the united action of all these fluids, aided by the movements imparted to the aliment by the contractions of the muscular fibres contained in the coats of the intestines, is gradually to convert part of what was chyme into a new substance called *chyle*, which is the most nutritious portion of the aliment, and has the appearance of a milky fluid. The chyle is received into a set of very minute tubes called *lacteals*, which are exceedingly numerous, and arise by open mouths from the inner surface of the duodenum and its prolongations, the *jejunum* and *ileum*. They collect the chyle together, and pour it into an intermediate receptacle, whence it is conveyed along a large tube, called the *thoracic duct*, into other cavities, of which we shall presently speak. That portion of the chyme which is not converted into chyle, descends into the lower portions of the intestinal canal, is collected in the larger intestines, of which the *colon* is the principal one, and finally ejected from the body.

(41.) The next step in the assimilatory process is the conversion of the chyle into blood, a change which has been termed *sanguification*. It is in the great system of vessels which contain the blood already formed, and in the course of the passages through which the blood is moved, that this gradual change is effected. The great reservoir of this important fluid, on which the nutrition of every part of the body, and its maintenance in a state of action, immediately depend, is the *heart*. The thoracic duct opens into one of the veins or tubes leading directly to the heart; the chyle is therefore immediately conducted into this reservoir, and thoroughly mixed with the general mass of food.

(42.) The heart is a powerful muscular organ; from its cavity arise the trunks of large tubes, called *arteries*, which subdivide and ramify as they proceed in their course to every part of the body, being distributed in abundance to every organ, with a very few exceptions. No sooner are the cavities of the heart distended with blood, than the muscular structure which surrounds their cavities contract with enormous force, and propel their fluid contents through the system of arteries, sending it in one great wave, even to the extremities of its minutest ramifications. From these extremities of the arteries it passes into corresponding branches of another set of vessels, the *veins*, which proceed in the opposite direction, towards the heart, uniting in their course into larger and larger trunks, till they reach the heart, to which they deliver back the portion of blood that has thus percolated through every part of the body. No sooner has it again filled the cavities of the heart, than it is again sent with renewed force into the same arterial channels, and again brought back by the veins. The functions by which this circular course is given to the blood, is termed *the circulation*.

(43.) The blood, in the course of its circulation, furnishes to all the organs the materials which are necessary for their growth, for the renovation of their powers, and for the supply of those fluids and other animal products which are wanted in various parts of the economy. The separation of these fluids, and the formation of these peculiar animal products, are the objects of another function, that of *secretion*. Particular organs are in most cases provided for the purpose of effecting these processes. These are the glands, which are variously constructed according to the particular offices they have to perform; each is furnished with an elaborate apparatus of vessels; and the fluid which is formed by them, is generally conducted to the place of its destination by a pipe, or *excretory duct*, as it is termed.

(44.) The fluids which are thus separated from the blood are, for the most part, applied to useful purposes in different parts of the economy; some for the repair of that loss of substance in the part of the body incident to the exercise of their respective functions, others for different subsidiary purposes related to those functions. The substance of the bones, for example, undergoes a gradual change during the whole of life; each particle is removed in succession and is replaced by others, so that in the course of time the whole substance of the body undergoes renovation. Two important functions are called into action for the completion of these processes; the first of these is concerned in the removal of the old and decayed materials; the second, in the due application of those which are to replace them.

(45.) The removal of those particles which have become useless, and whose presence might be injurious, is effected by a distinct set of vessels, called *lymphatics*. The lymphatics are met with in almost every part of the body; and resemble, both in structure and mode of distribution, the lacteal vessels already described. The mode of their origin is not well ascertained, but, like the lacteals, the smaller branches successively unite into trunks, which terminate either in the thoracic duct, or into the larger veins leading directly to the heart. Through these channels, then, it is that all the particles which require removal are conveyed away, and deposited into the general mass of circulating fluids. The function thus performed by the lymphatics in common with the lacteals, is termed *absorption*.

(46.) The function having for its object the reparation of the substance of the different organs, is designated by the general name of *Nutrition*. It includes the developement and growth of the parts, and their maintenance in the healthy state, that is the state in which they are fitted for the exercise of their several functions; as well as the restoration of what they may have lost from accidental causes, such as mechanical injuries.

When a bone is broken, for instance, a solid union is by degrees effected by the deposit of new ossific materials, consisting chiefly of phosphat of lime, which is secreted or separated from the blood by the irritated vessels in the neighbourhood of the injury. In all these cases the absorbents are also at work in modelling the shape of the part to be restored, in removing all roughnesses or angular projections, and making room for the new formations which are to take place. The functions of absorption and nutrition are thus, in some respects, opposed to each other, producing contrary effects, though both co-operating in the accomplishment of one final purpose, and balanced and adjusted to one another with that manifest intention. The general bulk of the body, and of its parts, varies according to the predominance of the one or the other of these actions of absorption and nutrition; wasting when the former is in excess; thriving and enlarging when the latter prevails.

(47.) There is one peculiar mode in which superabundant nutrition manifests itself. When the supply of nutriment is greater than what the wants of the system require, the superfluous portion is converted into an oily fluid, which is laid up in store for future use. This fluid is the *fat;* and it is accumulated in various parts of the body, and especially between the skin and the muscles, and in other places, where it may also serve a subsidiary purpose of mechanical protection against inequalities of pressure. The fat is thus useful as a soft cushion on which delicate organs, such as the eye, may move in security; and also as a convenient material for filling up hollows in various unoccupied situations. The chief use, however, of large accumulations of fat, is to serve as a magazine of nutriment, out of which the body may be supported in those seasons when the supply of food is deficient, and more particularly during those periods which are, by some animals, passed in a state of complete inactivity. This is the case in those animals which are said to *hybernate*, or continue during the whole of winter in a perfectly torpid state.

(48.) Whilst some of the products of secretion are thus employed in nutrition, others are subservient to the functions of particular organs. Thus, the tears are useful in washing away from the surface of the eye, dust, and other materials which might obstruct vision; the gastric juice is subservient to digestion; and the mucilaginous secretion of the wind-pipe and nostrils defend those passages from the acrimony of the air. But, in other cases, these secreted matters have noxious qualities; and it is the object of their separation from the blood, to get rid of them altogether. This is the case with the secretions from the kidneys, and from the skin, and perhaps, also, partly with that from the liver. These are termed the *excretions*, in contradistinction to the proper *secretions*, and the organs which separate them are termed the *emunctories*.

(49.) The organs which, in this sense of the term, must be considered as the principal emunctory of the body are the *lungs*. It would appear that the blood, from which the animal solids and fluids derive their nourishment, contains a larger proportion of carbon than what is required for the formation and reparation of these solids and fluids; the elements abstracted from the blood by the processes of secretion and nutrition, being principally oxygen, hydrogen, and nitrogen.

The continuance of these processes must tend therefore, to produce an accumulation of carbon in the blood; and accordingly we find that this fluid, in the course of its circulation, gradually acquires a darker colour. From being of a vivid scarlet hue in the trunks of the arteries, it has changed to a dark purple by the time it has reached the veins. It is returned to the heart, therefore, in a state unfit for the purposes of nutrition, and not proper to be again circulated through the vessels of the body. In order to restore it to its original state, it is necessary to deprive it of the ingredient it contains in excess, that is, of carbon, which, when thus present in the blood, is found to exert a positively deleterious power on the parts to which it is applied.

For this purpose the blood is transmitted by an appropriate system of arteries, to the lungs, where it is exposed to the influence of atmospheric air, alternately received into, and expelled from that organ. By a process which appears to be analogous to slow combustion, the superfluous carbon of the blood combines with the oxygen of the atmospheric air, and is expelled, in the form of carbonic acid gas, along with the air expired. The blood thus purified, and restored to its salutary qualities, is conducted back again, by a corresponding set of veins, to the heart, and is again sent, by the contractions of that organ, into the arteries of the body, and performs the same round of circulation as before. *Respiration*, which is the title of the function we have now been describing, completes this class, which we have termed the chemical functions of the economy.

(50.) The three classes of functions we have been reviewing, namely, the *mechanical*, the *chemical*, and the *sensitive*, relate only to the preservation and welfare of the individual alone. But as nature has assigned a limit to the *duration of life, it became necessary that a provision should be made for the multiplication of individuals, and the conservation of the race.* Such, then, is the object of a fourth class of functions, namely the *reproductive functions*, including the processes of *fecundation*, of *evolution*, of *gestation*, and of *parturition*, and the auxiliary function of *lactation*, provided for the supply of the new-born infant with nourishment adapted to the tender condition of its organs of assimilation.

(51.) Having studied the phenomena and the circumstances which lay the foundations of individual existence, the physiologist has next to occupy himself with the consideration of the long series of changes which intervene between the cradle and the grave, and constitute the "strange eventful history" of the physical life of man. He follows the rise and developement of the several organs, and the occasions on which their functions are called forth: he notices their entry on the stage of life, in which they are destined to play more or less important parts; he watches their progress, maturity, and decay, till they finally disappear from the scene, when their functions having successively declined, and passed away, the vital spark becomes extinguished, and the curtain drops on the fleeting drama of our probationary existence. A multitude of interesting subjects press on his attention in this division of his subject, so replete with wonder, and so calculated to impress us with exalted ideas of divine prescience, and of the unbounded resources of creative power.

To this department of physiology properly belong, first, the history of the changes which take place in the organs, during their natural course of developement, in what has been styled their *normal condition*, such as the formation of the vital organs, the process of ossification, the general *growth of the body, the changes occurring at the period of* puberty, the slow but sure progress of consolidation attending the decline of life, and the successive decay and obliteration of the faculties which precede death ; and, secondly, the study of phenomena exhibiting the operation of those powers of repair and renovation, which exist in the constitution, and which are called forth only on certain occasions, when the organization has been injured or destroyed, or when the functions have been deranged or suspended, by various accidental causes.

(52.) These topics introduce to our notice the varieties which are observable in different classes of individuals in the general mode in which the functions are performed with reference to their balance, or relative preponderance : conditions which constitute the different *temperaments*, as they are called, and which are severally characterised by peculiar external indications.

(53.) Physiology, lastly, comprehends within the scope of its inquiries, those more strongly marked diversities that are met with in the inhabitants of different regions of the globe, and which appear to form separate races of mankind. These constitutional peculiarities, as shown by differences both in external conformation, and in the internal endowments of an intellectual and moral nature, are of so distinct and permanent a character, as to have suggested the hypothesis of their indicating, in a zoological sense, not merely varieties of a single species, but several different species of the genus *Man*.

(54.) The present treatise is intended to exhibit a condensed view of the actual state of our knowledge on all the subjects comprised in the above outline, and to conclude with a review of the progressive history of the science from the earliest periods to the present time.

(55.) It is hardly necessary to remark, that the province of *Physiology*, is restricted to the consideration of the phenomena of the living body in its perfectly *normal* or healthy state: while those which are presented when these limits of healthy action are passed, and the *abnormal*, or diseased state commences, are the subjects of another branch of science, denominated *Pathology*, no less interesting and important than the former, as furnishing the principles by which the art of medicine derives all its powers; but which, it must be obvious, must have its foundations laid in an extensive and correct knowledge of *physiology*.

(56.) It is evident that the foundations of all physiological knowledge must be laid in a thorough acquaintance with the structure or internal mechanism of animals. The study of anatomy, indeed, derives its chief interest from its connexion with physiology; for unless viewed with reference to their uses, or subserviency to particular purposes, the examination of the forms and properties of the parts of a machine would be a barren and an irksome task. Let us imagine, for example, a person, who had never seen a ship, and had no idea of the object for which it is intended, to visit it for the first time, and to be at liberty to examine at his leisure every part of its rigging and internal construction. A restless curiosity might indeed lead him to handle the ropes and blocks, and climb upon every mast; to descend between the decks, and minutely inspect every part of its fabric; to explore, in a word, the whole anatomy of this most stupendous product of human ingenuity. But his labour would avail him nothing. The most complete survey would afford him no instruction, or leave any distinct impression as long as he had no principle to connect them in his mind. But let him review the same objects with an experienced guide, instructing him, as he proceeds, with the general purposes of the whole machine, and the particular uses of every part, as well as the mode in which they operate and concur in the production of the intended effect. Then it is that he will feel a real interest in the examination: then it is that he will attach due importance to each part of the inquiry. Perceiving the relations which connect the objects, and understanding the functions of the several instruments he sees, he is no longer perplexed and bewildered; individual facts arrange themselves in a natural order, and the whole forms in his mind one connected system of knowledge, readily retained and easily communicated.

The case is perfectly similar with regard to the body of an animal, of which anatomy lays open to us the structure. Dissection can only shew us that it consists of various parts, some hard, some soft, and others fluid. The harder parts, such as the bones, are of various forms, perforated by numerous apertures, and joined together in different ways. The soft parts are found to be composed of various kinds of textures, of which the elements appear to be collections of fibres or plates, curiously disposed and interwoven, so as to constitute a cellular or spongy tissue, and, occasionally, more extended layers of membrane. In every part we find innumerable tubes and passages, branching out and again uniting, in an infinite variety of ways. We arrive at cavities of different forms and extent, enclosing organs of various descriptions, or containing fluids which pass through appropriate channels of communication to very distant parts; composing altogether a vast and complicated system of mechanical and hydraulic apparatus. Thus whilst we confine our attention to the mere anatomy, all is perplexity and confusion; we are overwhelmed by the multiplicity of objects, and lost in the immense mass of unconnected detail. But no sooner do we study the parts of the animal frame with reference to their uses, and their subserviency to the several functions of the living body, than the whole appears under a new aspect. Aided by the light of physiology, we trace order and connexion in every part, and gather increasing delight and instruction as we proceed. The requisite adaptation of the organs to their respective offices, and the correspondence established between these offices, by which they concur in the same ultimate object, must ever excite our most profound admiration, and exalt our ideas of that infinite intelligence which planned, and that transcendent power and beneficence which executed the vast and magnificent system of creation.

CHAPTER II.

APPLICATIONS OF PHYSIOLOGY.

(57.) Physiology claims our attention, not merely as an ornamental branch of speculative knowledge, but as a science of immediate and vast practical utility. Numerous are the occasions on which a scientific knowledge of the structure of our own bodies, and of the operations that are carried on within us, is highly valuable to its possessor; and more especially if combined with the more enlarged views derived from the study of comparative physiology. It may be useful here to point out some of the most important applications of physiological knowledge.

(58.) It is scarcely necessary to dwell on the utility of a knowledge of anatomy, enlightened by physiology, in its application to the art of medicine; for the very foundations of that art must be laid by these sciences. It is, however, proper to advert to the limited advantage which would accrue from such application if those sciences were confined to the human structure and the human functions, instead of comprehending within its range the whole of the animal creation. All the important discoveries of modern times with regard to the economy of the human body have been derived from observations made on the lower animals. That of the circulation of the blood, for instance, which has immortalised the name of Harvey, was obtained principally from this source. John Hunter, one of the greatest benefactors to the healing art in modern times, was so deeply impressed with the necessity of an extended study of comparative physiology, that he devoted his whole life to its cultivation, with an ardour and a perseverance that have been rarely equalled, and never surpassed; as is attested by the unrivalled museum of preparations in every department of comparative anatomy, which he formed by his own unaided exertions, and which will ever remain an imperishable monument to his fame.

(59.) The various combinations of faculties, which are met with in the different tribes of animals, exhibit in a most striking manner the mutual dependence and relations of the animal and vital functions. As if with the express intention of assisting us in our physiological researches on the attributes of that vitality which eludes our experimental investigations, nature offers to our view, in the diversified structures of each successive order of animals, a series, as it were, of varied experiments; and exhibits the several organs under every degree of simplicity and complication of structures, and every possible mode of combination. The application of all this knowledge comes home to our own bosoms; for the human race is then viewed as composing a member of the great family of nature; and we ourselves, as well as all the individuals of that race, are placed under the governance of those general laws which regulate all animated beings. Our deepest interests, our future comforts and enjoyments, our powers of action, our intellectual existence, our capacities of feeling and of reasoning, all that renders life desirable, nay, that very life itself, are wholly dependent on the operation of those laws, and on the minutest results produced by their varied combinations. In a word, we ourselves are animals, and nothing that relates ever so remotely to animal life can be to us a matter of indifference.

(60.) Although the researches into comparative physiology necessarily imply a knowledge of the forms and history of the different races of animals, it tends to reflect, in its turn, the most important light on the science of zoology; and more especially on that department which relates to the classification of animals. All scientific knowledge must be founded on correct classification; but in zoology a methodical arrangement is indispensable; for scarcely any progress could be made without it. The number of animals in the habitable globe is immense, while our faculties and means of observation are extremely limited. Of insects alone, the number of distinct species which have been already determined considerably exceeds one hundred thousand. Of the other classes of animals, though less numerous, the catalogue of known species is at least half as great. Each of these races of beings has its distinct and characteristic form, its peculiar organization, habits, and faculties. It is obvious that if, at the outset of our inquiries, we were to attempt describing, or even of taking an inventory of all the living objects that presented themselves to our notice without regard to any principle of order, our attention would soon be distracted, and our memory overwhelmed by the confused accumulation of details; and it would not be possible to deduce from them any useful result. Classification affords the only clue which can extricate us from this intellectual labyrinth, which can resolve this state of chaos, and reduce this crude and indigested mass of materials into the form of regular science. It is only by a methodical arrangement of objects that we can arrive at the perception of the more extended relations which subsist among them, or establish general propositions, embracing a multitude of subordinate facts, and capable of an indefinite number of useful applications.

(61.) In framing a system of classification of the animal kingdom, there are two objects which we may have in view; first, that of being able readily to ascertain the name of any animal which may present itself to our notice, and of recognising its identity with a species already known and described; or, secondly, that of becoming acquainted with the general nature and character of the animal in question; with the affinities which it has with others of the same class, and with the rank which it holds in the scale of animation. The first of these objects is attained by what are called *artificial methods* of classification; the second by what are called *natural methods*. Much error and confusion have prevailed in the reasonings of naturalists from their neglecting to discriminate the respective objects of these two kinds of methods, which nevertheless are perfectly distinct from each other.

(62.) In endeavouring to accomplish the first of these objects, we take, as it were, an inventory of nature, we record all her productions, and follow her in all her variations; we collect the fullest and most faithful description of every known species, and assign to each a particular name.

The end we have in view being simply to devise a ready method of identifying animals, we follow a process of this kind. We first unite those species which are most nearly allied to each other into one genus. We observe, for example, several species which have much resemblance to the stag; such as the rein-deer, the elk, the roebuck, the fallow-deer, the axis, the muntjac, and several others: we assemble all these into one genus, which we call the *deer* kind. By a similar process we form another genus of animals resembling the bull; such as the buffalo, &c. The genus *antelope* will, in like manner, comprehend the gazelle, the chamois, the nylghau, the oryx, the saiga, the gnu, and a multitude of others. In the same way, the *camel-leopard*, the *goat*, *sheep*, *camel*, and *musk*, may be regarded as so many generic terms, each including a number of different animals, distinct in race, but similar in appearance. Having thus constituted the genera, we may apply to them the same principle of generalization that we did to the species; uniting them, according to their similitudes, into more comprehensive assemblages. Thus the genera above mentioned, having many features of resemblance, are considered as composing a tribe or order, to which Linnæus has given the name of *pecora*.

(63.) We may continue this process till we have gone through the whole animal kingdom; but it will then be necessary to adopt in some respects a contrary method; and instead of ascending as we have done from particulars to generals, to descend from generals to particulars. Regarding the animal kingdom as one entire subject, we must partition it into provinces, and again subdivide these into smaller portions. All these divisions and subdivisions must be founded upon distinct variations of external organs, and must be characterised by concise definitions, enumerating the leading circumstances common to all the animals they comprehend, and by which they may be contrasted with those included in the collateral divisions. The great primary divisions of the animal kingdom are the *classes*; the subdivisions of these form the *orders*; these comprehend the *genera*, which again include the separate races or *species*;

while the ultimate ramifications of the system, expressive merely of diversities arising in the same race, constitute what are called *varieties*. By thus confining our attention to a small number of essential characters, we are enabled to ascertain, by a sort of analytical process, the name of any animal that we may wish to examine or identify. We have converted our rude inventory into a convenient dictionary of nature, where every object may be found at its appropriate place. The characters of the classes resemble in their office the initial letter of a word; the characters of the subsequent divisions that of the succeeding letters, conducting us with certainty and precision to the place we seek. The full developement of this method, and of the logic which should regulate it, and its successful application to natural history, we owe to the genius and industry of Linnæus, to whom the science will ever have to record a lasting obligation.

(64.) But however perfectly we may have accomplished the purpose we had in view in these artificial arrangements, it is impossible not to perceive that we have obtained them by the sacrifice of that order which nature herself points out. A strict adherence to any arbitrarily assumed principle of classification, is, in truth, incompatible with the preservation of the natural affinities of animals. Thus, in the system of Linnæus, the order *primates*, among the mammalia, presents the incongruous association of man with monkeys, lemurs, and bats. In the order *belluæ*, the horse is placed by the side of the hog. The *feræ* offer us the unnatural association of the seal, the dog, the bear, the opossum, the hedgehog, and the mole, merely because these animals, in most respects totally dissimilar, happen to agree in having the incisor teeth of a conical shape. The continual violation of natural analogies, which is yet necessarily incident to all artificial systems, has exposed them to much censure and ridicule, from those who forget that the purpose for which they are framed, is that of convenient reference, and that it is essential to arrangements adapted to that end, that they should be arbitrary. As well might it be made the subject of complaint, that, in a dictionary, words having very different meanings, are found placed in juxtaposition.

(65.) Cuvier has justly remarked that a perfect natural method should be the expression of the science itself, that is, of its most general propositions. By assembling animals in groups, according to their general resemblances in the more important circumstances of their organization and functions, we are enabled to connect them under one description, and afterwards apply to each individual species all the particulars comprised in this description, and thus we obtain more or less comprehensive statements, or, as it were, zoological laws, enabling us both to acquire and to retain the facts with greater facility, and to apply them with readiness in every case; in a word, it gives us the entire command of that knowledge, by imparting to it the form of science. The tribe of *pecora*, formerly mentioned, may be taken as an excellent example of a natural family of animals; for they consist of species which bear a striking resemblance with one another in form, organization, and manners. If we meet with a new animal having one or two of the leading characters of this tribe, we deduce at once all the most important features of its history. We know, for instance, from its possessing a double hoof, that it belongs to this tribe, and consequently that it feeds on herbage, that it has four stomachs, and that it ruminates its food; that it belongs to a species disposed to assemble in flocks or herds, and that it has a disposition to be domesticated. We may pronounce that its upper jaw has no incisor teeth, and so forth.

(66.) It is evident that from the discovery of these analogies, on which the arrangement into natural families is founded, we must resort to the aid of comparative physiology. It is this science alone that can teach us to discriminate the circumstances which are of real importance in the animal economy, and on which their very nature and character depend. The immense progress which has been made in this branch of knowledge since the time of Linnæus, has enabled us to determine with much greater precision the relative affinities of animals, and the rank which each tribe is entitled to hold in the natural system of classification.

(67.) Attempts have often been made to combine these two methods into one, by a sort of mutual compromise between them, that is, by an arrangement partly natural and partly artificial, to obtain the principal advantages of both. The most perfect specimen of this union of the two methods is that of Duméril, which he has published under the title of *Zoologie Analytique*. The characters on which his divisions are founded are distributed in a strictly analytical order, and they conduct us to classes much more natural than those of Linnæus. Thus he divides the Linnæan class of insects into two, namely, *crustacea*, and *insects* properly so called. The very miscellaneous class of *vermes*, in which animals very dissimilar in their nature had been thrown together as it were in a lumber closet, compose in this system the more natural assemblages of *mollusca*, *vermes*, and *zoophytes*. Duméril has pursued this plan throughout the whole of the animal kingdom, reducing all the characters which lead to the determination of classes, orders, families, and genera, to the form of synoptic tables.

(68.) The arrangement which makes the nearest approach to a natural distribution is that adopted by Cuvier, in his celebrated work, entitled *Le Régne Animal Distribué d'après son Organization;* as it is founded chiefly on the structure of the organs most essential to life, and having most influence in determining the intelligence, sensibilities, activity, habits, and manners of animals. Physiology is, in fact, the basis of Cuvier's classification, for it proceeds on the following principles.

(69.) The powers of sensation and of voluntary motion being the chief attributes of animal life, it follows that the organs of primary importance in the economy are those which are immediately subservient to the performance of these functions. They are, as we have seen, the organs composing the nervous system; and the general form and distribution of the nervous system, therefore, should lay the foundation of the primary divisions of the animal kingdom. There appear to be four general types or models of structure of these organs presented in the animal creation. The first consists of a brain, or large mass of nervous substance, from which a cylindrical process, called the *spinal marrow*, is continued; and these are protected respectively by the bones of the skull, and by a series of bones, called *vertebræ,* which form a jointed column along the whole length of the back. Animals formed on this construction are called *vertebrated animals*, a division which comprehends all the higher classes of the animal kingdom, namely, *mammalia*, *birds*, *reptiles*, and *fishes*.

In the second form of the nervous system, there is properly but one central mass of nervous substance, or brain, without any spinal marrow, and from this mass filaments of nerves proceed, in various directions, to be distributed to all the other parts. This division comprehends all the *mollusca*, including both the mollusca and testacea of Linnæus.

The third form is that of a longitudinal series of masses connected together by lateral filaments, and sending out, as from so many centres, ramifications of nerves. This structure is the distinctive mark of *articulated animals*, and may be recognised in insects, and worms properly so called.

The fourth and last division of Cuvier, he denominates *radiated animals*, in which, wherever nerves are found, they appear as a number of equal masses disposed in a circle, and sending out fibres, which diverge like rays from a common centre. Hence the whole body of the animal, or at least some of its principal organs, has a radiated or star-like form. This is the case with the *asterias*, *medusæ*, *polypi*, and all the other animals comprehended under the name of zoophytes.

As frequent reference will be made, in this treatise, to the zoological classification of Cuvier, we shall here give a table of the principal divisions which it comprises, together with examples of animals included in each order.

I. VERTEBRATA.

1. MAMMALIA.

1. Bimana..............*Man.*
2. Quadrumana.......*Monkey, ape, lemur.*
3. Cheiroptera........*Bat, colugo.*
4. Insectivora.........*Hedgehog, shrew, mole.*
5. Plantigrada.........*Bear, badger, glutton.*
6. Digitigrada.........*Dog, lion, cat, martin, weasel, otter.*
7. Amphibia...........*Seal, walrus.*

8. Marsupialia......... *Opossum, kanguroo, wombat.*
9. Rodentia............ *Beaver, rat, squirrel, porcupine, hare.*
10. Edentata............ *Sloth, armadillo, anteater, pangolin, ornithorhynchus.*
11. Pachydermata...... *Elephant, hog, rhinoceros, tapir, horse.*
12. Ruminantia......... *Camel, musk, deer, giraffe, antelope, goat, sheep, ox.*
13. Cetacea.............. *Dolphin, whale.*

2. AVES.

1. Accipitres.......... *Vulture, eagle, owl.*
2. Passores... .... *Thrush, swallow, lark, crow, sparrow, wren.*
3. Scansores........... *Woodpecker, cuckoo, toucan, parrot.*
4. Gallinæ .... *Peacock, pheasant, grouse, pigeon.*
5. Grallæ................ *Plover, stark, snipe, ibis, flamingo.*
6. Palmipedes......... *Auk, grebe, gull, pelican, swan, duck.*

3. REPTILIA.

1. Chelonia............ *Tortoise, turtle, emys.*
2. Sauria............... *Crocodile, lizard, gecko, chameleon.*
3. Ophidia............. *Serpents, boa, viper.*
4. Batrachia........... *Frog, salamander, newt, proteus, siren.*

4. PISCES.

1. Acanthopterygii... *Perch, mackerel, sword-fish, mullet.*
2. Malacopterygii..... *Salmon, herring, pike, carp, silurus, cod, sole, remora, eel.*
3. Lophobranchii...... *Pipe-fish, pegasus.*
4. Plectognathi........ *Sun fish, trunk-fish.*
5. Chondropterygii... *Lamprey, shark, ray, sturgeon.*

II. MOLLUSCA.

1. Cephalopoda........ *Cuttle-fish, calamary, nautilus.*
2. Pteropoda........... *Clio, hyalæa.*
3. Gasteropoda........ *Slug, snail, limpet, whelk.*
4. Acephala............ *Oyster, muscle, ascidia.*

5. Brachiopoda........*Lingula, terebratula.*
6. Cirrhopoda.........*Barnacle.*

III. ARTICULATA.

1. ANNELIDA.

1. Tubicola............*Serpula, sabella, amphitrite.*
2. Dorsibranchia......*Nereis, aphodrite, lob-worm.*
3. Abranchia..........*Earth-worm, leech, nais, hair-worm.*

2. CRUSTACEA.

1. Malacostraca.......
   Decapoda ....*Crab, lobster, prawn.*
   Stomapoda ....*Squill, phyllosoma.*
   Amphipoda ....*Gammarus, sand-hopper.*
   Læmodipoda........*Cyamus.*
   Isopoda.............*Wood louse.*
2. Entomostraca......*Monoculus.*

3. ARACHNIDA.

1. Pulmonalia.........*Spider, tarantula, scorpion.*
2. Trachealia..........*Phalangium, mite.*

4. INSECTA.

1. Aptera..............*Centipede, podura.*
2. Coleoptera ....*Beetle, glow worm.*
3. Orthoptera.........*Grasshopper, locust.*
4. Hemiptera ....*Fire-fly, aphis.*
5. Neuroptera.........*Dragon-fly, ephemera.*
6. Hymenoptera......*Bee, wasp, ant.*
7. Lepidoptera.........*Butterfly, moth.*
8. Rhipiptera..........*Xenos, stylops.*
9. Diptera.............*Gnat, house-fly.*

IV. ZOOPHYTA.

1. Echinodermata.....*Star-fish, urchin.*

2. Entozoa............*Fluke, hydatid, tape-worm.*
3. Acalephæ.....,......*Actinia, medusa.*
4. Polypi...............*Hydra, coral, madrepore, pennatula.*
5. Infusoria...........*Brachionus, vibrio, proteus, monas.*

It has long been a favourite notion with speculative naturalists, that organized beings might be arranged in a continued series, every part of which, like the links of a chain, should be connected with that which preceded and that which followed it. Linnæus was even impressed with the idea that nature, in the formation of animals, had never passed abruptly from one kind of structure to another. But the idea of a chain, or continuous gradation of being, was cherished with enthusiastic ardour by Bonnet, who, assuming man as the standard of excellence, attempted to trace a regular series, descending from him to the unorganized materials of the mineral world. Many other writers have adopted this speculation; but none have carried it to a more extravagant length than Lamarck, who blends it with the wildest and most absurd hypothesis that was ever devised, to account for the diversities of animal structures. He conceives that there was originally no distinction of species, but that each has, in the course of ages, been derived from some other less perfect than itself, by a *spontaneous* improvement in the race. He believes that the animalcula of infusions gave birth, by successive transformations, to all other animals; aquatic animals acquiring feet and legs, fitting them for walking on the ground, and, after a time, being converted into wings, merely from the long continued operation of a desire to walk or to fly.

(70.) In support of the theory of continuous gradation many anomalous animals are produced as instances of links of connexion between different classes of animals. The bat has been regarded as one of these intermediate links between mammalia and birds. The cetaceous tribe, including the *whale*, *cachalot*, *dolphin*, and *narwhal*, though properly belonging to the class mammalia, make an apparently near approach to the tribe of fishes. The ornithorhyncus is allied both to quadrupeds and to birds. Many similar examples might be produced among the inferior classes of the animal kingdom. A little attention, however, will soon enable us to perceive that they occupy but small portions of the wide spaces intervening between different orders of animals. Even in the best arranged systems, such as that of Cuvier, we discover innumerable chasms wholly unoccupied, between adjacent orders; and in many instances animals, which are scarcely in any respect allied to each other, are placed in immediate sequence. This defect, as I have already observed, is unavoidable, because it is inherent in the very nature of the subject. Instead of a single continuous line, nature presents us with a multitude of partial series, with innumerable ramifications, and occasionally a few insulated circles. If metaphor must be employed, it would be better to say, that instead of being a chain, the natural distribution of animals offers the idea of a complicated network, where several parallel series present themselves, and are occasionally joined by transverse or oblique lines of connexion. The great divisions of Cuvier represent these principal parallel series. The last, however, or that of the *radiata*, appears to be the least perfect of these series, and might with advantage be farther divided. On the subject of natural classification Mr. Macleay[1] has advanced a hypothe-

[1] Macleay, *Horæ Entomologicæ*, or Essays on Annulose Animals, 1821.

sis, which he supports with some ingenuity, namely, that the real types or models of structure may be represented by a circular or recurring arrangement; and he gives a number of instances in which this principle appears very happily to apply. But speculation on these subjects can lead to satisfactory conclusions only on the supposition that an extensive comparison of organs has been instituted throughout the whole of the animal kingdom.

(71.) A scientific knowledge of the organization and functions of animals is valuable, not only in its application to zoology, but also in reference to many other sciences, such as geology, with which it might at first view appear to have but little connexion. By attending to the arrangement of mineral bodies as they occur in nature, we have sufficient proofs that the earth has undergone frequent and considerable changes prior to the existence of any living beings. But we find, besides, a great number of strata, which contain unequivocal remains of vegetable and animal bodies. A large proportion of these are shells, exuviæ of zoophytes, and other marine animals. We also find, in other strata, a multitude of fossil bones, and teeth of various quadrupeds and reptiles; and occasionally, but more rarely, of birds and fishes. Whole mountains and extensive districts appear to be composed entirely of these animal remains. It is by the aid of comparative anatomy and physiology alone that we are enabled to compare these relics of antiquity with similar facts of living or recent animals, to discover their differences or identity, and to deduce certain conclusions with regard to the nature, habits, and characters of the animals to which they had belonged; and by studying their relation with the strata in which they are found, to draw inferences with regard to the changes which must have taken place in those parts of the earth, inferences which are of the highest importance towards establishing a correct theory of those changes. The difficulties attending researches of this nature were of course exceedingly great; but they have been at length surmounted by the persevering zeal and industry of modern naturalists. In these arduous investigations Cuvier stands pre-eminent; and his labours have been rewarded with a number of highly interesting results. The great principle which he has assumed as the foundation of his researches, is that every organized individual constitutes a system of itself, of which all the parts are connected to each other by certain definite relations. In passing from each of these structures to that of other animals in the natural series, we find that all the changes of form which take place in any one organ are accompanied by corresponding alterations in the form of every other organ; so that by the careful application of certain rules, deduced from this observed reciprocal dependence of its functions, we are enabled to ascertain with considerable certainty the forms and habits of animals, of which only small fragments have been preserved. We have already given an instance of this mode of reasoning as applied to ruminant animals. By following this guide Cuvier ascertained and classed the fossil remains of nearly 100 different quadrupeds in the viviparous and oviparous classes. Of these above seventy were distinct species, hitherto unknown to naturalists.

It appears from these researches that the earth has sustained more numerous convulsions than had before been suspected, and that these must have been separated by considerable intervals of time; that the ocean has deposited various strata in regular succession; that the species of animals whose remains are found in these strata change with every variation in the nature of the deposit, and become more and more analogous with the living animals of the present day, in proportion as the deposits have been of more recent date. It appears from an examination of these fossil remains, that the sea must have retired at intervals from the districts it had formerly covered, and left dry land, affording habitation for large quadrupeds; and that after a certain unknown space of time, the sea has suddenly returned to the same spot, has destroyed all the terrestrial animals, and has formed subsequent deposits of shells and other marine productions.

These sudden irruptions and recessions of the ocean, which have occurred several times in the same district, must have been attended with extensive destruction of animal life. Whole races have perished irretrievably, and are known to us only by the durable memorials they have left behind of their own existence, and of the several epochs of antediluvian chronology.

(72.) The study of the fossil remains of animals has also extended our views of the animal kingdom; it has in many instances supplied chasms which had occurred in the natural series, and has enlarged our ideas of the extent of creative power. Another important conclusion which has resulted is, that the human race has been the last created; for nowhere do we find any vestiges of human bones. These researches tend also to throw light on the history of mankind, and to refute the pretensions to high antiquity which have been arrogated by certain nations, and particularly the Chinese, &c. which Voltaire and other modern philosophers had so zealously defended. All that science has brought to light, indeed, is in conformity with the testimony of the cred writings, when rationally interpreted, and may eve adduced as illustration of their truth. Geology and comparative physiology concur with these writings in teaching us that man was the last act of creative power; that a great catastrophe took place on the surface of the globe a few thousand years ago, during which the sea covered for a time every part of the land; and that the subsequent diffusion of the population of the earth is of comparatively recent date. It is pleasing to see conclusions, derived from such different sources, converging to the same points, and affording each other that reciprocal confirmation which is the invariable concomitant and surest test of truth.

(73.) The enlarged views to which we are conducted by the study of comparative physiology afford us a glimpse of some of the plans or models of structure which appear to have been followed in the formation of the animal world. The analogies of form discernible in corresponding organs, throughout a very extensive series of tribes, have been lately traced and developed with extraordinary care by the modern naturalists of the French and German schools, and especially by Cuvier, Blainville, Savigny, Geoffroi St. Hilaire, Oken, Carus, and Milne Edwards. The conclusions they have drawn from their labours, though sometimes overstrained, are always ingenious, and in general satisfactory; and they strongly tend to prove, that several distinct types, or standards of figure, have been adhered to in all the multiplicity of forms with which it has pleased the Author of nature to diversify the animal creation.[1]

(74.) These inquiries, however, suggest still higher subjects of contemplation. They illustrate the connexion and

[1] See the Bridgewater Treatise on Animal and Vegetable Physiology, where this subjet is enlarged upon, and especially the chapter on "Unity of Design." Vol. ii. p. 625.

relationship of every part with the rest of the system. They prove the unity of design with which the system has been planned and executed. They demonstrate the perfection with which all its parts are mutually adjusted, and the harmony which pervades the whole. The evidences of express design and contrivance are so distinct and palpable, and they so multiply and accumulate upon us as we advance, that they may almost be said to obtrude themselves on our notice; and we cannot avoid being impressed with the notion of its being intended that we should observe them. Whilst the purpose to be answered continues the same, the means are varied in every possible manner, as if designedly to display to us the exhaustless resources of inventive power, and the supreme intelligence with which that power is wielded. Nor is it possible to overlook the general object to which every thing so manifestly tends in the system of animal existence. Every element in every part of the habitable globe, teems with life, and that life is replete with enjoyment. Happiness is unquestionably the great object of animal existence. The benevolence which pervades the whole system of creation, is no less conspicuous than the power and intelligence from which it emanated. Revealed religion is thus in unison with the theology derived from the contemplation of nature, and the lights of modern science.

(75.) The facts derived from comparative physiology which more especially support the arguments of natural theology have been collected by authors who have written professedly on the subject. Derham's work, entitled *Physico-Theology*, has been deservedly held in estimation; but since the time it was published, which is now above a century, the sciences have been prodigiously extended. Dr. Paley, in his *Natural Theology*, has produced a great multitude of facts and observations in support of the same arguments, has applied them with singular felicity, and impressed them with the most fascinating perspicuity and eloquence. But his object being purely theological, he has not professed to adhere to any scientific order in stating them. The design of the Bridgewater Treatise, already referred to, is to supply this desideratum, by presenting the details of animal and vegetable physiology, arranged according to the functions to which they relate, or in other words, in reference to final causes. As theological arguments, the value of these facts cannot fail to be better appreciated when they are studied in all their bearings, and as forming a part of the science to which they belong. It is by the aid of genuine science alone, that we can avoid the dangerous error of building arguments, on so momentous a subject, upon equivocal or unstable foundations, and of injuring a cause already established upon incontrovertible grounds, by weak and inconclusive evidence.

(76.) It has been too hastily inferred, from the abuse which has too often been made of philosophical inquiries, that they are to be avoided as dangerous, and even pernicious; and that of the fountain of philosophy, as of the Pierian spring we should "drink deep," or abstain from tasting. Superficial knowledge has often been decried as mischievous, and extremely liable to abuse. The hackneyed maxim of Pope, that "a little knowledge is a dangerous thing," has furnished a ready text for those who declaim against all attempts to render science popular, and to include it as a branch of general education. Willing proselytes to this doctrine will always be found among those whom indolence or frivolity render averse to mental exertion, when bestowed on subjects not immediately connected with the common concerns of life, as well as among those who, already enjoying some of the advantages of knowledge, are desirous of securing to themselves the monopoly of those advantages. But their sophistry is soon detected when we examine into the real meaning of the expressions they employ. What is commonly denominated superficial knowledge, may certainly be useless, or even dangerous; but the mischief or danger arises, not because it is superficial, but because it is incorrect. It is error, under the guise of knowledge that alone deserves such reprobation. The value of information is to be estimated much more by its accuracy, than by its extent. Although it may be true that there is no royal road to science, it is equally true that many are the roads that lead astray; and that much fruitless labour may be spared by having that one pointed out which leads directly to the object we wish to attain. Though the distance we have to travel cannot be abridged, yet the path may be rendered smoother, and the velocity of our progress accelerated, by availing ourselves of such guidance as may be afforded by concise treatises, which, however superficial in appearance, or popular in their garb, are yet, as far as they go, perspicuous, accurate, and comprehensive.

CHAPTER III.

ARRANGEMENT OF FUNCTIONS.

(77.) The general review we have taken, in our introductory chapter, of the objects and mutual connexions of the functions of the animal economy will furnish us with the principles on which the methodical arrangement and classification of those functions should be established. Various attempts have been made by different systematic writers on physiology towards the accomplishment of that object; but they have generally been deficient in that logical precision, which alone can ensure entire comprehensiveness of every branch of the subject, and at the same time convey clear perceptions of the bearings of every part to one another. Some physiologists have limited their views to the human economy, or that of animals which most nearly resemble man; others have framed their systems so as to embrace the whole animal kingdom, and even all beings endowed with life. Some have been wholly governed by anatomical considerations, regarding mere structure as the basis of physiological distinctions; others, overlooking the unity of purpose in each function, and pursuing their subdivisions to an excessive degree of minuteness, have overloaded the subject by needless multiplication and superfluity of detail. Many have introduced confusion by a loose and vitious nomenclature, derived from partial or hypothetical views; which were often tinctured with mysticism, and which, by biassing their judgments, have betrayed them into a wide field of delusion and of error.

(78.) Another source, to which the greater part of the mistakes, pervading all the systems of physiological arrangement that have been hitherto framed, may be traced, is inattention to the essential distinction which exists between physical and final causes. The study of the phenomena of life differs from all the other branches of philosophical inquiry, by its involving considerations relating to both these kinds of causes; the latter of which introduces a totally new principle of arrangement, wholly inapplicable in those sciences which concern the physical properties of inert and inorganic matter. The rules of a strictly philosophical induction, which alone can guide our steps in the pursuit of these sciences, must be greatly modified, and in some measure superseded, by those derived from another department of human knowledge; namely, psychology. The knowledge of those general facts, which, when once established, and the conditions on which they depend ascertained, constitute what are called the laws of nature, is obtained first, by comparing together phenomena and uniting in one class such as are of the same kind, and carefully separating them from others which are essentially different; and next, by endeavouring to remove all extraneous influences, so as to reduce each class of phenomena to its simplest conditions; an object to be attained by *experiments*, that is, by varying the circumstances under which they occur, and also by combining them in different ways, so as to enable us to verify our theories, by comparing their results with the actual observation of nature. But the attempt to apply the same process of induction to the physiology of organised beings, is attended with peculiar difficulty; for while the changes which occur in the inorganic world exhibit the operation of forces or agents characterized by their simplicity, their constancy, and their uniformity, the phenomena presented to our view by living beings, so prodigiously varied in their form, so extensively spread throughout every element, every clime, and every habitable region of the globe, and so infinitely diversified in their nature, and complicated in their connexions, are calculated to baffle the efforts of the most cautious reasoner, and elude the penetration of the most sagacious inquirer after truth. The resources of experimental research are here extremely narrowed, in consequence of the simultaneous and connected operation of a great number of powers, which prevent us from studying the influence which each would exert when isolated from the rest, and ascertaining the laws which are peculiar respectively to each. Hence it is that we have hitherto made but very imperfect approaches to the determination of those laws.

(79.) Some compensation is, however, afforded us, while struggling with the obstacles which impede our progress in the direct and thorny path of science, by the abundant resources accessible to us in the psychological considerations, which every where arise in this vast field of contemplation. All the phenomena of organic beings reveal to us so palpably the indications of *design*, that we cannot resist the impression thus created in our minds; nor can we avoid recognising the connexions which are so established between the objects and the changes they present, as being those of means employed for the accomplishment of certain ends. Thus, then, the relation of means to ends becomes a leading principle of association among the facts of physiology; giving a new aspect to the science, and creating an interest of a different and much higher kind, than could ever be inspired by the study of mere physical relations. So deep has been this impression, and so completely has the principle of final causes been interwoven with the pursuits of physiologists, that the study of the *functions of life*, that is, of the purposes to which the actions constituting life are subservient, has been almost universally regarded as the principal, if not the sole object of the science. It has, accordingly, been assumed as the basis of arrangement, in all systematic treatises of Physiology; and likewise in framing theories for explaining the phenomena of life, physiologists have generally been satisfied with pointing out their final, rather than their physical causes.

(80.) This natural proneness to substitute final for physical causes has been a frequent source of delusion, by insensibly leading to the belief that we have reached the physical law which regulates the phenomena we are viewing, when we have, in fact, done nothing more than traced their relation to the intelligent agency by which they have been each adjusted to their respective objects, and given that law a name with reference to that agency; thus, in our eagerness to grasp at hidden knowledge, mistaking the shadow for the substance.

(81.) Frequent instances of this confusion of ideas occur in the writings of the older physiologists; but at all times the predominant tendency has been to refer the phenomena to their final causes; that is, to the purposes which they answer in the animal economy. The functions were arranged by the ancients into three classes, designated by the titles of *animal, vital,* and *natural;* the first comprising those powers of sensation and of voluntary motion which are more especially characteristic of animal, as contradistinguished from vegetable life; the second, those powers, the continued exercise of which are immediately necessary for the maintenance of life, such as respiration of the blood; and the third, those which are directly concerned in the continuance of its vital actions, but which are yet indispensable in preserving the organs in the conditions enabling them to perform their respective offices, by supplying the materials requisite for their nutrition, and for counteracting their tendency to decomposition; in this class were included digestion, secretion, and absorption. To these were added by many, a fourth class, the *generative*, comprehending all the functions which have for their object the continuance of the species by the reproduction of individuals similar to the parent animal. The principal objection to this arbitrary division of the functions is, that the line cannot be drawn with sufficient distinctness between what are called the vital and the natural functions, their connexion with the maintenance of life being one of degree only, and not of kind; as is evident from their being united together in the lowest tribes of the animal kingdom. This classification appears also to be defective, inasmuch as it omits all notice of those functions which have immediate reference to the mechanical condition of the frame; conditions which are the foundation of their physical capabilities of executing the operations assigned them in their respective places in the general system. It is also liable to the imputation of employing terms to designate the classes which are obviously incorrect, and bear not the meaning they are intended to convey. In one sense, and that which would first present itself to the mind, the term *animal* functions would comprehend all the others, for there are none in which powers peculiar to animal life are not called into play; and, on the other hand, the strictly animal functions are equally entitled to the appellation of *vital*, as being directly essential to the support of life; and no specific meaning can attach to the term *natural*, as applied to any description of functions.

(82.) Vicq D'Azyr proposes to establish a preliminary division of the functions into two great classes; the first, comprising those concerned in the preservation of the individual; and the second, those concerned in the preservation of the species. The former class he divides into two orders; the first having for their object the assimilation of food into the substance of the body, and designated as the interior assimilative and nutritive functions; and the second, establishing the relations of the individual to surrounding objects, and denominated the exterior or relative functions.

The first of these orders comprises six genera; namely, 1st, *digestion*, by which the nutritive particles are extracted from the food; 2d, *absorption*, by which this nutritive matter is conveyed into the blood; 3d, *circulation*, by which it is carried to all the organs; 4th, *respiration*, by which it is exposed to the influence of atmospheric air; 5th, *secretion*, by which it is made to undergo various modifications; 6th, *nutrition*, by which it is applied to the organs for the purposes of growth and nourishment.

The second order of the first class comprehends three genera; namely, 1st, the *sensations*, which give to the individual notice of the presence of surrounding objects; 2d, the *motions*, which bring him towards, or remove him from them; 3d, *voice* and *speech*, which enable him to communicate with his fellows without transporting his body to a different place.

The second class, or the generative functions, likewise comprise two orders; the first, including the functions of *conception* and *generation*, requiring the concourse of both sexes; the second, including *gestation*, *parturition*, and *lactation*, performed exclusively by the female. To these were subjoined by Vicq d'Azyr, as a kind of supplement to his system, the several facts relating to the progressive changes taking place during the advance of life from infancy to decrepitude, through the ages of growth, of maturity, and of decay, and to those which attend the absolute extinction of life, and the subsequent decomposition of the organs.

The arrangement of Vicq d'Azyr is entitled to much commendation, and has been followed in all its essential features by Dumas,[1] Richerand,[2] and other systematic authors on physiology, with the exception of Haller,[3] who adopted a classification of functions founded altogether on the anatomical relations of the organs by which they are performed.

(83.) Bichat,[4] whose original genius led him to disregard the opinions of his predecessors, and to strike out for himself new paths of inquiry, aimed at giving greater simplicity to physiological classification, by pursuing a more rigid analysis, and infusing a more philosophical spirit into the methods of research. With this view he distributed the functions into two classes, which he denominates respectively the *animal* and the *organic*; the former coinciding nearly with those already known by that title; and the latter comprehending both the vital and the natural functions of preceding writers. Impressed, however, with the necessity of drawing distinctions among the powers of life, he has per-

[1] *Principes de Physiologie.* [2] *Elémens de Physiologie.*
[3] *Primæ Lineæ Physiologiæ.* [4] *Anatomie Générale.*

plexed his system by intermixing with those final causes, which he takes as the basis of his divisions, the results of a philosophical analysis of those powers. He is thus led to make continual efforts to establish a distinction between muscular contractibility, which is one of the simple and elementary powers of life, when that power is employed in subservience to the animal functions, and when it is subservient to the functions of organic life; a distinction which regards only the final, and not the physical causes of the phenomena. Dumas[1] has been guilty of a still more palpable error in deeming it necessary to add to his catalogue of principles, consisting of the acknowledged powers of sensibility and contractility, a third power, which he terms "*the force of vital resistance*;" thus associating a final cause in the same rank with causes that are strictly physical.

(84.) To the animal and vital functions of Bichat, Cuvier has added, in his physiological arrangement, a third class, the *generative*, which cannot, indeed, be, with any propriety, included in any of the former. He still, however, falls into a similar mistake as that of Dumas, which we have just now pointed out; for he describes sensibility and muscular contractility not as primary principles, but both of them functions of the nerves. Adelon[2] distinguishes the following eleven actions as being the functions of life; namely, *sensibility*, *locomotion*, *language*, *digestion*, *absorption*, *respiration*, *circulation*, *calorification*, *secretion*, and *generation*. Bourdon[3] reduces them to seven, which are as follows: *caloricité*, *nutrivité*, *absorptivité*, *exhalativité*, *durabilité*, *reproductivité*, et *resistabilité*; thus presenting a strange jumble between physical principles of action, and actions

[1] *Principes de Physiologie.* [2] *Physiologie de l'Homme.*
[3] *Principes de Physiologie Médicale.*

referred to definite purposes. The same confusion may be remarked in the classification of the functions by Béclard,[1] who has arranged them into six classes, viz. *nutrition* in its most extended sense, *generation*, *muscular action*, *sensation*, *nervous action*, and the functions of the *intellect*. But it would be needless to multiply examples of this error, since it will be found to pervade almost every physiological system that has yet been framed, not excepting even that adopted by Dr. Bostock, in his valuable *Elementary System of Physiology*.

(85.) Dr. Bostock regards contractility and sensibility as the two primary attributes of animal life, each equally characteristic of it, and peculiar to it, and each performed by its appropriate organs. "The functions," he remarks, "depend on the exercise of these powers, and although probably, in all cases, they are both of them exercised, yet generally one of them seems to be the principal agent, or the prime cause of the ensuing operation; we may consequently divide them into the contractile and sensitive functions, or those which more directly belong to contractility and to sensibility, and which, of course, serve respectively for motion and sensation, and to these two classes must be added a third class of the intellectual functions." Among the contractile functions, the essence of which consists in motion, Dr. Bostock considers the circulation as being the first in point of importance, and the one which may be regarded as the most necessary to the direct support of life, and to the indirect maintenance of all the rest. Next in importance is respiration, which modifies the blood so as to adapt it to the maintenance of life. After these two functions, by the

[1] *Elémens d'Anatomie.*

former of which the blood is carried to all the parts of the body, and by the latter of which it acquires its vital properties, Dr. Bostock places those of calorification, secretion, digestion, including assimilation and sanguification, and absorption, functions which contribute, he observes, to the continuance of the motion of the animal machine, and which preserve all its parts in their proper condition, without, however, being essential to the immediate support of life. In this class he places the function of generation, which, although one of the most inexplicable of all the operations that are performed by the animal powers, and acting in a specific manner of which we have no other example, may be considered as essentially consisting in secretion.

The sensitive functions are divided by Dr. Bostock into two classes; first, those which originate in the action of the external agents on the nervous system; and, secondly, those of a reverse kind, which depend on the reaction of the nervous system on these agents. In the first of these divisions are included what are called the external senses, the sight, hearing, taste, smell, and touch; and in the same division must be placed the sensation of hunger, that of temperature, and some others, which have not been correctly discriminated from general feeling, but which possess specific characters. In the second class, those functions which depend on the reaction of the nervous system on external bodies, he places volition; and to the same class he also refers instinct, association, sympathy, habit, and some other faculties of a similar kind, which appear to hold an intermediate rank between the corporeal actions and those of a purely intellectual nature. As the functions which compose the first of these classes may be all referred to a species of perception, so the latter may be considered as more or less analogous to volition; in the former, the effect on the nervous system, whatever it may be, is propagated from the extremities to the centre; in the latter, it proceeds in the opposite direction, from the centre to the extremities of the body.

The intellectual functions compose, in this arrangement, the third class. These, Dr. Bostock observes, are a less direct object of physiology than the two former, yet many ot them are so closely connected with the physical changes of the body as to require being included in a complete view of the animal economy. Among those intellectual operations which possess a decided action on the corporeal frame, he places the *passions;* and also refers to this class that compound of mental and physical influe ice, from which results what are called *temperament* and *character.* These lead to the consideration of functions of a more purely intellectual kind, which, as they recede from the corporeal, and advance towards the mental part of our frame, are less within the province of the physiologist, and belong more to the metaphysician or the moralist.

(86.) Dr. Alison[1] has adopted a principle of arrangement, which, though differing in some of its applications, is essentially the same as that of Dr. Bostock, as it is derived from the analysis of the phenomena of life into certain powers; or, if these phenomena be considered as the results of a single principle, which we may denominate *vitality,* the study of physiology will resolve itself into an inquiry into the conditions under which the various phenomena of life take place, that is, into the *laws of vitality.* These laws are ranked by Dr. Alison under three heads: 1. Those of

[1] *Outlines of Physiology and Pathology.* Edinburgh, 1833.

vital contractions, by which the visible movements of living animals are chiefly effected: 2. Those of *vital affinities*, by which the chemical changes peculiar to living animals are determined, and their physical structure maintained: 3. Those of *nervous actions*, by which the physical changes in living animals are placed in connexion with mental phenomena, and subjected to the control of mental acts. The first and third of these divisions correspond to those of Dr. Bostock, which he has denominated the contractile and the sensitive functions. The second division of Dr. Alison is founded on the principle pointed out by the writer of the present article, in a treatise on Physiology which appeared many years ago in the last Supplement to this work, and to which he gave the designation of *the organic affinities*.

Dr. Alison considers that the movement of the fluids, in all the higher classes of animals, is in a great measure dependent on vital contractions in certain of their solids, and may accordingly be regarded as the first and most important consequence of the exercise of the vital power. This subject he divides into two parts; first, the movement of the mass of blood in the heart, arteries, and veins, or the function of circulation; and, secondly, the continual evolution of matters from, and absorption of matters into, the mass of blood; or the functions of nutrition, exhalation, secretion, and absorption, to which the circulation is subservient, and on which all the other functions are dependent. The study of these nutritive functions naturally introduce the consideration of the properties of the different textures and secretions which are formed from the blood, and which are the materials combined in the construction of the organs themselves.

The nervous system has been endowed with peculiar properties or powers, in order that it may be the seat, and the instrument, of mental acts. These mental acts, and all the functions in which they bear a necessary share, constitute, according to Dr. Alison, the animal life, or animal functions. As in all animals the reception of food into the digestive organs, and in all vertebrated animals, and many of the inferior orders, in the adult, the reception of air into the respiratory organs is accomplished by movements which are excited through the intervention of sensations and of instincts and volitions; he considers the commencement of the processes of respiration and digestion in them as belonging to the province of animal life, and as dependent on the nervous system. Dr. Alison, ther fore, commences his account of the animal functions, with the consideration of respiration, animal heat, and digestion, which he refers to that class: proceeding afterwards to notice the physiology of the external senses, of the mental faculties, voluntary and instinctive motion, the involuntary action of the mind on the body, sleep and the analogous states of somnambulism, reverie, and other irregular actions of the nervous functions. The subjects of generation, and the peculiarities of age, sex, and temperament, occupy the concluding chapters of his work.

(87.) The order in which Mr. Mayo has treated of the functions,[1] differs but little from that adopted by Dr. Alison.

(88.) The author of this article has given, in his *Bridgewater Treatise*,[2] an arrangement of the functions founded altogether on the basis of final causes: and corresponding

[1] *Outlines of Human Physiology*, 3d edition, London, 1833.

[2] Roget, *Animal and Vegetable Physiology, considered with reference to Natural Theology*, two vols. London, 1834.

therefore with the views, which have been explained in the preceding chapter, of the relative subordination of purposes which the functions are designed to answer in the economy; and not limited to human physiology, but embracing all the different forms and modifications which those functions present in the animal kingdom. Taking them in the order of their increasing complexity, he has distributed them into the four following classes; namely, first, *the mechanical functions*, which include the consideration of all the circumstances relating to the mechanism of the frame and of its different organs; the arrangements provided for procuring the proper cohesion, strength and mobility requisite for the different actions they have to perform; and also for the preservation of their connexions, support, security and other mechanical conditions adapted to the exercise of their respective functions. To this head are also referred the operation of the moving powers, derived principally from muscular contractility, by which the various parts of this system of machinery are set in motion.

Secondly, the *nutritive*, or *chemical functions*, corresponding to what has been formerly denominated the vital functions; and the object of which is the preservation of the organs in those states of chemical composition which enable them to sustain life, and to perform their destined offices in the economy. The functions by which, in the higher orders of animals, this object is accomplished, may be arranged under the following heads; each, however, admitting of further subdivision. 1. *Assimilation*, including the processes which prepare the food for *digestion*, *chymification*, which is the office of the stomach, and *chylification*, which is performed in the intestines. 2. *Lacteal absorption*, by which the chyle so prepared, is collected into the heart and blood-vessels. 3. *Circulation*, by which the blood, or nutrient fluid, is regularly diffused over the system. 4. *Respiration*, or the aeration of the blood. 5. *Secretion*, by which the properties of that fluid are modified. 6. *Excretion*, by which various chemical principles are separated from the blood, and discharged from the system. 7. *Absorption*, by which substances are conveyed from different parts back again into the general mass of circulating fluids. 8. *Nutrition*, by which the nutritive matter is applied to the growth or restoration of the various organs of the body, so as to maintain them in the state which enables them to discharge their proper functions. 9. For effecting all these various processes, the agency of a peculiar power, derived from the properties of the nervous system, is requisite. This may be termed the *nervous power*, in contradistinction to those actions of the same system, which have reference to mental phenomena, and which come under the next class of functions.

Thirdly, the *sensorial functions* comprehends all those corporeal changes in which the mind is concerned; and consequently include those of *sensation*, of *perception*, of *volition*, and all those intellectual functions which employ for their agency the physical organization of the body.

Fourthly, the *reproductive functions*, which have for their object the continuance of the species, and the multiplication of its numbers. This subject is naturally connected with the progressive developement of the organs, the growth of the body from infancy to manhood; and the stages of its decline, till all the vital phenomena cease by the death of the individual.

CHAPTER IV.

THE VITAL POWERS.

(89.) We have already remarked, that there are two ways in which the assemblage of phenomena presented to us by living beings may be studied. We may, in the first place, view these as mere physical phenomena, applying to them the same methods of induction which have been employed with so much success in other departments of natural science. The object of philosophical induction is the reference of the events occurring in nature to their proper causes. This is accomplished by comparing the phenomena together, observing in what they agree, and in what they differ, classing them in the order of their agreement; and distinguishing them according to their differences. The result of this process, when it has been carried as far as the extent of our mass of facts will allow, is the establishment of certain general relations between these facts, or conditions, under which they occur, and which we may consider as so many *laws of nature:* and any appearance we may afterwards meet with which corresponds in its character to any single law, or combination of these laws, is at once referred to them, and considered as a particular instance or exemplification of these laws. When we can succeed in tracing these coincidences with a previously established law or general fact, we are said to have discovered its cause. Philosophy, in this sense, then, comprehends the collection and comparison of phenomena, their classification, the establishment by careful induction of general laws; the verification of these laws by experiment; and lastly, the subsequent reference of particular phenomena to their appropriate laws.

(90.) In the sciences which relate to the laws of matter in its inorganic state, this inductive method of philosophising admits of being pursued to an indefinite extent, and with comparative facility. The phenomenon themselves, which are the subjects of induction, are of a simple and more definite character than those of animal or vegetable life; they are generally more under our control · and more easily subjected to the test of experiment. The endless variety of the forms of life, the extent and intricacy of the connexions between the different parts of the animal system, introduce a degree of complexity in the phenomena, incomparably greater than is ever met with in the combinations of inorganic matter. We shall accordingly find that the knowledge we have hitherto acquired of the physical laws which govern the vital phenomena, is as yet exceedingly imperfect.

(91.) In entering upon the philosophical study of the phenomena presented to us in the living body, and carefully arranging them according to the rules of induction, and without reference to the final causes that connect them, (a subject which forms a totally different branch of inquiry,) we easily recognize the operation of many of those powers and principles to which inorganic matter is also subjected. The living system, with all its complicated apparatus of solids and fluids, is obedient to the universal laws of gravitation, of cohesion, of elasticity, of capillary attraction, &c., as well as to the ordinary principles of mechanics, hydrostatics, hydraulics, and pneumatics, which result from combinations of these laws; and we may pursue the application of these laws to the mechanism of the body, as far as no other causes intervene, without danger of error.

(92.) The laws of chemistry apply also, to a certain extent, to the changes which are going on in the living system; but in tracing the operation of these laws, we soon become sensible of the apparent interference of other principles which seem to control the ordinary chemical affinities which the same kinds of matter are found to exert when deprived of life. Here, then, we perceive a sensible deviation from the course of phenomena exhibited by inorganic matter; and we are forced to recognize the existence of new and unknown powers peculiar to, and characterizing the living state. We discern the operation of such powers in the processes of digestion, of sanguification, of nutrition, of secretion, of the growth and organization of the various structures that compose the fibres of the body. Powers of a similar kind are exhibited in the phenomena of vegetation: they seem, therefore, to attach to vitality in all its forms. In order to distinguish them from the ordinary chemical affinities to which they are so frequently opposed, we shall designate them by the name of *Organic Affinities*, although, as we shall afterwards attempt to shew, they probably do not differ in their kind, but only in the circumstances and conditions of action, from the ordinary inorganic affinities.

(93.) Another power which more peculiarly appertains to animal life is *Contractility*. This is especially a property of those fibres which compose the muscles. It is often denominated *Irritability*, a name originally given to it by Glisson, but which has justly been objected to by Dr. Bostock as a term employed in many different senses, according as it is applied in physiology, pathology, or ethics. Haller speaks of it frequently under the designation of the *Vis insita.* The term *Contractility*, adopted by Dr. Bostock,[1] and sanctioned by many other eminent physiologists, is in itself unobjectionable, and has the advantage of being a simple expression of the fact itself. It consists in the spontaneous shortening of muscular fibres, in consequence of the impression of certain agents termed *stimuli*, by a power residing in the fibres themselves, and which operates with a force greatly superior to any of the ordinary mechanical sources of motion.

(94.) The remarkable property which the nerves possess of conveying with electric celerity impressions made on one of their extremities, or even on any part of them, to the opposite extremity, and to other parts in the line of their course, the influence of which impressions are rendered apparent by certain effects, such as the contraction of the muscles, increased or modified action of the blood-vessels, absorbents, and organs of secretion, and the evolution of animal heat. All these effects may take place from impressions, or *irritations*, (by which term is meant impressions of a certain degree of intensity,) which do not excite sensation, or volition, or any other mental change; and they even occur after the destruction or removal of those parts of the nervous system which are connected with affections of the mind. A power of the same kind is also possessed by those nerves which are connected with the sensorium, on the parts in immediate connexion with the sentient principle.

[1] *Elementary System of Physiology*, third edition, pp. 91, 92.

(95.) It is by the exertion of this power that impressions made on those nervous filaments which are instrumental in sensation, and especially if made on their extremities which are distributed to the organs of the external senses, are instantly transmitted to the sensorium, in which they may be said to terminate, and the changes produced in which are attended by the mental affection termed *sensation*. In like manner, certain other changes in the sensorium, consequent on *volition*, which is a mental affection, are followed by the contraction of certain muscles, by means of some unknown influence communicated through the medium of certain other nervous filaments having their origin in the sensorium, and their termination in those muscles. The nature of the power by which these transmissions are effected in the course of each of these sets of nervous filaments, judging from the similarity of the circumstances under which it takes place, especially in the instantaneousness of the effect, is probably the same in every case; the only perceptible difference in the mode in which it is exerted consisting in the direction of the transmission. This remarkable power, which is totally distinct from any mental effect that may accompany its exertion, we shall distinguish by the name of the *nervous power*.

(96.) A fourth power, perfectly distinct from any of the former, although it also belongs to a portion of the nervous system, is that from which the corporeal changes which take place in those parts immediately connected with sensation, volition, and the intellectual operations, proceed. To this specific property, which should be carefully distinguished from the mere faculty of transmission possessed by the fibres of the nerves, the name of *sensorial power* has been given.

We are indebted to Dr. Wilson Philip for the establishment of this important distinction in the specific powers of the nervous system, and for having bestowed upon it the above appropriate designation. The same term had, indeed, been employed by physiologists in a different and much more extended sense, as including muscular irritability, which had been regarded as in some way or other analogous to nervous power. In the sense in which we shall use the term, it is meant to apply exclusively to those physiological changes occurring in certain parts of the nervous system, which produce or accompany changes or affections of the mind.

(97.) It is evident that the astonishing properties belonging to the refined organization of the brain, which constitute sensorial power, and which are, in a manner utterly incomprehensible to us, connected with the affections of the sentient and intelligent principle, present subjects of far higher interest than even the organic, muscular, or nervous powers, and are infinitely more remote from the ordinary attributes of matter.

(98.) Thus we may perceive that the system of the living body exhibits not only a multiplicity of new powers, which we no where meet with in unorganized matter, but also presents us with a gradation of powers ascending from those of a mechanical nature, but yet derived from highly artificial arrangement of particles, to those of a refined and elaborate chemistry silently at work in the secret laboratories of the body; rising again to principles of a still more elevated order, acting through the medium of the nerves; till we lose ourselves in the more lofty contemplation of those mysterious agencies, which confer on the central portions of the nervous system the power of exciting sensation;

which render them instruments of thought and of volition, and which stamp on the being they compose the distinctive character of individuality.

(99.) Viewed with reference to their subserviency to final causes, it is to the sensorial powers, which confer the capacity of enjoyment, that the supreme rank in point of importance must be assigned. The faculties of sensation, of voluntary motion, and of enjoyment, are the only ultimate ends for which, as far as we can judge, the animal has been created and endowed with life. Those ultimate ends of its being are attained primarily by the sensorial powers; and to the maintenance of these are the muscular and the nervous powers subservient. Of these latter powers it is also evident that the muscular is placed in obedience to the nervous, in the same manner as the nervous is obedient to the sensorial power. Thus, the views now presented of the classification and distribution of the physical powers which operate in producing the phenomena of life, are in strict accordance and harmony with the results obtained from the consideration of final causes, which we have already presented in our preliminary chapter.

(100.) If the analysis we have here offered of the vital powers, that is, of powers peculiar to the phenomena of life, and the distinctions we have endeavoured to establish between them be correct, we shall be enabled at once to detect the fallacy of those views of life, and of those definitions of the vital principle which are generally received; and which, we apprehend, have been laid down in violation of the just rules of philosophical induction. The truth is, disguise it how we may by a vain parade of words, that the real state of the science is not sufficiently advanced to authorise that degree of generalization which these definitions would imply. We are certainly not warranted, by the phenomena already known, in regarding life as the effect of any *single* power. The attempt of *Brown*, of *Hunter*, and of *Bichat* to reduce the science to this state of simplification, though highly ingenious, are yet premature; and have, it is to be feared, had rather the effect of retarding than of advancing the progress of real science.

(101.) Many of the older physiologists entertained the notion of a principle, endowed with qualities in some measure partaking of intelligence, and as if it were a spirit presiding over and governing the vital actions. Such was the idea attached by Van Halmont, and by Stahl, to the principle which they termed the *archæus*, or *anima*, and which they conceived regulated the operations of the different powers of the system; an assumption which, however naturally suggesting itself to the mind, while contemplating the harmonious adjustments that pervade every part of the animal economy, is in no respect a philosophical explanation of the phenomena, and is even utterly irreconcilable with some of these phenomena. In like manner, the *vis medicatrix naturæ*, which Hoffman and Cullen have so largely employed in their pathological theories, and which supplied them with ready solutions of every obscure morbid change that embarrassed them, was, in fact, nothing more than a branch of the same doctrine. Nor have the more sober theorists of modern times been sufficiently on their guard against this illusion. In the attributes which John Hunter ascribes to his *vital principle*, we may continually trace the same want of discrimination between that intelligence, by which the conditions of organization were originally adjusted to a variety of contingent circumstances, and those physical agents, by the instrumentality of which the intended objects are attained. When it is said, for example, in the language of this school, that the coagulation of the blood is occasioned by "the stimulus of necessity," it is clearly the final cause alone which is indicated, while the real physical cause is not assigned; and it is also evident that no advance is thereby made towards its discovery. This *principle of life*, with which organized beings are endowed, is represented as a new power, which modifies and controls the operation of those simpler physical laws, to which the same matter, in its unorganized state, is subjected; a power which imposes new cohesive and repulsive forces on the solid materials of the animal or vegetable structures, which imparts to the fluids a new property of coagulation, which alters the order of chemical affinities between their elements or primary compounds, retaining them, contrary to their natural tendencies, in a certain state of equilibrium, and resisting the agency of causes usually tending to destroy that state: and, lastly, which produces, in a degree corresponding with the wants of the system, either an evolution or an absorption of caloric. All these, it must be admitted, are purposes of manifest utility, being directly conducive to the welfare of the individual, and indeed essential to its continuance in the living state. In as far as they are means conducive to specific ends, the reference of all these phenomena to one class cannot be objected to. The fallacy lies in regarding it as a philosophical generalization of effects of a similar kind, resulting from the operation of a simple power in nature; for between many of these effects, considered as mere physical phenomena, there exists not the remotest similarity. But it is the fundamental principle of the method of induction, that similar effects alone are to be ascribed to the agency of the same physical cause. Judging, therefore, from the observed effects, which differ widely in their nature from each other, we ought to infer the operation of several distinct powers, the concurrence of which is requisite to produce the complex phenomena in question. We are, no doubt, unavoidably led to view these phenomena as conjoined, because we witness their existing combinations, and perceive that they are tending to the accomplishment of a specific purpose; namely, the preservation and welfare of the being to which they relate. But this unity of design is an attribute, not of matter, but of intellect, and does not necessarily imply the unity of the agent employed in their production.

(102.) We may take as an example, the phenomena of the circulation of the blood, which, when viewed with relation to that function, form together so beautiful and harmonious a system. These phenomena, taken abstractedly, are ultimately resolvable into such as result from a few general powers, as muscular contractility, membranous elasticity, the hydraulic properties of the blood, &c. The phenomena of digestion, in like manner, when subjected to analysis, are found to be results of the combined agencies of the muscular action of the stomach and intestines, of the chemical powers of the gastric juice, the bile, &c. of the organic powers of secretion, and so forth; all of which concur in the production of a definite object, namely, the conversion of the aliment into chyle. The combined processes subservient to this purpose, constitute, when viewed in their relation to final causes, the function of digestion.

(103.) However the laws which regulate the vital phenomena may appear, on a superficial view, to differ from those by which the physical changes taking place in inorganic matter are governed, still a more profound investigation of their real character will shew that, when viewed abstractly from the consideration of final causes, there is really no essential difference between them, either as to their comprehensiveness, their uniformity of action, or the mode in which they are to be established by the generalization of particular facts.[1] The difficulty of effecting these inductive generalizations is undoubtedly incomparably greater in the former than in the latter; but this difficulty is similar to that which impedes our progress in all cases where the existing combinations which are the objects of study, are too numerous and too complicated to yield to our powers of analysis. We have examples of this difficulty in many branches of physical science; in meteorology, for example, where no one can doubt that the phenomena are the results of the ordinary physical powers, of the laws of which we are tolerably cognisant; but the operations of which, in effecting the daily and hourly changes of atmospheric phenomena, have hitherto baffled the most persevering and penetrating inquiries directed to this highly important branch of physics. There is, in like manner, no distinct evidence of the material particles, which compose the organized and living fabric, being actuated by any powers or principles different from those which are inherent in them, in their ordinary or inanimate state. They are, in both cases, obedient to certain definite physical laws, the operation of which is determined by the peculiar circumstances of their mode of combination, and the peculiar conditions under which they are brought into action.

(104.) It may, in like manner, be contended, that the affinities which hold together the elements of living bodies,

[1] See an Essay by Mr. Carpenter on the difference of the Laws regulating Vital and Physical Phenomena, Edinburgh New Philosophical Journal, xxiv. 327.

and which govern the elaboration of organic products, are the same with those which preside over inorganic compounds; and that the designations of *organic* and *vital affinities* are expressive only of peculiarities attending the circumstances and conditions under which they are placed, but do not imply any real difference in the nature of the powers themselves. If our knowledge of these circumstances and conditions were complete, their identity would be at once revealed to us; but until that period, which must be very far distant, has arrived, we must be content with gathering a few indications, which occasionally break out from the clouds of mystery in which the subject is obscured, of the similarity of operation between these two apparently contending powers, the ordinary chemical, and the extraordinary vital affinities. Every fresh discovery in animal and vegetable chemistry, by shewing the mutual convertibility of many of the proximate principles of organic compounds, adds to the number of those indications. Hence it becomes every day more and more probable that the forces immediately concerned in the production of chemical changes in the body, are the same as those which are in constant operation in the inorganic world; and that we are not warranted in the assertion that the operations of vital chemistry are directed by distinct laws, and are the results of new agencies.

(105.) We are therefore led to the conclusion, that the vital properties are not, as it is commonly expressed, superadded to matter in the process of organization, but are the result of the material constitution, that is, of the peculiar combinations and arrangement of the ultimate molecules of the organized tissues, which call out and develope the properties previously existing in those molecules, but which cannot be effective unless these circumstances exist.

(106.) However natural it may be to conceive the existence of a single and presiding principle of *vitality*, we should recollect that this, in the present state of our knowledge, is only a fiction of the mind, not warranted by the phenomena themselves, in which we perceive so much real diversity, and therefore inadmissible as the result of a philosophical induction. We find that vitality ceases in different textures, at different periods, prior to the total extinction of life ; a phenomenon which appears scarcely compatible with the unity of any such power.

(107.) It is well known that attempts have in like manner, from time to time, been made to reduce the phenomena of the inorganic world to a single primordial law ; instead of being content to refer them to the operation of distinct laws, such as those of gravitation, cohesion, elasticity, light, heat, electricity, magnetism, and chemical affinity. The phenomena usually ascribed to these great powers of nature have, for instance, been considered as resolvable into one universal principle of *attraction*. By other philosophers, they have been regarded as the effects of a general and sole power of *repulsion*. None of these simplifications are as yet warranted by facts ; and equally vain, in the present state of the science, is the endeavour to reduce all the vital phenomena to one single law. It is possible, or perhaps even probable, that future researches may be successful in establishing the identity of some of the powers we now conceive to be distinct, with other powers already known. Thus, in the physical sciences, the recent discoveries that have taken place in electro-magnetism, have satisfactorily established the identity of the magnetic and electric agencies. The same may possibly be accomplished in future times, with regard to heat and light, which are already connected together by so many analogies. But no such approximation can yet be attempted with any prospect of success, between the muscular, the nervous, the sensorial, and the organic powers. No speculative ingenuity can reduce them to a single physical power; nor can we establish any kind of association between them, but by the consideration of another and a totally different class of relations, namely, those they bear to the general object which they combine to produce. This, however, is to substitute final for physical causes; a mode of procedure which we have seen, is totally at variance with the principles of philosophical induction. It is physical causes only which are the legitimate objects of philosophical analysis, and the true bases of the physical sciences.

(108.) We shall now proceed to give an account of each separate function; taking them in the order of their respective simplicity, with reference not only to their objects, but also to the powers which are concerned in their accomplishment.

We shall accordingly begin with the consideration of the *mechanical functions*, as being more simple in their character, and implying the operation of the simpler powers of organization; together with the peculiar faculty of muscular contractility, which is the great source of mechanical power provided for carrying on the greater movements of the machine. We shall, in the second place, review that class of functions which depend more especially on the operation of the *organic affinities*, and which have for their objects the nutrition and extension of the organs, and their maintenance in that state of chemical, as well as mechanical condition, which fit them for the performance of their respective offices. We shall then be properly prepared for the study of that higher class of functions, which appertain to *sensation*, and all the other faculties connected with mind; functions which imply, in addition to all the powers concerned in the preceding functions, others of a superior order, but which, although in the highest degree interesting and important, are incomparably the most obscure and complex of all. Our attention will, in the last place, be directed to the functions relating to *reproduction*, the study of which requires a previous knowledge of every other department of physiology.

CHAPTER V.

THE MECHANICAL FUNCTIONS.

SECT I.—*On Organization in general.*

(110.) If we analyze the ideas attached to the term *organization*, we find that it implies, as its essential condition, a specific arrangement of parts, adapted to some particular purpose, and composing by their assemblage, an individual system endowed with life. It seems impossible, therefore, to attach the idea of organization to a mere fluid, because the mechanical condition of the particles of a fluid is such as to preclude the capability of any permanent arrangement. It appears to be essential to every organized structure, that there shall be solid parts provided for containing those which are fluid. All animal bodies accordingly, are composed of solids and fluids; the former being more permanent in their nature and arrangement, and constituting the basis by which the general form of the body is determined; and the latter, being lodged in appropriate cavities formed by the solids, but capable by their mobility of undergoing more rapid changes of place, and of chemical composition.

(111.) It may in general be said, that the solids bear but a small proportion to the fluids, which enter into the composition of the body. It is difficult, however, to determine the exact proportion which they bear to one another; in the first place, because this proportion is not fixed, and admits of variation in different ages, circumstances, and conditions of the system; and, secondly, because it is scarcely possible to effect the complete separation of these two constituent portions; partly from the ready conversion of the solids into fluids, and *vice versa*, and partly from the tenacity of their mutual adhesion. Some estimate of this proportion has been attempted to be formed, by carefully drying the dead body in a stove, or oven; and the result of some experiments has been, that in an adult man, the weight of the fluids is to that of the solids, as six to one, or, according to other experiments, as nine to one. From the examination of an adult Egyptian mummy, which may be supposed to contain nothing but the dry fibres of the body, a still lower proportion has been assigned to the solid part; since this mummy weighed only seven pounds and a half.[1]

(112.) The possibility of reducing all the organic textures of the human body to one elementary material, which might be regarded as the basis of the whole, was long a favourite subject of speculation among anatomists: and Haller has devoted to it the first section of his great work on Physiology.[2] He conceives that all the solid parts of the frame are ultimately composed of fibres; the animal fibre being the simplest form of organized matter, and being to the physiologist, what the line is to the geometrician, that from which all other figures are produced. This simple fibre, he observes, is invisible, even with the assistance of the microscope; it is only by the union of the primary fibres, that visible fibres are constituted; and from the assemblage

[1] See Béclard, *Elémens de Anatomie Générale*, p. 77.

[2] *Elementa Physiologiæ Corporis Humani.*

and lateral adhesion of these, again, thin plates of animal substance are formed, while the grosser substance of the organs themselves, is composed of a complicated contexture of these plates and fibres. This supposed basis, or essential constituent, of all animal textures, has been by some termed the *animal parenchyma*, and by others, has been designated by the general name of *animal membrane*.

(113.) Besides this spongy or areolated texture, which composes by far the greater bulk of the organs of the body, Haller has also admitted two other constituent parts, namely the *muscular*, and the *nervous substances*. These views have since been generally adopted by physiologists, with some slight modifications. Many have thought it necessary to introduce, in addition to the preceding, an element which they consider as of a tubular form, constituting vessels fitted to contain fluids. This was the favourite doctrine of Boerhaave, who supposed that the simple fibres, or the smallest into which they can be conceived to be divisible, formed by their lateral adhesion, a membrane of the first order, which, when coiled up into a tube, would constitute a vessel of the first order. These vessels, again, when interwoven together, composed a new order of membranes, by the duplication of which a second order of vessels was formed. Successive series of membranes and vessels were thus constructed, until they acquired a magnitude sufficient to be visible to the eye. According to this hypothesis, therefore, all the parts of the body might ultimately be resolved into a congeries of vessels, arranged in these ascending orders. This hypothesis, which evidently rested on the most visionary basis, has been ably refuted by Albinus, and by Haller. It has, however, left some traces in the opinions expressed by many subsequent anatomists, who still cherished the idea of the universal vascularity of the animal fabric, and of this vascularity being essential to organization. The skilful injections of Ruysch, who succeeded in introducing coloured fluids into vessels, the contents of which are naturally transparent, had long ago shown that there exists an order of vessels too minute to be otherwise detected. Dr. William Hunter has, even in later times, adopted the opinion that every living part is necessarily vascular; and that where there is no circulation, there can be no life. Mascagni was also a strenuous advocate of the hypothesis of the universal vascularity of the animal textures; but he conceived that every part is made up of a congeries of minute lymphatic vessels. We shall have occasion afterwards to point out the fallacy of these views.

(114.) Although the analysis of animal tissues, into the three primitive elements we have pointed out, namely, into the membranous, the muscular, and the nervous fibres, be founded on the most prominent and well marked features of distinction which they exhibit, yet there are perhaps other kinds of texture also, which possess sufficiently characteristic properties to entitle them to rank as elementary tissues: these are the *albugineous fibre* of Chaussier, and the *epidermoid substance;* and to these we might also add, in order to make the analysis complete, the *cartilaginous* and the *osseous structures.*

(115.) But this analysis of animal textures, has, by some later anatomists, been carried, in another point of view, still farther. With relation to the forms assumed by the elementary tissues, they have been referred to three kinds, the *fibrous,* the *lamellar,* and the *granular,* or *globular.* The two former are exemplified in the structure of the cellular substance, which composes the greatest portion of the animal fabric; the fibrous is characteristic of the muscular and ligamentous structures; the fibrous, united with the granular, is exhibited in the texture of the glands, and in the medullary substance of the nervous system; and the globular is most perfectly shown in the composition of the chyle, the blood, and several of the secretions.

(116.) Anatomists have sought for still more general results, by means of microscopical investigations. When very high magnifying powers are employed, both the muscular fibre, and the nervous or medullary matter, appear to be resolvable into a mass of globular particles, analogous to those which compose the opaque portion of the blood. Meckel has founded upon these observations the following system: He conceives that every animal structure is ultimately resolvable into two kinds of substance, the one formed into minute, but solid spherular masses, or globules; and the other, being an homogeneous, but amorphous matter, either uniting together these globules in the way of a cement interposed between them, or constituting by itself, what has been termed the cellular substance, membrane, and the various structures derived from membrane. Dr. Edwards, on the other hand, has carried this notion to the utmost possible length; for he represents the cellular and membranous substances, as being themselves composed of globules; so that, according to his views, the whole structure of an animal body will consist of globules.

But the later, and more careful investigations of Dr. Hodgkin and Mr. Lister,[1] appear to have established, that the globular appearance of the different organized textures, when viewed with microscopes of high magnifying power,

[1] *Philosophical Magazine*, and *Annals of Philosophy*, vol. ii. p. 186; and also in the appendix to their translation of Dr. Edwards' work.

is altogether an optical deception. A similar conclusion, indeed, was, many years ago, deduced by Dr. Monro, from his microscopical researches, detailed in his work on the Nervous System.

SECT. II.—*Combinations of Textures.*

(117.) Such being the results of the general analysis of animal textures, into a few primary elements, we are next to consider the combinations of these textures which are actually presented to us by nature, in the various organs of the body; and in order to possess the most comprehensive views on the subject, it will be proper to study these organs as forming systems of which the several parts are related to each other by similarity of composition and of properties. The most elaborate arrangement founded on this principle is that of Bichat, who distinguishes the constituent textures of the body into twenty-one different kinds.[1] But it may be objected to his classification, that it is founded on distinctions of function, as well as on those of structure. We therefore prefer following on this subject, the arrangement of Béclard, which proceeds on one uniform principle, namely, that of mechanical conformation. Taking this principle as our guide, we shall find that the systems of organs may be easily reduced to eleven different classes; namely, 1, the *Cellular;* 2, the *Adipous;* 3, the *Membranous;* 4, the *Dermoid;* 5, the *Ligamentous;* 6, the *Cartilaginous;* 7, the *Osseous;* 8, the *Muscular;* 9, the *Medullary* or *Nervous;* 10, the *Vascular;* and, 11, the *Glandular* systems of structures. The properties of these several tissues will come under our review in connexion with the functions to

[1] See his *Anatomie Générale.*

which they are more immediately subservient. The three first of these, however, claim our immediate attention, as being the simplest, and most generally diffused over the body.

1. *The Cellular Texture.*

(118.) This is the simplest form in which the animal substance presents itself to our observation; and it appears to be not only the real basis of the structure of all the other organs, but also the general medium which unites their several parts together, as well as the bond of connexion between adjacent organs. It is accordingly, of all the simpler textures, that which is the most extensively diffused over the body; not only pervading the substance of the organs, but also filling up all the intervening spaces, and preserving them in their proper relative situations. Haller found it to consist of an irregular assemblage of plates and fibres, crossing one another in all manner of directions; so that when stretched or expanded by the insinuation of any fluid between the plates, the whole presents a cellular structure. These cells, which are produced by the separation of the plates from each other, are of no regular shape, but communicate freely with one another throughout the whole extent of the substance in which they are met with.

(119.) As there is a continuity of the cellular substance in every part of the body, where it exists in this form, there must, in like manner, be a continuity in the cavities of these cells; and the consequence of this structure is, that any fluid, such as air, or water, which may happen to be introduced into any one part, will readily find its way into adjoining parts, and will thus gradually be diffused over the whole body. If the fluid be water, as happens in dropsies, it will, by its gravity, tend to accumulate in the most depending parts of the body, as the ankles, while a person is standing or sitting; and it will leave these parts, and be more generally distributed, after he has remained for some time in a horizontal posture.

The cellular texture may easily be inflated by air; and this may happen in consequence of injury, even during life; in which case the air gradually insinuates itself into every part of the frame, puffing up the skin to an extraordinary degree, so as totally to obliterate the features of the face, and disfigure the whole body. If measures be not taken to let the air escape, the patient is at length destroyed by suffocation. A remarkable instance of this disease, which is termed *Emphysema*, is given by Dr. William Hunter, in an essay on the properties of cellular texture, contained in the second volume of the *Medical Observations and Inquiries*,[1] and which also deserves particular notice, as presenting the best account of this branch of general anatomy.

(120.) The cells, or rather intervals between the plates and fibres of this substance, contain in the natural and healthy state, a quantity of aqueous fluid, which has been termed the *cellular serosity*, and which serves the purpose of lubricating the surfaces of the plates, and thus, by diminishing friction, of facilitating their relative motions on each other. To this circumstance we may also trace many of the mechanical properties of the cellular texture; such as its perfect flexibility, and its great extensibility in various directions; while it exerts, at the same time, considerable powers of cohesion. The combination of these two latter

[1] Page 26, et seq.

properties is the source of another, which it possesses in a very eminent degree, that of *Elasticity*, or the power of recovering its original form, when the disturbing force, whether producing compression or extension, has ceased to act. It is evident that by possessing all these properties, the cellular texture is eminently qualified to fulfil the important offices assigned to it, of serving as the elastic scaffolding or canvass for sustaining all the other parts, and retaining them in their proper situations ; and whilst it is the universal mechanical cement, or medium of connexion between them, it is at the same time admirably adapted to facilitate their relative movements and mutual actions, which are required for the performance of their respective functions.

(121.) Another property, besides elasticity, has also been ascribed to the cellular substance and other textures derived immediately from it. It consists in a peculiar kind of contractility, attended by a sudden corregation and curling up of its substance. As this property has been supposed to bear some relation to muscular contractility, we shall defer its consideration till we come to treat of that property.

2. *Adipose Texture.*

(122.) This texture contains the oily secretion which is known by the name of *fat.* The adipose matter, or fat, is lodged in particular portions of the cellular texture, appropriated to this office. It consists of very minute grains or globules, distinguishable only by the aid of the microscope. Each of these globules is contained in a separate investment, or sac, constructed of an exceedingly fine and delicate membrane, formed out of the constituent plates of the cellular substance, and having no external opening. The size of these vesicles is stated to be from the eight-hundredth to the six-hundredth part of an inch in diameter. They are collected together in small rounded masses, united by vessels, and presenting an appearance under the microscope, not unlike that of a bunch of grapes. They are lodged in the cells of the cellular substance in various situations throughout the body, and contribute to fill up the hollows which occur in different places between the bones and muscles, and other organs. They are very abundant immediately under the skin; and in some parts are evidently interposed as cushions for the protection of organs exposed to injury from pressure or other mechanical violence.

It is evident that the cells in the cellular substance which are occupied by the fat, are different from those which are the seat of dropsical accumulations of fluid; and that they do not, like the latter, communicate with one another; for it is found that each portion of fat always remains stationary in the same cell in which it was originally lodged.

(123.) The fat varies considerably in its consistence in different parts of the body, according to the purpose it is intended to serve. At the usual temperature of the living body, however, it is retained very nearly in a state of fluidity. The quantity accumulated in the body is very different at different periods of life; and varies also according to the state of health, and the peculiar habit and constitution of the individual. It is whiter in its colour, and more firm in its consistence, during the earlier periods of life, and becomes more soft, and acquires a yellow tinge as age advances.

(124.) The fat of animals has been resolved by *Chevreul*, who undertook an elaborate analysis of this substance, into two proximate principles, to which he gives the names of *stearin* and *elaïn*. The former, derived from the Greek word στεαρ, signifying tallow, is of a much more solid consistence than the latter in ordinary temperatures, and does not melt under a heat of from 110° to 120° of Fahrenheit. It is obtained from fat by digesting it in alcohol, in the form of white crystalline needles, which are deposited as the fluid cools. It is a white brittle substance, void of taste or odour, and resembling wax in its appearance. If, after the stearin has been deposited, heat be applied to the remaining solution, so as to drive off the alcohol, there remains an oily matter, which continues fluid at 59° of Fahrenheit, and is called, by *Chevreul*, *elaïn*, from the Greek term for oil, ἔλαιον.

The consistence of the fat of different animals, and in different parts of the same animal, admits of considerable diversity, according to the proportions in which these two ingredients are contained; the abundance of stearin is the principal cause of the hardness of tallow or suet, whilst an increased proportion of elain characterises the composition of marrow, which is one of the most fluid kinds of fat.

(125.) The marrow which occupies the central cavities of the cylindrical bones, and which also exists in small quantities in the canals that pervade the substance of the denser portions of the bones, is perfectly analogous in its composition and structure to the fat in other parts of the body. The oily particles are contained in membranous vesicles, which are themselves connected together, and retained in their places by a fine net-work of plates and fibres, corresponding to the general cellular structure of other parts, but of a peculiarly delicate contexture.

3. *Membranous Structures.*

(127.) When the texture of cellular substance becomes consolidated by the intimate adhesion of the plates and fibres of which it is originally composed, which, of course, produces the complete obliteration of its cells, it constitutes the different varieties of *membranous structures.* These structures are of different degrees of thickness, and compose masses of different degrees of density. When expanded into a continuous sheet or plate, it forms what is more properly termed a *membrane.* These membranes, when sufficiently thin, are semi-transparent, and have a smooth and uniform surface. Haller found that all membranes are resolvable, by long maceration in water, into a flocculent spongy substance, in which the original cells of the cellular texture from which they were formed, could be rendered apparent by inflating them with air.

(128.) Membranes retain almost all the mechanical properties belonging to the cellular substance from which they are derived; for they are equally flexible and elastic, although possessing superior strength and firmness. But in one respect they exhibit a marked difference, while the simple cellular texture, as we have seen, allows of the general communication of fluids introduced into its cells, from one part to another; membranes are for the most part impermeable to fluids, and are in consequence employed with the express design of preventing their diffusion.

(129.) The property possessed by membranes of contracting in their dimensions by the evaporation of the water they contain, and which is united with the animal material by a very weak affinity, constitutes what may be termed the *hygrometric property.*

All the membranes are capable of being dried by the continued application of a moderate heat, and may be kept in this dry state for a great length of time without undergoing any change. But if a dry membrane be immersed in water, it absorbs a considerable quantity, recovers its softness and flexibility, and expands in all its dimensions. These effects are greater when the action of warmth is combined with that of moisture. A membrane will absorb moisture even from the atmosphere, and again part with it, according to its different states of humidity. Philosophers have availed themselves of this property in the construction of an hygrometer, or instrument for indicating these varying states of the atmosphere with respect to dryness or humidity. Any long slip of dried membrane, suspended in the air, and stretched by a moderate weight, may be made to act on a moveable index by any mec' anical contrivance rendering the variations in its length visible on a large scale, and will serve the purpose of an hygrometer. The membrane will be found to lengthen by exposure to a humid atmosphere, from which it imbibes moisture, and again to contract by the evaporation of this moisture in a drier air.

A piece of catgut, which is prepared from the membrane of a sheep, will answer the same purpose. We find, accordingly, that the state of the weather has a considerable effect upon the tone of a musical instrument made of catgut. A violin, or harp, may be in perfect tune in one situation, and yet become quite out of tune when placed in an atmosphere of greater humidity, as in that of a room filled with company.

The principle of which these facts are illustrations, is to a certain extent applicable to the animal body. The doctrine of the animal fibres being braced or relaxed, which was formerly a more fashionable language than it is at present, may perhaps have been carried too far, but it has certainly a foundation in truth. Warmth and moisture have a powerful influence on the body, and their effect is partly mechanical; and this operation, which is primarily exerted on the skin, renders them efficacious in the relief of inflammatory action, by diminishing the tension of the inflamed parts. This effect is not merely temporary, but may become the permanent habit of the system. Thus, we find that the inhabitants of elevated countries where the air is peculiarly dry, are more hardy, and possess more of the *vis tonica* in their frames, than those who dwell in a humid climate, or in low and swampy plains. The Swiss and other inhabitants of mountainous tracts, may in this respect be contrasted with the Dutch and Flemish, who have in general a constitutional laxity of fibre; and similar differences have been observed in the lower animals among varieties of the same race.

(130.) All these properties of membrane, taken together, adapt them for being employed in various useful ways in the animal economy. Membranes in general are employed to establish relations not only between adjacent, but also between distant parts; they strengthen their connexions, and, whilst in some they allow of relative motions in certain directions, and to a certain extent, in others they restrain them and limit their degrees. Almost every organ is furnished with a firm covering of membrane, which gives it protection and support. For all these purposes, a looser and more yielding cellular tissue would not have possessed adequate strength.

(131.) As the cellular substance is the basis of membrane, so membrane, in different modifications, constitutes the essential portion of many other parts of the body; such as all those recipient organs, having the form of sacs or pouches, like the stomach, and especially those which are provided for the retention of fluids, as the gall-bladder, and urinary bladder. Membranes are also formed into tubes of various kinds, destined to transmit their fluid contents to various parts. These tubes, known under the name of *vessels*, *canals*, or *ducts*, are also frequently furnished with a valvular apparatus, likewise composed of membrane, allowing of the passage of the fluid only in one direction.

(132.) The structure and properties of every description of membranes have been minutely investigated by Bichat, who, in his *Anatomie Générale*, has given us an elaborate classification of the animal textures. He establishes two general divisions of membranes, namely, the simple and the compound. Of the former he makes three classes; first, the mucous membranes, the surface of which is defended by a mucous secretion; secondly, the serous membranes, characterised by the serous nature of the fluid with which their surface is constantly moistened; and, thirdly, the fibrous membranes, which are distinguished by their peculiar structure, as being composed of dense and inelastic fibres. The compound membranes are formed by the intermixture of two or more of the simpler membranes, and exhibit a combination of the characters of each.

(133.) *Serous membranes* are universally met with whereever there are internal cavities in the body, which are closed on every side, that is, have no communication, by any channel, with the external air; such cavities being always lined by serous membranes. This is exemplified in the cavities of the chest, which are three in number; namely, one on each side, containing the right and left lung, and the intermediate cavity, occupied by the heart. The membranes lining the former are called the *pleuræ*; and the membrane lining the latter, the *pericardium*. The great cavity of the abdomen, in which are situated the organs of digestion and chylification, is lined by the *peritoneum*, which is also a serous membrane. The same, also, applies to the cavities in the interior of the brain, which are called *ventricles*, and also the external surface of the organ, which are lined by the *dura mater*, the *arachnoid coat*, and *pia mater*. The serous membranes, after lining their respective cavities, are extended still farther, by being reflected back upon the organs inclosed in their cavities, so as to furnish them with an external covering. If it were possible, therefore, to dissect these membranes from off the parts which they invest, they would have the form of a sac without an opening, the organ invested by one of their folds, being altogether external to the cavity of that sac; just as happens when a double night-cap is worn, of which the part immediately covering the head is analogous to that portion of the serous membrane which adheres to, and invests the organ; whilst the external portion of the cap represents the lining of the cavity in which that organ is said to be contained.

(134.) Hence it will readily be understood, that the serous membranes never open, or allow of any perforation, for the passage of blood-vessels, nerves, or ducts, to or from the enclosed organs; but that they are always reflected over those parts, forming a sheath round them, and accompanying them in their course. It also follows, as a necessary consequence, that their free surfaces completely isolate the parts between which they intervene. The great viscera, suspended in the bags formed by their serous coverings, can have no communication with the adjacent parts, except at the points where their vessels enter; in all other situations there is no continuity of parts, although there may be contiguity.

(135.) In every serous membrane we may distinguish two surfaces having very different characters: the external surface, or that by which they adhere to the surrounding organs, and the internal surface, which is in immediate contact with another portion of the same membrane, but without adhering to it. This interior surface is remarkable for its perfect smoothness and polish; and it is continually preserved in a state of moisture by a serous fluid, which exudes from it. This fluid has been termed the *liquid of surfaces*, and consists almost entirely of water, with a very minute proportion of albuminous matter. Its presence is evidently of the greatest use in facilitating the motions of the parts contained within the cavities, with relation to their sides, by diminishing friction, preserving the smoothness of the surfaces applied to each other, and preventing their mutual adhesion. When the internal surface of these membranes is exposed to the air in living animals, or immediately after death, this fluid exhales in the form of vapour, to which formerly great attention was paid, and which was dignified with the name of *halitus*. In consequence of disease, this fluid of surfaces sometimes accumulates in one of these cavities, and thereby produces a dropsy of that respective cavity: a fact which proves the power of serous membranes to retain these fluids, and not, as in the case of the cellular substance, to allow of their diffusion into the adjoining organs.

(136.) The serous membranes constitute the simplest form of condensed cellular substance; they are not divisible into any regular layers; although cellular portions may be removed from the outer surface by which they are attached to the surrounding parts. In the natural state they are exceedingly thin and transparent; but become thicker and opaque by disease. Although perfectly flexible, they possess considerable strength; they are exceedingly extensible; but they are not in the same proportion elastic: for after they have been stretched, they give but feeble indications of a power of retraction.

4. *The Osseous Fabric.*

(137.) For the purpose of thoroughly understanding the whole mechanism and operations of any complicated engine, or system of machinery, the best and most natural course is to commence with the study of the solid framework, which gives stability to the whole fabric, and affords fixed bearings from which the powers, regulating the movements of its different parts, exert their respective powers. This purpose of procuring mechanical rigidity and support, is the appropriate function of the osseous system, or *skeleton*; which is composed of a connected series of solid structures, called *bones*, deriving their mechanical properties from their peculiar chemical composition, and almost crystalline hardness, and which constitute one of the most important of the constituent textures of the body. Our first object of attention, therefore, in considering the mechanical functions, is the study of this system of structures.

(138.) The bones, then, are to be viewed as the densest and most solid parts of the animal frame; constituting the basis of support to the softer textures, affording protection to all the vital organs, and furnishing those powerful levers which are essential to the advantageous action of the muscles concerned in locomotion, and in the various movements of the limbs. With reference to their form, they have usually been divided into three classes: the *long cylindrical bones*; the *broad and flat bones*; and the *short or* *square bones*, which include those of a more irregular form, and not referable to either of the other two heads. To the first class belong the principal bones of the upper and lower limbs, which are adapted more especially to the purposes of motion. Under the second may be ranked the bones of the skull, which serve for the protection of the brain; and the third include the vertebræ, the bones of the face, and the small bones which concur in the formation of the wrist and the ankle. There are, besides, other bones, such as the ribs and the bones of the pelvis, of a more anomalous description, which are rather distinguished by their irregularity than by any definite character.

(139.) On examining the mechanical structure of bones, we find that their external surface is generally their hardest part, and that it consists of a solid plate, or layer of bony matter, of different thickness in different bones, and in different parts of the same bone. In the cylindrical bones this firm and compact substance extends only to a certain depth, and within this the structure is spongy and cellular. To the latter part the name of *cancelli* has been given. In the middle of the long bones the central parts are occupied by the marrow; but as we continue our examination, by taking different sections across the bone, in proportion as we approach the extremities, we find the dense external substance diminishing in thickness, while the proportion of the spongy part increases, and encroaches upon the space in the centre occupied by the marrow, which at length disappears, so that at the very extremity of the bone, nearly the whole area of the section is filled by the cancelli, while the outer covering of solid bone is merely a thin superficial plate. In the flat bones, having, of course, an upper and under surface, the plates of bone forming each of these surfaces, are termed the two *tables*, and the cellular portion which is found between them is called the *diplöe*. In many of the more irregularly shaped bones, neither cancelli nor diplöe are found, the whole substance being compact. Dr. Bostock observes, that the transition from the compact to the spongy part of a bone is not marked by any decided limit; but they pass into each other by insensible degrees, so as to shew that there is no essential difference between them.[1]

(140.) Bones present the appearance of fibres on their surface. This is seen particularly in all bones that have been long exposed to the weather, or that have been long boiled. In the cylindrical bones most of these fibres are longitudinal; but in the flat bones they generally run in a radiated direction. In the short bones their course is much more irregular and difficult to trace. In the compact part of the section of a bone, the appearance of plates is not very distinguishable; but certain cavities are discovered which, for the most part, run in a longitudinal direction, and nearly parallel to one another. They are of various lengths; and their diameters are exceedingly small. They have transverse or oblique canals, which establish communications between them; and some of which also open into the larger cancelli in the middle of the bone. These cavities have been called the canals of Havers,[2] who first discovered them. Their existence, however, was for a long time considered as dubious; but it has been lately verified by Mr. Howship,[3] who, with the help of the solar microscope, obtained distinct views of them, and was enabled to trace their course. He ascertained the diameter of these canals to be about the

[1] *Elementary System of Physiology*, third edition, p. 61.

[2] *Osteologia nova*, § 35, 37.

[3] *Medico-Chirurgical Transactions*, vii. 393.

400th of an inch; and farther discovered that they are lined with an extremely fine vascular membrane, and that they are filled with marrow.

(141.) The intimate structure of bone was first minutely investigated by Malpighi, who discovered that its basis consists of an animal membrane having an areolated, or cellular form. Duhamel[1] next ascertained that this membranous matter was frequently disposed in plates or laminæ; and he described these plates as forming concentric rings, analogous to those which compose the trunk of a tree; but there is no other foundation than mere fancy for this analogy. We owe to Herissant[2] the important fact, that the chief properties of bone are derived from the presence of an earthy ingredient, which is deposited in the animal basis, or parenchyma of the bone.

(142.) The analysis of a bone into its two constituent parts is easily effected by the agency either of acids or of heat. By macerating a full-grown bone for a sufficient time in diluted muriatic acid, the earthy portion of the bone, amounting to nearly one-third of its weight, is dissolved by the acid; the animal portion only remaining. This animal basis retains the bulk and shape of the original bone, but is soft, flexible, and elastic; possessing, in a word, all the properties of membranous parts, and corresponding in its chemical character to condensed albumen.[3] A portion of this solid animal substance affords gelatine by long boiling in water, especially under the pressure, admitting of a high temperature, to which it may be subjected in Papin's digester. On

[1] *Mémoires de l'Académie des Sciences*, pour 1739, 1741, 1742, and 1743. [2] Ibid. 1758.

[3] This was first satisfactorly shewn by Mr. Hatchett. *Phil. Trans.* for 1800.

the other hand, by subjecting a bone to the action of fire, the animal part alone will be consumed, and the earth left untouched, preserving, as before, the form of the bone, but having lost the material which united the particles, presenting a fragile mass which easily crumbles into powder. This earthy basis, when chemically examined, is found to consist principally of phosphate of lime, which composes eighty-two hundredths of its weight; and to contain also, according to Berzelius, minute portions of fluate and carbonate of lime, together with the phosphates of magnesia and of soda.

Dr. G. O. Rees, who has lately made exact analysis of different bones taken from the same individual, in a state of perfect dryness, and quite free from fat, periosteum, or cartilage, deduces from his researches the following conclusions:[1]

1. The long bones of the extremities contain more earthy matter than those of the trunk.

2. The bones of the upper extremity contain somewhat more earthy matter than the corresponding bones of the lower extremity; thus the humerus more than the femur, and the radius and ulna more than the tibia and fibula; this difference is, however, small, being about one half per cent.

3. The humerus contains more earthy matter than the radius and ulna, and the femur more than the tibia and fibula.

4. The tibia and fibula contain, as nearly as possible, the same proportions of animal and earthy matter, and the radius and ulna may also be considered alike in constitution.

5. The vertebræ, ribs, and clavicle, are nearly identical as regards the proportion of earthy matter; the ileum contains somewhat more of the earth, the scapula and sternum

[1] *Medico-Chirurgical Transactions*, xxi. 409.

somewhat less; the sternum contains more earthy matter than the scapula.

6. The bones of the head contain considerably more earthy matter than the bones of the trunk, as observed by Dr. J. Davy; but the humerus and other long bones are very nearly as rich in earths.

7. The metatarsal bones may probably be ranked with those of the trunk in proportional constitution.

8. The cancellated structure (at least in the rib) contains less earthy matter than the more solid parts of the bone; this difference, however, is not considerable.

9. The bones of the trunk of the fœtal skeleton are as rich in the proportion of earthy matter as those of the adult; at least the difference is too small to be material.

10. The bones of the fœtal extremities, on the other hand, are deficient in earthy matter, which is a fact simply explicable from the circumstance that such an excess of earths as appears necessary to very great strength of bone is not needed at birth, and therefore only appears in after life.

The existence of a general law, regulating the proportion of earthy deposit in the different bones, (which is shown by the curious agreement of relative proportions observed between the fœtal and adult skeletons,) adds one more to the many proofs of the regularity and perfection of design which nature evinces in her operations.

(143.) It appears evident, then, from these and other facts, that the basis of the osseous structure is essentially the same as that of membranous parts, being composed of fibrous laminæ or plates, which are connected together so as to form, by their intersection, a series of cells analogous to those of the cellular texture. In the interstices of these plates, or in the cells themselves, the particles of phosphate of lime are deposited; the particles being held in union by the interposed membrane, which performs the office of a cement. Hence there is no necessity for admitting the hypothetical explanation of Gagliardi,[1] who maintained that the bony plates are held together by small processes, like nails, which, rising from the inner plates, pierce through the adjoining ones, and are fixed into the more external plates. Of these processes, or *claviculi*, as he called them, he described four different kinds, the perpendicular, the oblique, the headed, and the crooked. But no subsequent anatomist has been able to verify these observations; and the account given by Gagliardi remains on record as a curious instance of the extent to which an observer of mere appearances is liable to deceive himself by the influence of too vivid an imagination. Monro states, that in bones fitly prepared, he could only see numerous irregular processes rising out from the plates. Duhamel, trusting to a fancied analogy between the process of ossification, and the growth of trees, imagined that a bone is composed of a series of regular concentric laminæ. But this hypothesis has been refuted by Scarpa,[2] who investigated, with great care, both the mechanical structure of bone and the mode of its formation; and concludes that the ultimate texture of bone is not lamellated but reticular. Raspail has indulged in speculations of a still more questionable nature respecting the ultimate osseous texture, which he endeavours to assimilate with that vesicular form, which he views as the essential character both of animal and of vegetable organization. Dr. Benson observes[3] that all writers, before the time of Scarpa, considered the structure of bone as laminated, or fibrous

[1] *Anatomia Ossium.* [2] *De Perit. Structura Ossium.*

[3] *Cyclopædia of Anatomy and Physiology*, vol. i. p. 433.

and laminated; whilst, according to all later authorities, it should be regarded as cellular. In the works of the former, however, we may notice intimations of a reticular texture; and in those of the latter, on the other hand, we meet with the expressions of a *tendency* or *disposition* to a laminated arrangement. "If, with these opinions before us," he continues, "we come to examine for ourselves, we shall have no hesitation in agreeing with Scarpa that it is really cellular. At the same time, it must be confessed, that the sides of the cells are, in the compact tissue, so pressed together, that the appearance of laminæ is often very striking; and, again, that the sides of the cells have, in most places, the appearance of fibres; when the earthy portion is removed by an acid, we can tear out with a pin the membranous fibres, and almost demonstrate the fibres. But a closer examination will shew that we have torn the cells, and destroyed the true texture. The laminated disposition supposed to be shewn by exfoliation, the weather, burning, &c., may all be proved to be deception; and there can seldom, indeed, be exhibited a plate, however small, of equal thickness throughout, which has been removed by any of these agents. There is, however, an approach to the laminated arrangement, and every cell is formed of particles which approach to the form of fibres. The longitudinal canals of Havers, Leuwenhoeck, and Howship, probably result from the flattened cells, and may be deceptive appearances in the old bone, or the channels for blood-vessels, &c."

(144.) Bones are invested on every part of their surface, excepting in those parts where they are plated with cartilage, with a firm plate of membrane, termed the *periosteum*, which conveys blood-vessels to the bone, and establishes mechanical connexions between it and surrounding parts.

This membrane belongs to the class of fibrous textures, being composed of numerous inelastic fibres of great density and strength, passing in various directions, and composing a kind of ligamentous tissue, interlacing with the fibres of the ligaments which encircle the joints.

The inner surface of the periosteum is connected with the bone by the vessels passing from the one to the other, and also by numerous prolongations which dip down into the osseous substance. The blood-vessels of this membrane are numerous, and easily rendered apparent by means of injections, especially in young subjects. Besides the more obvious uses of the periosteum, in affording protection to the surface of bones from injurious impressions they might receive from the action of surrounding parts, and interposing a membranous layer for the defence of the latter, Bichat ascribes to it the more important office of affording fixed centres of support to the general system of fibres, in its mechanical relations to the rest of the frame. The periosteum which covers the bones of the skull has received the name of the *pericranium*.

(145.) The internal cavities of the bones are, as is well known, occupied by an oily secretion, termed the *marrow*, contained in a delicate structure, composed of minute vesicles which are filled with the fluid oil, and which are connected by fine threads and plates of fine cellular tissue. Monro describes the vesicles as perfectly distinct, having no communication with one another, and as presenting, under the microscope, the appearance of a cluster of pearls.

Many have been the conjectural uses assigned to the marrow by the older physiologists; it was at one time very generally imagined that it served, by its mechanical properties, to temper the brittle quality of the earthy materials form the chief constituent portion of the bone; a purpose, however, which it is impossible it could fulfil, as, instead of being mixed up and blended with the phosphate of lime, or diffused generally through the substratum of the bone, it is lodged in separate cavities, and thereby prevented from any union with bony matter, or intermixture with its substance. The marrow is, in general, possessed of little sensibility, except in a few points, where it is traversed by the nervous filaments supplying the bone itself. It is regarded by physiologists of the present day rather as constituting a part of the general store of nutritious matter, which is kept in reserve for particular occasions of exigency, than as having any mechanical relation with the dense texture within which it is lodged. The circumstance of its being wholly absent in the bones of birds is a clear proof that there is no mutual dependence between the functions of the latter and the presence of the marrow.

(146.) All the internal cavities of bones occupied by the marrow are lined with a vascular membrane, which follows all the windings of the canals and of the cancelli, and has been called the *internal periosteum*. It may easily be rendered visible by sawing a long bone longitudinally, and plunging it in boiling water, by which treatment the membrane is made to detach itself from the bone, and contract upon the marrow which is within it, and to which it is closely attached. It has then the appearance of a fine cobweb.

5. *Cartilage.*

(147.) The structure which ranks next to bone in respect to its density is *cartilage*, a term which expresses a firm and dense substance, apparently homogeneous in its texture, semipellucid, and of a milk-white or pearly colour. Substances of this description are found to enter into the composition of several parts of the body. The surface of a cartilage is perfectly uniform, and presents no visible eminences or pores; nor can any cavities or inequalities of any kind be perceived in its internal texture. When it is cut into with a sharp knife, the section exhibits an uniform appearance, like that of a piece of glue. Yet, after exposure for a certain time, the surface thus cut begins to contract, and a serous fluid is perceived slowly to exude from it, proceeding from certain invisible pores, which are in all probability minute capillary vessels, of which the diameters are too small to admit the coloured globules of the blood. That a delicate system of circulating passages exist in cartilages, is shewn by various diseased conditions, in which sometimes granulations have been seen to arise from their surfaces, and at other times extensive absorption of their substance has taken place; and although insensible, on ordinary occasions, to wounds inflicted by cutting instruments, yet in others, when sudden pressure is made on them under peculiar circumstances, extreme pain arises, giving warning of serious injury impending.

Cartilaginous structures appear to be composed of albumen alone, with scarcely any intermixture of gelatin. Dr. John Davy found that they contain a small proportion of phosphate of lime, amounting to about the two hundredth part of their weight. Mr. Hatchett, however, does not regard this substance as an essential ingredient in their composition.

The mechanical property which particularly distinguishes cartilage is elasticity, a quality which it possesses in a greater degree than any other animal structure, and which adapts it to many useful purposes in the economy. Hence it forms the basis of many parts where, contrary to the purposes answered by the bones, pliancy and resilience as well as firmness are required; and hence cartilage is employed when a certain shape is to be preserved, together with a capability of yielding to an external force. The flexibility of cartilage, however, does not extend beyond certain limits; if these be exceeded, fracture takes place. Great density bestowed upon an animal structure, indeed, appears to be in all cases attended with a proportionate degree of brittleness. These mechanical properties of cartilages, as well as their intimate structure, although nearly homogeneous in all, are subject to modification in different kinds of cartilage. Cartilages are covered with a fine membrane termed the *perichondrium*, analogous in its structure and office to the periosteum, which we have already had occasion to point out among the fibrous membranes, as investing the bones.

(148.) Cartilages are distinguished into those which are *temporary* and those which are *permanent structures*. The former are only met with in the earlier periods of life, during the growth of the body, and are gradually removed to make way for the deposition of bone. When about to undergo this change, small canals have been detected in the substance of these temporary cartilages. The permanent cartilages are those which retain the cartilaginous structure throughout every period of life. They have been distinguished into three or four different kinds, such as the membraniform, the interosseal, the articular, and the interarticular cartilages.

(149.) The *membraniform cartilages* are included by Bichat in the class of fibro-cartilaginous structures hereafter to be described. They furnish a basis of support to the softer parts, and in some measure supply the place of bone, giving a determinate shape and firmness to parts where bone would have been inconvenient. They possess greater tenacity and less brittleness than the other kinds of cartilage. By their elasticity they admit of considerable variation of figure, yielding to external pressure, and recovering their proper shape as soon as the pressure is removed. Of this kind are the cartilages of the nose and ear, and also those of the larynx and trachea. These cartilages are extremely thin, and are invested with a very thick and firm perichondrium, to which they are connected by means of a number of fibres traversing their substance, and rendering their surfaces rough and porous. Long maceration enables us to detect these fibres, and to resolve the whole into a cellular and albuminous substance.

(150.) The *interosseal cartilages* pass from one bone to another, adhering firmly by their extremities to each. They answer the same purpose as would be attained by an increase of extent in one or both of the bones, with the further advantage of allowing of obscure degrees of motion, and deadening the effects of jars incident to percussion. The cartilages of the ribs are of this class. They are covered with perichondrium. When they have been steeped in water for a great many months, they are divisible into laminæ, of an oval shape, which are united by fibres passing obliquely between them.

(151.) The *articular*, or *diarthrodial cartilages*, are those plates of cartilaginous substance which adhere firmly, and almost inseparably, to the surfaces of those bones which are opposed to each other in the joints, or over which tendons and ligaments slide. In some joints the whole of the surface of the bone within the capsular ligament is covered with cartilage; in others, only the parts of bones which move upon each other; the remaining part being covered with ligament. This latter disposition is met with in the joint of the hip. This kind of cartilage, like the others, appears perfectly smooth on its surface, and also when a section is made through its substance; but by a sufficiently long maceration, to allow of a commencement of putrefaction, its fibrous structure may be detected. The elastic resilience of these cartilages has a powerful tendency to lessen the shocks incident to sudden and violent actions.

(152.) Cartilages of a similar kind are found in the cavities of certain joints, and have hence been called *interarticular cartilages*. They have no immediate connexion with the bones forming the joint, but are attached only to the inside of the capsular ligament. They are thus rendered somewhat moveable, and being interposed between the bones, allow them a greater latitude of motion, while they at the same time contribute to adapt their surfaces more perfectly to each other. By long maceration in water, a laminated structure is more distinctly perceived in this kind of cartilage than in any of the others.

6. *Fibro-Cartilaginous Structures.*

(153.) Many structures exist in the human body which appear to be of an intermediate nature between ligament and cartilage, in which a fibrous texture is united to a cartilaginous basis, and which combines the characteristic properties of both these textures. They are distinguished from the purely ligamentous parts by their high degree of elasticity, and from cartilage by their fibrous texture. Accordingly we find them employed when this combination of properties is requisite for the functions of the parts. They form additions to interarticular ligaments, and eke out the borders of cavities adapted to the reception of the rounded heads of bones.

(154.) The principal instances of large masses of fibro-cartilaginous structures occur in those which unite the bodies of the vertebræ and of the bones of the pelvis. These *intervertebral substances*, as they are termed, impart great elasticity to the spine; and diminish the effects of concussion. When the body has been long in the erect position, the weight of the head and upper parts of the trunk occasions the compression of these intervertebral substances, and the height of the person is diminished. By continuance for an equal time in a horizontal posture, this superincumbent pressure being removed, they recover their original dimensions. Hence a person is taller when he rises in a morning than after sustaining the fatigues of the day; and the difference of stature often amounts to a whole inch.

7. *Ligamentous Structures.*

(155.) Structures possessing inferior degrees of solidity, but still exhibiting structures of considerable density, are met with in the interior of the body, and serve various mechanical purposes of cohesion and support. Many of these may be regarded as mere modifications of membrane; but yet the peculiarities of structure and of properties exhibited by ligamentous textures point them out as requiring to be classed separately. Bichat, who has viewed them as composing a system of structures, has given to it the title of *the fibrous system*; a name which is liable to the objection of not being sufficiently distinctive; since, as we shall afterwards find, many other parts, and especially the muscles, are no less fibrous than the tendons and the ligaments. As a general designation of this class of fibres, we have therefore preferred the term of *ligamentous system*, which sufficiently expresses the general mechanical purpose which they are designed to serve in the animal economy.

(156.) This system includes a great number of structures, which, although very similar in their nature and office, have received different names, such as *ligaments*, *tendons*, *fasciæ*, *aponeuroses*, *capsules*, &c. Fibres of a similar kind to those which constitute these parts, also enter into the composition of other organs, imparting to them different degrees of mechanical strength.

(157.) Various as are the forms and dispositions assumed by ligamentous fibres, they present us with two principal varieties, according as they are expanded into thin and broad plates, or ligamentous membranes, or collected into thick and elongated cords. The first division includes fibrous membranes, fibrous capsules, tendinous sheaths, and aponeuroses.

(158). *The fibrous membranes* resemble ordinary membranes, but have, superadded to the structure of the latter, numerous denser fibres, which give them greater strength, and fit them for affording mechanical support to various organs. Thus the periosteum of the bones is a membrane of this description. The internal periosteum of the skull or *dura mater* has a similar structure. The external coat of the globe of the eye, or *sclerotica;* the investing membranes of many of the glands, as the kidneys, belong to the class of fibrous membranes; to which also we may perhaps refer some of the coats of the larger blood-vessels, and of the excretory ducts of glands. Besides enveloping organs, these fibrous membranes often extend into their interior, forming partitions, or even cells, which contribute to their firmness and support.

(159.) *The fibrous capsules* present the form of sacs, which surround certain joints, especially those of the shoulder and hip, and preserve the connexion between the bones which form these joints. These capsules, again, are lined internally by serous or synovial membranes, supplying the fluid which lubricates the surfaces of the parts playing upon each other.

(160.) *The tendinous sheaths* are formed by fibrous membranes of a cylindrical shape, which surround the tendons in those parts where they pass over bones, and are particularly subjected to friction, or liable to occasional displacement during the action of the muscles which move the joint. Some of these include only one tendon in their respective cavities, as those of the fingers and toes: others receive several tendons, as those belonging to the muscles of the wrist and ankle joints.

(161.) *Aponeuroses* consist of extended sheets of fibrous texture, principally belonging to the organs of locomotion; and disposed in some instances so as to form coverings of parts; while in others they constitute points of attachment to muscles. Thus they may be distinguished into aponeuroses for enveloping, and aponeuroses for insertion. The former, which are generally termed fasciæ, either surround the muscles of the limb, forming a general sheath for it, as in the fore-arm and thigh; or else they invest and confine some particular muscles. The aponeuroses for insertion either form broad or narrow surfaces, or consist of separate fibres, giving attachment to particular portions of muscles, or form arches, which both admit of their connexion with muscular fibres, and at the same time allow of the passage of vessels.

(162.) The second division composes the proper ligatherefore preferred the term of *ligamentous system*, which sufficiently expresses the general mechanical purpose which they are designed to serve in the animal economy.

(156.) This system includes a great number of structures, which, although very similar in their nature and office, have received different names, such as *ligaments*, *tendons*, *fasciæ*, *aponeuroses*, *capsules*, &c. Fibres of a similar kind to those which constitute these parts, also enter into the composition of other organs, imparting to them different degrees of mechanical strength.

(157.) Various as are the forms and dispositions assumed by ligamentous fibres, they present us with two principal varieties, according as they are expanded into thin and broad plates, or ligamentous membranes, or collected into thick and elongated cords. The first division includes fibrous membranes, fibrous capsules, tendinous sheaths, and aponeuroses.

(158). *The fibrous membranes* resemble ordinary membranes, but have, superadded to the structure of the latter, numerous denser fibres, which give them greater strength, and fit them for affording mechanical support to various organs. Thus the periosteum of the bones is a membrane of this description. The internal periosteum of the skull or *dura mater* has a similar structure. The external coat of the globe of the eye, or *sclerotica;* the investing membranes of many of the glands, as the kidneys, belong to the class of fibrous membranes ; to which also we may perhaps refer some of the coats of the larger blood-vessels, and of the excretory ducts of glands. Besides enveloping organs, these fibrous membranes often extend into their interior, forming partitions, or even cells, which contribute to their firmness and support.

(159.) *The fibrous capsules* present the form of sacs, which surround certain joints, especially those of the shoulder and hip, and preserve the connexion between the bones which form these joints. These capsules, again, are lined internally by serous or synovial membranes, supplying the fluid which lubricates the surfaces of the parts playing upon each other.

(160.) *The tendinous sheaths* are formed by fibrous membranes of a cylindrical shape, which surround the tendons in those parts where they pass over bones, and are particularly subjected to friction, or liable to occasional displacement during the action of the muscles which move the joint. Some of these include only one tendon in their respective cavities, as those of the fingers and toes: others receive several tendons, as those belonging to the muscles of the wrist and ankle joints.

(161.) *Aponeuroses* consist of extended sheets of fibrous texture, principally belonging to the organs of locomotion; and disposed in some instances so as to form coverings of parts; while in others they constitute points of attachment to muscles. Thus they may be distinguished into aponeuroses for enveloping, and aponeuroses for insertion. The former, which are generally termed fasciæ, either surround the muscles of the limb, forming a general sheath for it, as in the fore-arm and thigh; or else they invest and confine some particular muscles. The aponeuroses for insertion either form broad or narrow surfaces, or consist of separate fibres, giving attachment to particular portions of muscles, or form arches, which both admit of their connexion with muscular fibres, and at the same time allow of the passage of vessels.

(162.) The second division composes the proper ligaments and tendons, all of which have more or less the form of cords.

The *ligaments* connect together the articular surfaces of bones, and oppose a very considerable resistance to any force tending to their displacement. The fibres which enter into their composition, generally preserve a direction nearly parallel; but frequently they are extended in various ways, forming an intertexture calculated to resist extension in different directions; and from their mere flattened form, bringing these ligaments nearer to the description of fibrous membranes.

(163.) The *tendons* are generally more simple in their structure, consisting of elongated cords; but in some instances they are more complicated, being divided into several smaller cords.

(164.) Bichat[1] has exhibited, in the following table, a general view of the preceding classification of what he calls the *fibrous system.*

Fibrous organs,	In the membranous form.	Fibrous membranes.		
		Fibrous capsules.		
		Fibrous sheaths, .	Partial.	
			General.	
		Aponeuroses. .	For envelopment.	Partial.
				General.
			For insertion	In a broad surface.
				In an arch.
				In separate fibres.
	In the form of cords.	Ligaments. .	With regular fasciculi.	
			With irregular fasciculi.	
		Tendons. .	Simple.	
			Complicated.	

(165.) The structure of all these parts, as their name imports, is essentially fibrous; the individual fibres which

[1] See his *Anatomie Générale*, tom. iii. p. 142.

compose them being exceedingly slender filaments of a very dense, firm, and inelastic substance; sometimes parallel to each other, as in the tendons and ligaments, and sometimes variously interwoven, as in the fibrous membranes. In some portions of the denser structures hereafter to be noticed, the fibres are so closely united as to present an almost homogeneous appearance; but in all the parts hitherto considered, the bundles of fibres admit of being separated by maceration; and are resolvable into lengthened filaments of extreme tenuity. It has not been perfectly ascertained what is the diameter of the fibres when this subdivision has been carried to its utmost limit; but they appear in this ultimate state of division to be as fine as the filaments spun by the silk-worm. These ultimate fibres are distinguished by their flexibility, their extreme tenacity, and their brilliant whiteness. They are probably in no case tubular, but solid throughout, although Mascagni, extending to them his general system of organic textures, regards them as formed of lymphatic vessels. Chaussier,[1] with great appearance of truth, considers them as a peculiar and primary organic tissue, to which he has given the name of the *albugineous fibre*, in order to distinguish it from the mere simple cellular or membranous fibre, which constitutes the basis of the general substance of the body.

(166.) The fibres which enter into the composition of these ligamentous textures, are united by a cellular tissue of extreme fineness and tenuity, which is rendered evident after maceration when the ligamentous fibres are drawn asunder. Their arrangement at the surface of these structures is such as to produce that glistening and satin-like lustre

[1] *Dictionnaire des Sciences Médicales.* Organization.

which results from a surface of high polish and density; an appearance which is very characteristic of the fibrous structures. This smoothness and resplendent white colour is possessed in the greatest degree by tendons, which have in general a greater extent of motion than the ligaments, and therefore require a higher degree of polish.

SECT. III.—*Mechanical Connexions.*

1. *Articulation.*

(167.) Having noticed the properties of those elementary textures that furnish those cohesive and resisting forces which are necessary for the mechanical purposes of the animal fabric, we have next to review those combinations of structure which have been adopted for establishing the connexions between the various parts of the frame, and which adapt them to those objects. These modes of connexion admit of great variety, according to the different mechanical relations which must take place between them; and more particularly with reference to the degrees of mobility which are to result from their union. In many cases the parts placed in juxtaposition require to be fixed in their places by the firmest bonds which can secure their relative immobility: in others, the freest motion must be allowed; while in various other instances, we find almost every intermediate degree of flexion allowed, and every kind of connecting mechanism employed. But from the deep implanting of the teeth in the jaws, like nails firmly fixed in wood, and the mutual locking in of the bones of the skull by indented sutures, like the dove-tailed junctions of carpentry, to the freely rotating joints of the limbs, as in those of the shoulder or the hip, we may trace various modes of articulation which are calculated to limit the extent and to regulate the kind of movements, in subordination to particular ends. There is certainly no part of the human fabric, wonderfully and fearfully as the whole of it has been made, which exhibits more palpable evidences of express mechanical contrivance and adaptation to specific purposes, than the construction of the joints, and of the whole of their auxiliary apparatus. It is well observed by Paley,[1] that every joint is a mechanical curiosity, and a proof of contriving wisdom. They are, indeed, as Cicero has truly expressed it, "mirabiles commissuras, et ad stabilitatem aptas, et ad artus finiendos accommodatas, et ad motum, et ad omnem corporis actionem."[2]

(168.) There are two circumstances which determine the kind of relative motion of which a joint, by which term is more particularly meant the connexions of adjacent bones, is capable. The first of these comprises the form of the contiguous surfaces of the bones themselves which are brought to play on each other, and their mode of apposition; the second relates to the structure and mechanical conditions of the interjacent flexible parts, such as the ligaments, the cartilages, and the membranes, which impart different degrees of elastibility or springiness, and variously modify the motions which result. With respect to the first, the principal diversities arise from the various extent of range allowed with regard to the planes of motion; and these varieties are naturally distributed under two heads; the one being a semi-rotatory motion within a considerable extent of a spherical surface, as exemplified in what are called the ball and socket joints; the other, in which the

[1] *Natural Theology.* [2] *De Natura Deorum*, l. ii. c. 35.

angular motion is restricted to a single plane, as is the case with what are termed the hinge-joints. It is not necessary here to advert to the further distinctious to which a minute examination of all the different modifications of these kinds of mechanism, which are exhibited in the solid structures of the body, would lead us; which the older physiologists pursued with great diligence, and which they were fond of dignifying with a formidable array of technical terms; a sufficient account of these now obsolete denominations having been already given under the head of ANATOMY in this work. It will be sufficient for our present purpose to observe, in general, that the long bones of the limbs have their extremities expanded so as to form broad surfaces where they are in apposition with the contiguous bones, between which a joint is formed. In the ball and socket joint, it is the moveable bone which has the rounded head, and the fixed bone, or that nearest to the trunk of the body, which contains the corresponding cavity or socket. Such at least is the case in man; but some animals present us with examples of a contrary arrangement; that is, of the concave surface of the moveable, turning on a convex projection of the fixed bone. Bones of a flat or irregular shape are, in general, much more limited in their motions, when they form joints, than those of a lengthened cylindrical form.

(169.) In proportion to the extent of motion allowed in the joint, we find provisions adopted for diminishing friction, and guarding against injury. In all the articulations the ends of the bones which enter into their formation, are invested with a smooth and polished plate of cartilage; a substance which, by its modified hardness, and great elasticity, is especially adapted to both these purposes. Its limited degree of organization, also, gives it many advantages in withstanding the influence of pressure, especially if suddenly made, and frequently repeated. In some joints this investing layer of cartilage is of equal thickness throughout, so that it appears as a crust, regularly moulded over the articular surface of the bone which it covers, and exactly preserving its figure; but, in other cases, it is found to be thicker at the middle than at the marginal parts; thereby increasing the convexity of the projecting portion, or diminishing the concavity of those which recede; both of which appear to be provisions for ensuring, as the case may be, the uniformity of contact of the adjacent parts composing the joint. These superficial articular cartilages, or "cartilages of incrustation," as they have been termed, appear to be composed of a multitude of slender fibres, strongly adhering together, and all of them being perpendicular to the tangential planes of the surface of the bone they invest, like the pile of velvet, and disposed, therefore, in a manner very similar to that of the fibres of the enamel of the teeth, which is superimposed in nearly the same way on the bony part of the tooth. The most complete investigation of this structure will be found in a paper of Dr. William Hunter's, published in the *Philosophical Transactions*.[1] It results from this conformation, that the fibres, on the application of pressure, yield to a certain degree, and bend in waves; just as happens to velvet when it is compressed; and they again resume their perpendicular positions on the removal of the compressing force.

(170.) The whole of the interior surface of each joint is lined with a smooth and glistening membrane of great tenuity, forming a cavity closed on every side, and supplying

[1] For 1743, vol. 42, p. 544.

a peculiar secretion, termed the *synovia*, obviously intended for the lubrication of all the contiguous surfaces. Similar *synovial membranes*, as they are called, forming, in like manner, closed sacs, are met with, surrounding the sheaths of the tendons, and interposed between other parts, the motions of which would expose them to considerable friction. In the former case, when employed in the articulations, they are termed *capsules* of the joints; in the latter, they have received the inappropriate name of *Bursæ Mucosæ*. The synovia is a transparent and viscid fluid, slippery to the feel, and capable of being drawn out into strings by the fingers. It has been imagined that the secretion is principally derived from certain fringe-like processes, chiefly visible in the knee and hip-joints, and constituting what have been called the *alar ligaments*. These membranous appendages, which project into the cavity of the joint, and appear to be formed by folds of the synovial membrane, containing some cellular substance, and small pellets of adipose matter, present an appearance very similar to that of the epiploic duplicatures of the peritoneum, and especially of the appendices epiploicæ of the colon.

(171.) The motions which a joint is capable of performing are often modified and extended by the interposition of detached plates of cartilage, connected only by ligament with the synovial capsule, and capable of shifting their position, so as to enlarge the range and modify the mode of action. Those which we have already described under the title of *interarticular cartilages*, are met with chiefly in those joints where the motion is frequent and considerable, and where the ends of the bones are subjected to great pressures; as in the junction of the lower jaw with the temporal bone, and in the knee-joint. The *semilunar* cartilages, in this latter example, increase the depth of the articular cavity, and ensure, in all the motions of the joint, a perfect adaptation of the surfaces to one another.

(172.) The bones are retained in connexion, their junction strengthened, and their relative movements farther regulated, by the ligaments which invest the joint. Of these there are two kinds, the *capsular*, and the *fascicular*; the former investing the joint on all sides in the case of the ball and socket articulation; and the latter passing from bone to bone in different directions, limiting the motion more or less to a particular plane. When, in the hinge-joint, they are placed externally on the two sides, they form what are called *lateral ligaments*; but in the case of the knee, additional securities are provided, by short and round ligaments, crossing one another in the interior of the joint; these are the *crucial ligaments*. Besides these, we often find other ligamentous bands, passing more obliquely, and dispersed in different directions, which assist in strengthening the joint, preventing the displacement of the bones, and thus completing the mechanical apparatus of each articulation. The muscles which surround the joint also contribute very powerfully in retaining the bones in their proper places, and preventing the sudden dislocations which might otherwise occur during the strains incident to rapid and violent actions.

2. *Package of Organs.*

(173.) The great mechanical objects of adhesion and support being provided for by the organic systems we have now considered, our attention may next be directed to purposes of a subordinate and special nature, and which relate to local adaptations, comprehending what Paley has aptly termed the *package* of the organs. Art and contrivance have been as manifestly displayed in fulfilling these more limited objects, as in the more extended designs of the general fabric. When we consider the vast multiplicity of parts, which it requires the study of years of patient instruction and dissection to be thoroughly acquainted with, which are closely arranged and stowed in the narrow space allotted for them in the body, we cannot but be struck with the care that has been taken in their disposal in the most convenient manner, and with the greatest economy of room. The brain consists of a prodigious number of fibres, gathered together in curious folds, or convolutions, in or. er that they may occupy the smallest possible bulk, and be contained within the circumscribed cavity of the skull, which is to afford them protection. Within how small a compass are lodged all the delicate parts which compose the complex organ of hearing, and which are encased in a hollow space, scooped out of the most solid parts of those bones. Equal care has been bestowed in the lodgment and package of the viscera which occupy the other cavities of the body, namely, the thorax and abdomen. Those which are of greatest importance to life, and whose delicate texture admit most easily of being injured, are always placed in situations of greatest security, and effectual care is taken to provide additional protection by means of bones, cartilages, or other denser mechanical fabrics. All the organs are tied down and secured in their places by membranes, so adjusted in regard to breadth and flexibility, as to allow of those motions which their functions require; or, in other cases, to restrain their displacement, by tightly binding them in their situations. All the important viscera are invested with coverings proper to themselves, composing capsules, which are generally of great density and strength, and calculated to give them effectual protection against pressure or other mechanical causes of injury. The muscles, which are in strongest and most frequent action, are firmly braced and tied down by sheets of fibrous tissue, inserted into the neighbouring bones, and preventing them from starting from their places when urged into sudden and violent contractions. Lastly, all the spaces intervening between the muscles, blood-vessels, nerves, and bones, are filled up with a quantity of cellular and adipose substances, sufficient to leave no vacuity. Hence arises that rounded and flowing outline which has been given to the body, and which forms one of the constituent elements of its beauty.

(174.) The provision of a general envelope to the whole of this complex system of organs, may be regarded as another consideration which appertains to the subject now before us, namely, the package of the body; but its importance is such as to entitle it to be treated of under a separate section.

(175.) This combination of structures, individually possessing different degrees of rigidity, but cemented together by a highly elastic medium, and bound down by a general envelope of considerable strength, produces a result, which, being of considerable importance with reference to the mechanical condition of the fabric, is deserving of special notice. It is matter of observation that the sum of the cohesive forces among the particles composing the mass of animal tissues, is balanced, in the living body, only by the resistance arising from the rigidity or incompressibility of the parts opposed to them; or, in other words, the force of elasticity in the cellular and membranous textures is not in a state of neutrality, but the equilibrium is maintained only by the mechanical circumstances of situation. Thus it happens that, when these circumstances are altered, and the equilibrium disturbed, elasticity comes into play and produces a shrinking of the whole mass. The result is that, in the natural state, every part is kept on the stretch; but retracts as soon as its elasticity is allowed to act by the removal of the extending cause. This will happen whenever the contents of hollow organs are withdrawn, whenever the parts themselves are divided transversely by a cutting instrument, and also when, by a change of position, their extremities are brought nearer together, and the mass assumes a more rounded figure. This property, the result of a high degree of unbalanced elasticity, has long been known, though described under various names. The term by which it has most frequently been designated is that of *tone* or *tonicity*; but Bichat, who has given a good description of its effects, denominated it "contractilité de tissu" and "contractilité par défaut d'extension," whilst he regards tonicity as another and distinct property not of a mechanical, but of a vital nature. The observations we have formerly made on the vital properties, will show that we regard the distinction which he here makes as being founded on very questionable grounds.

SECT. IV.—THE INTEGUMENTS.

1. *The External Integuments.*

(176.) The skin, which gives covering to the whole body, together with its various prolongations and parts connected with it, and constituting altogether the *integuments*, are complex structures. They consist, in the first place, of ordinary cellular tissue; secondly, of the same substance in a more condensed and membranous form; and, thirdly, of a stratum of adipose substance; but they also present us with a kind of structure which differs totally from any of those we have hitherto had occasion to notice. For the clear understanding of these distinctions, it will be necessary, first to explain in greater detail the composition of the external integuments, or the skin.

The parts of which skin consists are arranged in layers; and in giving an account of these we shall take them in an order the reverse of that in which they are usually considered; beginning with the innermost layers, and proceeding successively to the more external.

(177.) That portion of the integuments which is called *the true skin*, is in most parts of the body separated from the subjacent muscles or bones, by a stratum of fat, or rather of adipose substance; that is, as we have already seen, of a cellular and vesicular structure, containing the minute globules of the fat. In other parts, the attachment of the skin is effected merely by interposed common cellular substance, of more or less thickness and density in different places. The succeeding layer is that which forms by far the largest portion of the integuments, and has been denominated *the corion*, or the *true skin*. Its ultimate structure is described by Haller as being analogous to that of membranous parts; that is, composed of a dense intertexture of short fibres and of plates, artificially interwoven together, and united by the close adhesion of their surfaces. It may in this view, therefore, be considered as merely a denser tissue of the common cellular substance, which is, in fact, the basis of most animal structures. This density increases gradually as we trace the texture from the inner to the outer parts; while at its interior surface it passes gradually into the looser cellular texture which is beneath it. Bichat gives a similar description of the essential structure of the corion, but states that, in addition to this, there are found a great number of dense fibres, of a whiter colour than the rest, interspersed throughout its substance, which pass in all possible directions, so as of themselves to compose a close net-work, and leave certain interstices or *areolæ*. This reticulated texture, with the interposed vacuities, may be discovered by long-continued maceration, which loosens the adhesion of the fibres. Small masses of fat are found occupying the intervals between them. Thus the dense fibres of the corion may be regarded as the chief support or skeleton, as it were, of the whole fabric, giving it its requisite form, consistence, and other mechanical properties.

(178.) The external portion of the corion is more finely organized than the rest. It has been considered as forming a distinct layer of the skin, named by Bichat, from the large proportion of minute blood-vessels it contains, the vascular net-work; and by other anatomists, *corpus papillare*, from its presenting on its outer surface, when viewed with the microscope, an immense number of little eminences or conical projections, which have been termed *papillæ*. These papillæ were discovered by Malpighi, and have been since described and delineated by Ruysch, Albinus, and many other anatomists. Cheselden and others, however, have doubted their existence, at least as a necessary appendage of the corion; for papillæ are perfectly visible to the naked eye on the upper surface of the tongue, where they are presented on a very large scale. They are also easily perceived, with a magnifying glass, at the tips of the fingers, as well as in other organs endowed with a peculiar sensibility to impressions of touch. But in those parts of the body which have not the same sensibility, and are seldom employed as the vehicles of touch, they are so minute as scarcely to admit of detection; and their existence has been inferred rather from analogy than from distinct and positive observation.

(179.) The external surface of the corion, or of the corpus papillare, is covered with a thin layer of a soft substance, which has been termed the *Rete Mucosum.* It was first observed by Malpighi, in the skin of the negro, and is hence often called after him the *Rete Malpighianum.* The structure, and even existence of this membrane have given occasion to much controversy. Malpighi had announced it as being a stratum of soft matter, disposed in the form of lines which crossed one another in various directions. Blumenbach and other anatomists describe it as merely a thin layer of pulpy matter, without any distinct reticulated structure. Bichat, on the other hand, denies altogether its existence as a proper membrane, and supposes that what Malpighi saw and described is merely a collection of very delicate vessels, which, after having passed through the corion, form a network on its surface. In this opinion he is supported by other anatomists of high authority, as Chaussier and Rudolphi. Mr. Cruickshank,[1] on the contrary, who has bestowed great pains on the examination of this subject, entertains no doubt of the existence of the rete mucosum, both in the external skin, and also even in some of its productions in the interior of the body. Dr. Gordon admits of the presence of the rete mucosum in the skin of the negro, where it is

[1] *On Insensible Perspiration.*

easily demonstrated; but asserts that it cannot be found in that of the European. On the whole, the positive evidence in favour of the real existence of this membrane appears to preponderate; and at any rate, it seems admitted on all hands, that the colouring matter of the skin, which is black in the negro, and has different tints in the other varieties of the human race, is situated in that part which has been assigned as the seat of the rete mucosum. By some it has been stated that the rete mucosum extends in a uniform layer over the whole surface of the true skin; by others that it is perforated in various parts by the papillæ of the corion, and exists only in the interstices of these papillæ.

(180.) The outermost layer of the skin is the *cuticle* or *epidermis*, which gives a uniform covering to every part of its surface, adhering closely to it, and being accurately applied to all its inequalities. It adheres with considerable tenacity to the subjacent skin, through the medium of the rete mucosum, and its attachment is perhaps also secured by fibres passing from the one to the other. In the dead skin a separation is easily effected by maceration in water, and by a state of incipient putrefaction. In the living body the cuticle is detached by the operation of a blister, or by scalding water, which produce an effusion of serous fluid on the outer surface of the corion. As the cuticle is impervious to this fluid, it is raised, and gives rise to a permanent vesicle.

(181.) When the cuticle is carefully separated from the corion, after its connexion has been loosened by putrefaction, a multitude of very slender transparent filaments are seen, stretching between these two layers, which are torn asunder when farther extended. Dr. William Hunter believed these filaments to be the terminations of those vessèls which exhale the perspiration, and nearly the same views have been entertained with regard to their nature by Bichat and by Chaussier. Cruickshank, on the contrary, considered them to be processes from the cuticle, and not vessels.

(182.) Many erroneous notions have at different times prevailed with respect to the intimate structure of the epidermis. Leeuwenhoeck conceived that it is composed of a number of laminæ, or scales, which he represented as having an imbricated arrangement, that is, overlapping each other successively, like the scales of a fish. But it is now generally admitted that this was a deceptive appearance. The division of layers, which it may seem to admit of in parts where it is of unusual thickness, is merely an artificial separation, not warranted by any natural distinction of textures. Although some have pretended to discover in it a congeries of vessels, especially lymphatics, yet the most accurate and unbiassed observers declare that they cannot perceive in the epidermis, a specific texture of any kind or any regular arrangement of its parts. Dr. Gordon gives it as his decided opinion that it is "truly inorganized, and non-vascular."

(183.) Leewenhoeck imagined also that he could discern a number of perforations, or pores, as he termed them, in the cuticle. But later and more scrupulous inquirers have looked in vain for these supposed pores; and it is now generally admitted that none such exist. Indeed, one of the most characteristic properties of the cuticle is its impermeability to fluids, under ordinary circumstances. The latest inquiries into this subject are those of Mr. Chevalier, who describes the cuticle as composed of an infinite number of small *velamina*, regularly arranged, so as to form a bibulous and exquisitely hygrometrical covering.[1] The mode in which the occasional transmission of fluids through this substance takes place in cutaneous absorption, and perspiration, will be the subject of future discussion. The only real distinguishable pores in the cuticle are those which give passage to the hairs, and to the sebaceous follicles hereafter to be noticed.

Thus, then, there is presented to us in this layer of the integument, a kind of structure differing essentially from either the cellular or membranous tissues which have already been described. The epidermis is an animal texture, nearly homogeneous in its substance, possessing but a moderate degree of extensibility, and approaching to the nature of an inorganic substance, inasmuch as it exhibits no appearance of vascularity, and a total absence of nerves, or other medium of connexion with the living system. Bichat even considers its vitality as exceedingly obscure; he doubts whether it can be said to possess life; but is inclined to regard it as a semi-organized, or rather inorganic body, placed by nature at the point of communication between external dead matter and the living skin, and serving as a gradation between them.

(184.) The nails and the hair are to be classed as structures very similar to the epidermis, of which, indeed, they are often regarded as mere appendages. The nails, in particular, have so intimate an adhesion to the epidermis, that both are generally detached together, by maceration. They consist of hard, transparent, and semi-elastic plates, formed of a substance analogous to the horns of animals. They adhere to the subjacent corion, (which is in those parts fur-

[1] *Lectures on the General Structure of the Human Body*, p. 133.

nished with a great abundance of minute blood-vessels, and of which the papillæ are arranged in longitudinal and parallel rows, very close to one another,) in a manner similar to that in which the epidermis adheres to the corion in other parts. The internal surface of the nail is soft, pulpy, and marked with longitudinal grooves corresponding to the lines which they cover and enclose; and by this mutual adaptation the connexion between them is extremely intimate. The innermost edge of the nail is received into a groove formed of a duplicature of skin fitted for its reception. The epidermis belonging to this portion of skin is folded back upon it, and on arriving at the root of the nail, quits the corion, is reflected over the external surface of the nail, and becomes identified with its substance.

The nails, in all their mechanical properties, correspond to the cuticle, and may be regarded as the same substance in a greater state of condensation.

The hair consists of slender filaments, which appear to be formed of nearly the same substance as the nails, and may be considered, in a mechanical point of view, as still more condensed forms of cuticle. Each hair is provided at its root, with an expanded portion, or bulb, from which its extension proceeds, and which, by the intervention of its vessels, connects it with the corion, in which it is imbedded, just as the roots of a vegetable attach it to the soil. The strength of hair is exceedingly great, compared with its small diameter, as has been frequently ascertained by trying the weights which it can support without tearing. There is no substance, indeed, which would be better adapted for making ropes than human hair, provided it could be procured of sufficient length. It scarcely possesses any extensibility, and is consequently inelastic. If exposed to moisture, it imbibes a certain quantity of water ; and this absorption is accompanied with an increase in the length of the hair. From its having this property, it has been employed by De Saussure as a hygrometer, or instrument for indicating the degree of moisture or dryness of the atmosphere. In order to adapt it to this purpose, however, it requires to be freed from a quantity of oily matter, which it naturally contains, by maceration in an alkaline solution. The colouring matter of the hair is supposed to correspond in its nature, as it does in its appearance, to that which is contained in the rete mucosum of the skin.

Thus we find that there is a very considerable similarity between the hair, the nails, and the cuticle, with regard both to structure, composition, and mechanical properties ; and that they may be regarded, when once their formation has been completed, as equally devoid of vascularity, and as possessed of the lowest degrees of organization and vitality ; if, indeed, these latter properties can at all be attributed to them.

2. *Of the Internal Integuments, or the Mucous Membranes.*

(185.) The structure which characterises the external integuments, is continued in various places into the internal parts ; and is found, with certain modifications, in all those membranes which line the internal surfaces of cavities or channels having an external opening. This is the case with the whole track of the alimentary canal ; including the mouth, pharynx, œsophagus, stomach, and intestines. It is exemplified, also, in all the passages of the air in respiration, as the nostrils, larynx, trachea or wind-pipe, bronchia or air tubes, and the air vesicles of the lungs. All those passages which open externally, such as those of the ears, urethra, and vagina, are likewise defended by a lining of mucous membrane.

(186.) Bichat has considered the mucous membranes as forming a distinct system of structure. Analogous in many respects to the serous membranes, they present, in others, the most marked differences. They agree in their office of affording protection to the organs to which they are attached; and their structure, in as far as it is chiefly resolvable into condensed cellular tissue, is very similar. But as they have to serve the additional office of defending the parts which they invest against the irritating qualities of the substances that may come in contact with them, and which may be either the external air or the food, or extraneous bodies, received from without; or else secretions formed by the internal organs, which are to be conducted to the surface, it was necessary that the fluid which covered them should have properties adapted to this object.

(187.) We find, accordingly, that instead of the watery liquid which exudes from serous membranes, the mucous membranes prepare a secretion containing a large proportion of mucus. Hence a more complicated structure is required in the mucous than in the serous membranes. They are divisible into several layers; that which connects them with the parts surrounding the passage or cavity which they line, is of a denser structure; while the one which forms the inner surface of the cavity is softer, and somewhat pulpy in its consistence. Its surface is beset, in many parts, with numerous minute processes, or *villi*, as they are termed. These have been supposed to bear some analogy to the papillæ of the corion; and the general correspondence of the structure of the mucous membrane and of the external integuments has been farther pursued in the examination of the fine pellicle which gives an universal covering to the pulpy portion, and which has been assimilated to the cuticle. There can be no doubt that the cuticle belonging to the skin is continued over the membranes which line many of the passages above enumerated, and may be traced for a considerable way in those passages. As we advance farther, this cuticular covering becomes gradually thinner, till it ceases to be perceptible.

(188.) But the circumstance which more especially characterises the mucous membranes, is the presence of a number of small cavities, *crypts* or *follicles* as they are called; which have more or less of a spheroidal shape, and which open upon the surface of the membrane by a distinct orifice, or duct of communication. These minute sacs or follicles are themselves lined with an extremely fine cuticular membrane, derived from the general covering of the surface on which they are met with. They are found filled with mucus, and are therefore considered as the sources whence that secretion is principally derived.

(189.) Follicles of a similar structure are found in the various parts of the skin; but the substance which they produce, and which they effuse upon the surface of the skin, is more of an oily, than of a mucous nature. It has been termed *sebaceous matter*; and the small cavities which prepare this matter, are known by the name of the *sebaceous glands* or *follicles*.

(190.) Thus it appears, that although the offices of the external integuments of the internal mucous membranes are sufficiently distinct, yet a general analogy exists between them in many points of their structure, sufficient to justify their being arranged under the same order, in a general classification of animal structures.

SECT. IV. MUSCULAR ACTION.

(191.) Having now considered the system which constitutes the passive instruments of the fabric, it is time that we direct our attention to the active powers which are the sources of motion, and the springs of animation and of energy in the living body.

(192.) As in an extensive system of machinery, economy is best consulted by the employment of a single moving power, such as a fall of water, the impulse of the wind, the current of a river, or the force of steam, so, in the animal economy, nature has provided the muscular power, and applied it in every instance where great mechanical power was required to accomplish the intended object. But before inquiring into the nature of this new animal power, it will be necessary to consider the properties of those organs, the muscles, in which this power appears to reside.

1. *Structure of Muscles.*

(193.) *Muscles* are organs composed of certain fibres, endowed with a peculiar power of contracting in their length, under certain circumstances. These fibres are generally disposed in a parallel direction, and variously united together by intervening cellular substance. The muscular system forms a large proportion of the weight, and certainly the greater part of the bulk of the human body.

(194.) On examining the structure of a muscle, we find the minuter fibres are every where surrounded by a fine cellular texture, which connect them together into bundles, which have been called *fasciculi.* These bundles are connected to each other by coarse cellular membrane, so as to form fasciculi of larger size: these, again, are united together into still larger fasciculi by a still more loose cellular tissue. This system of package is continued until we arrive at large cylindrical bands of fibres, which have been termed *lacerti*, and which, being applied laterally to each other, and covered by a general investment of membrane, compose the entire muscle. The fasciculi, as well as the cellular membrane, are coarser in some muscles than in others. Thus they are thicker in the large muscles of the limbs, than in the delicate muscles appropriated to the eye, and other organs of sense. The structure which has now been described is easily discovered in a portion of muscle which has been cut transversely, and then boiled for some time, or macerated in alcohol.

(195.) Physiologists have not contented themselves with these general views of the structure of muscles, but have been solicitous to ascertain the nature and dispositions of the ultimate fibres to which muscles owe their characteristic properties. The microscope has been resorted to for this purpose; but the success of those observers who have trusted to this instrument in establishing any certain facts, has by no means corresponded with the diligence and zeal with which they have engaged in the inquiry. We find in this, as in many other subjects where the appearances resulting from the employment of very high magnifying powers are the objects of research, that the greatest discordance prevails among the accounts given by different observers. Leewenhoeck, who was one of the first who applied the microscope to the investigation of the intimate structure of organized bodies, but who was too often led away from the truth by the ardour of his imagination, describes the ultimate muscular fibres, or those which admit of no further mechanical division without a separation of their substance, as being almost inconceivably minute. He states them to be many thousand times smaller than a fibre which would only be just visible to the naked eye. He represents them as cylindrical in their shape, and parallel to each other, but pursuing a serpentine course. He remarks that they are of the same figure in all animals, although differing considerably in their diameter in different animals, and that without any relation to the size of the animal. He observed, for example, that the fibril of the frog was larger than that of the ox.

(196.) Muys, a Dutch anatomist, who was engaged for a period of twenty-five years in the most laborious researches on this subject, arrived at a very different result from Leewenhoeck; for he concludes that the real ultimate fibrils of muscles are in all cases, even when the comparison was extended to animals, exactly of the same size.

(197.) Among the more modern anatomists, Prochaska[1] has bestowed the greatest care in the examination of this subject; and his account has every appearance of being entitled to our confidence. He states expressly that the muscular fibrils are not all of the same diameter, but differ in different animals, and even in different parts of the same animal. Each individual fibril, however, when carefully separated from all extraneous matter, is of uniform thickness throughout its whole extent, and perfectly continuous, even in the longest muscles, from one end to the other. He confidently asserts that they are solid; and instead of being cylindrical, that they have a prismatic, or polyhedral shape, generally flattened, or thicker on one side than on the other; a transverse section of the muscle thus presenting the ap-

[1] *De Carne Musculari.*

pearance of basaltic columns in miniature. Their diameter is stated to be about the fiftieth part of that of the globules of the blood. Their surface was found to present a number of depressions or wrinkles; a circumstance which gives them a serpentine appearance. These transverse lines he attributes to the numerous blood-vessels, nerves, and membranous bands which cross the fibrils at different points.

(198.) According to Hooke and Swammerdam, the muscular fibrils are composed of a series of globules. Other physiologists, such as Cowper and Stuart,[1] whose observations appear to have been influenced by preconceived theories, imagined that they were cellular. Borelli,[2] who was also biassed by his favourite hypothesis, believed them to be composed of a series of rhomboidal vesicles. The Abbé Fontana[3] in general agrees with Prochaska in his representation of muscular fibrils. He remarks that they are furnished with transverse bands at regular intervals, and that they may always be distinguished by their parallel disposition from the fibres of membrane, which are more or less contorted.

Sir Anthony Carlisle[4] states that a muscular fibre duly prepared, by washing away all adhering extrâneous substances, and viewed by a powerful microscope, appears to be a solid cylinder, the covering of which is a reticulated membrane, and the contained part, a dry pulpy substance, irregularly granulated, and of little cohesive power when dead.

(199.) Mr. Bauer,[5] who is one of the latest authorities on this subject, represents the ultimate muscular fibrils, as composed of a row of globules, exactly corresponding in

[1] *Dissertatio de Structura et Motu Musculari.*

[2] *De Motu Animalium.* [3] *Sur les Poisons.*

[4] *Philosophical Transactions* for 1805. [5] *Ibid.* for 1818, p. 164.

size to those of the blood when deprived of their colouring matter; that is, about the five-thousandth part of an inch. By long maceration in water, he finds that the mutual cohesion of these globules is loosened, and the fibre is consequently broken down and resolved into a mass of globules. The general results of Mr. Bauer's observations were confirmed by various observers in France, such as Dr. Edwards, and by Messrs Prévost and Dumas, Béclard and Dutrochet.

(200.) On the other hand, the more recent, and apparently accurate researches of Dr. Hodgkin and Mr. Lister,[1] and subsequently those of Mr. Skey,[2] have clearly shewn that the supposed globular structure of the muscular fibre is a mere optical deception, arising from deficient defining power in the microscope employed; and that the fibre is continuous throughout its whole length, and sometimes marked by transverse striæ, which occur at intervals much smaller than the diameter of the fibre itself. They have also pointed out this circumstance as constituting a remarkable distinction between the muscles of voluntary and those of involuntary motion, with regard to this striated structure; for it is only the fibres of the former which are characterized by innumerable very minute, but clear and fine parallel lines, or striæ, which cross the fibre transversely. Mr. Skey concludes from his researches, that these fibres in man have an average diameter of one four-hundredth of an inch, and that they are surrounded by transverse circular striæ varying in thickness, and in the number contained in a given space. He describes these striæ as constituted by actual elevations

1 Appendix to Dr. Hodgkin's translation of Dr. Edwards' work, "*De l'Influence des Agens Physiques sur la Vie.*"

2 *Philosophical Transactions* for 1837, p. 371.

on the surface of the fibre, with intermediate depressions, considerably narrower than the diameter of a globule of blood. Each of these muscular fibres, of which the diameter is one four-hundredth of an inch, is divisible into bands or fibrillæ, each of which is again subdivisible into one hundred tubular filaments, arranged parallel to one another in a longitudinal direction, around the axis of the tubular fibre which they compose, and which contains in its centre a soluble gluten. The partial separation of the fibrillæ gives rise to the appearance of broken or interrupted circular striæ, which are occasionally seen. The diameter of each filament is one sixteen-thousandth of an inch, or about a third part of that of a globule of the blood. On the other hand, the muscles of involuntary motion, (or as Bichat would term them, of *organic life)* are composed, not of fibres similar to those above described, but of filaments only; these filaments being interwoven with each other in irregularly disposed lines of various thickness, having for the most part a longitudinal direction, but forming a kind of untraceable net-work. They are readily distinguishable from tendinous fibres, by the filaments of the latter being uniform in their size, and pursuing individually one unvarying course, in lines parallel to one another. The fibres of the heart appear to possess a somewhat compound character of texture. The muscles of the pharynx exhibit the character of the muscles of voluntary motion; whilst those of the œsophagus, the stomach, the intestines, and the arterial system, possess that of the muscles of involuntary motion. The determination of the exact nature of the muscular fibres of the iris, presented considerable difficulties, which Mr. Skey was not able satisfactorily to overcome.

2. *Muscular Contractility.*

(201.) The proper muscular fibre is so completely surrounded by cellular membrane, and is of so small a diameter, that it is scarcely possible to determine with accuracy its physical properties, independently of those of the tissue in which it is imbedded. The contractile power with which it is endowed, can be studied only as its effects are exhibited by collections of fibres, such as those which constitute the muscles; although in these it must obviously be combined with the elastic power of the cellular texture entering into its composition.

(202.) It will soon be evident, however, that the property by which the muscular fibre is eminently characterized, is that of suddenly contracting in its length, and thus of bringing the two ends of the muscle, and the parts to which those ends are attached, nearer to each other. This contraction is produced with astonishing quickness and force, overcoming considerable resistances, and raising enormous weights. It is generally the effect of the will of the animal to move the parts to which the muscle is attached; but it may also be excited by other causes. The agent which thus produces muscular contraction is called a *stimulus*.

(203.) Under the appellation of stimuli, are included many things which seem scarcely to have any property in common, except that of acting upon the muscular fibres, either directly, or through the medium of the nerves which supply them. The contact of many bodies will produce this effect by mere mechanical impulse, independently of any other quality they may possess. Whatever occasions a mechanical injury to the texture of the muscle or nerve, or an actual breach of substance, such as the puncture, division, or laceration of the fibres, will immediately excite muscular contraction. This effect also results from the application of any substance exerting a chemical action on the part; a class of stimuli which comprehends a great variety of agents, such as acids, alkalies, and most of the salts which they form by their mutual combinations, as also the earthy and metallic salts, alcohol, the volatile oils; and above all, oxygen, either in the form of gas, or when contained in substances that part with it readily. Even water itself seems to have some corrugating power when it is applied directly to the muscular fibre; its action, however, is much increased by minute quantities of salt which it may hold in solution. Thus it is found that hard water promotes the contraction of the muscles of fish that have been crimped more than fresh water; and a similar difference of effect is often observed in boiling meat in soft or in hard water.

(204.) But besides these, there are several of the vegetable and animal products which, when applied to the body, produce muscular contraction by an agency which cannot clearly be traced to any chemical property they possess. This class of stimuli includes a variety of substances which are denominated *acrid*, and others which are called *narcotics*, because when largely applied they destroy altogether the power of contraction, and soon extinguish life. As an example of this latter class, we may take opium and hydrocyanic acid.

(205.) Some particular muscles have a disposition to be acted on more especially by particular kinds of stimuli. Each stimulus applied to the body generally, appears to exert a particular influence upon certain parts of the system which are predisposed to be affected by it, while on other it appears to be wholly inert. Thus emetic substances act principally on the stomach, even when applied to a different part of the system; and cathartic substances act specifically on the intestines. The muscular fibres of the heart are more particularly excited to contraction by the influx of blood into the cavities of that organ ; and, in like manner, every system of muscular fibres concerned in carrying on the vital functions, has a specific disposition to be affected by its appropriate stimulus.

(206.) All the muscles which move the joints of the limbs, and the several parts of which the skeleton is composed, together with several muscles attached to the softer parts, such as the eye, tongue, and throat, are excited to contract by the stimulus of the will, and are therefore called *voluntary muscles*. They compose a class by themselves, as distinguished from those muscles which are not under the control of volition, and which are therefore involuntary muscles, such as the heart, stomach, intestines, and blood-vessels. The nature of this distinction, and of the different laws under which each class of muscles act, will be afterwards pointed out, when we come to treat of the physiology of the nervous system.

(207.) The natural state of a muscle, or that in which it exists when not acted upon by any external cause, is relaxation. When contracted, its surface, from being smooth, becomes furrowed, its middle portion swells out, and grows exceedingly hard and firm, while the extremities are drawn nearer to each other, so that the muscle is now both thicker and shorter than it was before.

(208.) It has been frequently made a question whether the increase of thickness exactly compensates for the diminution of length. This point might be determined by ascertaining whether the specific gravity of a muscle undergoes any alteration during this change. Glisson had inferred from some experiments which he had made on this subject, that the bulk of a muscle is, on the whole, diminished when it is in a state of contraction. Sir Gilbert Blane,[1] on the contrary, inferred from experiments which he made on fishes confined in a glass vessel with a very slender neck, that the absolute bulk, and of course the specific gravity, of their muscles remains the same whether they are contracted or relaxed; for the level of the water in the narrow stem of the vessel was observed to be unaffected by the muscular exertions made by the fish. Mr. Mayo, by an experiment of this kind on the heart of a dog, found the bulk of that organ unchanged during its contraction or relaxation.[2]

(209.) The long-continued, or frequent application of a stimulus to a muscle, tends to impair its power of contracting, or, in other words, to exhaust its irritability. This liability to exhaustion is exemplified by all the muscles that are under the controul of the will. We cannot continue to exert the same muscle, or set of muscles, with the same degree of power beyond a certain time, however strong may be the motive to continue that action, and whatever mental effort we may make to persevere. If, for example, we extend the arm in a horizontal line, with a weight held in the hand, we shall find, in the course of a few minutes, that the source of fatigue becomes intolerably acute; and the arm at length drops from mere exhaustion, in spite of every voluntary effort.

(210.) The contraction of a muscle ceasing on the removal of the stimulus that produced it, relaxation succeeds, and the muscle becomes again elongated; not, however,

[1] *Phil. Trans.* for 1805, p. 22, 23.

[2] *Anatomical and Physical Commentaries*, p. 12.

in consequence of any inherent power of elongation, but from the operation of causes which are extraneous to it. The elasticity of surrounding parts is often sufficient to produce this effect; but in most cases the elongation of the relaxed muscle is the consequence of the action of other muscles, which produce motion in a contrary direction. Almost every muscle has another corresponding muscle, or set of muscles, which are antagonists to it. If the one, for instance, binds a joint, the antagonist muscle unbinds or extends it; and by this action must elongate the former muscle.

(211.) The swelling of the muscles of the limbs, when they are in strong action, is matter of familiar observation. It is this circumstance, above all others, which renders a knowledge of anatomy so essentially necessary to the painter and the sculptor. In every attitude and in every movement of the body some particular set of muscles are in action, and consequently swelled and prominent, while others are relaxed and less conspicuous; and unless these differences were accurately noted and faithfully expressed, it would be impossible to give a correct representation of the living figure.

(212.) Although the fibres which compose the smaller portions of a muscle are arranged in parallel directions, yet the disposition of the mass of fibres, relatively to the whole muscle, varies considerably according to the action which the muscle is intended to perform. We find them, in some cases, radiating from, or converging to a particular point; and sometimes we even find that the different portions of a muscle having this structure can act independently of the rest. The temporal muscle is an instance of a muscle of which the fibres converge from the circumference to a central point, where they are inserted into the coronoid process of the lower jaw. In other cases the fibres composing the muscle pass in a circular direction so as to close upon some organ which they surround, or to compress the bodies they enclose. Thus the eye and the mouth are closed each by a circular or orbicular muscle. In other parts, muscles of this description are called *sphincters*. Some parts, as the iris, are provided with both radiating and circular fibres, the one used for dilating, and the other for contracting the central aperture. We meet with a circular arrangement of muscular fibres in the coats of the various pipes and canals of the body, such as the blood-vessels generally, and also the alimentary passages; and together with these circular fibres are also often found bands of longitudinal fibres, which shorten the tube, while the former tends to contract its diameter, and press upon its contents. The several hollow receptacles for fluids, such as the heart and the stomach, present us with a still greater complication in the arrangement of their muscular fibres, in which we may sometimes trace layers of fibres having a spiral course.

(213.) But it very frequently happens that the action of a muscle is wanted when its presence would be exceedingly inconvenient. The common medium of connexion employed by mechanicians, when the object to be moved is at too great a distance to admit of the direct application of the power, is that of a rope or strap. In the animal machine the same purpose is effected by means of tendons, which are long strings attached at one end to the muscle, and at the other to the bone, or part to be moved. If the muscles by which the fingers are bent and extended, for instance, had been placed in the palm or back of the hand, they would have enlarged that part to an awkward and clumsy thickness, which would not only have destroyed the beauty and proportion of the organ, but have impeded many of its uses as an instrument. They are therefore disposed at the arm, even as high up as the elbow, and their tendons pass along the joints of the wrist, to be affixed to the joints of the fingers they are intended to move.

(214.) The employment of tendons also reduces the space which would have been necessary for the direct insertion of the muscular fibres in a bone, so that the same bone may be acted upon in a great variety of ways, by means of the tendons attached to it proceeding from a great number of muscles.

(215.) Another advantage resulting from the employment of tendons is, that by their intervention a great number of fibres are made to act in concert, and their united power is concentrated upon one particular point. In this respect, also, they resemble a rope, at which a great number of men are pulling at the same moment, by which means their combined strength is brought into action. These tendons are variously disposed with respect to the muscular fibres to which they are attached. It is but in a few muscles that the fibres are arranged in a perfectly longitudinal direction. We often find them covered on both sides with a tendinous investment, the muscular fibres proceeding obliquely from the one to the other. This arrangement forms what is called a penniform muscle, which may be either single or double. The structure is frequently even more complex than this, a number of tendinous layers being interposed among the fleshy fibres. By means of tendons a different direction may also be given to the moving power, without altering its position. There are many instances of this employment of tendons, in which they are made to pass through a loop, which serves as a pulley, an expedient which is adopted in one of the oblique muscles of the eye.

(216.) We have already seen, that wherever friction takes place by the motion of tendons over bones, or other hard parts, a bursa mucosa is interposed, which obviates in a great measure the injurious effects that would otherwise result from the rubbing of the parts.

(217.) But although it be true that the force with which muscles contract is very great, yet the extent to which they are capable of exerting that force is in general very limited, and would be insufficient for most of the purposes their contraction is intended to serve, unless it were very considerably enlarged by mechanical expedients. In the practice of mechanics we find a variety of contrivances had recourse to for attaining this object; namely, the production of a great extent of motion, by a power acting through very limited space. But most of these devices would not answer in the human body, from the inconvenience which would attend their application. We find that nature has solved this problem in the simplest possible manner. In the first place, the tendons are inserted into the bones they are designed to move, very near to the centres of motion, so that a small extent of contraction in the muscle will produce a great range of motion at the other extremity of the limb. The principle is here obviously that of what mechanicians have termed a lever of the third class, namely, that in which the power is applied at some point intermediate between the fulcrum and the weight to be raised, or resistance to be overcome. Secondly, the direction of the power so applied, with reference to the line connecting the point of application and the centre of motion, or what is termed the radius of rotation, is oblique; that is, it forms with it an acute angle. Here again we may perceive another cause of the increase of motion, obtained by a smaller extent of contraction above that which would have resulted if the power had been applied at right angles to the radius of rotation, which is obviously the most advantageous mode of employing that power, when the object is to economise it, by giving it the greatest mechanical advantage. It must happen, indeed, by such a disposition of the force, that a large portion of it is lost, being spent on a fixed obstacle, namely, on the bone of the joint, against which the pressure is exerted; but the quickness and velocity of the motion that results are undoubtedly increased. Thirdly, the muscular fibres are themselves obliquely disposed with respect to the tendons, so that the same cause operates in a similar manner here also. Lastly, pairs of muscles are placed so as to form an obtuse angle with one another, and are made to contract at the same time. Their actions, therefore, will partly concur, and partly oppose one another. They will conspire to produce a movement in the parts to which their extremities are attached, in a direction intermediate to that of the muscles themselves; for it is a fundamental law of dynamics, that when a body is urged by two forces inclined to each other at any angle, it will move as if it were urged by a force in the direction of the diagonal of a parallelogram, having for its sides lines corresponding in their direction and their lengths to the directions and relative intensities of the two component forces.

(218.) In all these cases it is evident that there must be a great loss of force; but when the muscular power is concerned, we almost always find that strength is sacrificed to convenience, and that construction adopted which unites in the whole the most advantages. We must allow, that the muscular power is turned to the best account when it is made to perform in the completest and quickest manner the intended motion. We find, in following the mechanism not only of the joints of the limbs, but of the whole system of organs, both internal and external, that the mode in which this force is applied is diversified in every possible way. Its combinations are varied, and its action modified beyond calculation, though the original power be still essentially the same, and observes the same laws in its action.

(219.) The source of that enormous mechanical power which seems to be an inherent property of the muscular power, has long been sought for by physiologists; but it has always continued to elude their most patient and laborious researches. It was at one period a favourite subject of speculation to devise hypotheses as to mechanical arrangements of particles capable of producing results similar to those of muscular contraction. Borelli[1] conceived that each muscular fibre might be composed of a series of minute bladders, or vesicles, of a rhomboidal figure. Stuart supposed that these vesicles were round. But on either hypothesis they were conceived to be empty, while the muscle remained in its natural state of relaxation. On the sudden introduction of a fluid of some kind into these vesicles, their sides would be separated, they would become distended, and assuming a more spherical form, would consequently be shortened in their longitudinal diameter; and as this shortening would take place simultaneously in all the vesicles, the whole muscle would be contracted in its length, and at the same time proportionally dilated in its breadth. The contrivance had certainly the merit of ingenuity, inasmuch as it explain-

[1] *De Motu Animalium.*

ed the swelling of the muscle as well as its shortening, in the act of contraction. But it evidently will not bear the test of serious examination. No such structure as is implied in the hypothesis has ever been rendered visible to the eye, however dexterously the microscope may have been applied to the muscular fibre; nor can we find any power sufficient to propel so large a quantity of fluid as would be required for the distension of the vesicles; an effect also which, in order that the theory may correspond with the phenomena, must be produced almost instantaneously The resistance that would be opposed to the entry of a fluid so propelled would be incalculable, and incomparably greater than that exerted by the muscle itself, which latter force, it may be observed, it is the professed object of this theory to explain. The hypothesis itself, therefore, on which the theory is built, involves a greater difficulty than the simple fact. Such, indeed, was a very common mistake in the speculations of the earlier philosophers, who were ever prone to theorize without having any legitimate basis for the formation of a theory; their foundations being often more in need of support than the superstructure they attempted to raise upon it. It reminds us of the Indian fable of the world being carried on the back of an elephant, whilst the elephant was supposed to require a tortoise for its own support.

(220.) The hypothesis that the fibres of muscles have a spiral shape, and pass in a contorted line from one end of the muscle to the other, like the turns of a corkscrew, a form which readily admits of elongation or contraction, according as it is more or less contorted, is quite as unsatisfactory as the former; and equally open to the fundamental objection, that it leaves the original source of motion still unexplained. Muscular power, indeed, does not appear, from what we hitherto know of its laws, to bear any close analogy to any of the other great principles in nature, which we recognize as original sources of mechanic force; and until such analogy can be traced, all our endeavours to explain the phenomena of muscular contraction must be fruitless.

(221.) It was a favourite notion with the physiologists of the seventeenth century, that an effervescence was excited in the interior of the muscle, by some chemical operation; such as a mixture of acid and alkali. Willis and others ascribed muscular contraction to a fermentation occasioned by the union of the particles of the muscle, with a supposed nervous fluid, or ethereal spirit contained in the blood.

(222.) But in fact, the only power in nature to which irritability can be compared in the quickness and suddenness of its variations, as well as in its dependence on peculiar qualities of matter, is electricity, and more particularly that form of electricity which constitutes galvanism. Attempts have accordingly been often made, since the phenomena of galvanism have engaged so much attention in the philosophic world, to explain muscular contraction by means of this principle; and endless have been the fanciful hypotheses invented for this purpose. Each muscular fibre was at one time considered as performing the office of a separate Leyden jar, charged with opposite electricities on its exterior and interior; whilst the filament of nerve which penetrated into its substance was the conducting wire, that occasioned the discharge of the jar. After the discovery of the voltaic pile, it was immediately conceived that an arrangement corresponding to the plates of the pile, existed among the particles of nerve and muscle, thus composing a galvanic apparatus, ready to discharge itself when the proper communications were effected. The latest hypothesis of this kind, is that of Prévost and Dumas, who conceived that the muscular fibre was thrown, during its contraction, into serpentine flexures, in consequence of the attractions of electrical currents, passing in similar directions through minute filaments of nerves, the directions of which were at right angles to the axis of the fibres. But in the present state of the science, all these analogies are far too vague and remote to serve as the foundation of any solid theory.

(223.) It has been the fashion among some physiologists to consider muscular contraction as only a particular mode of attraction, and as included in the general law of attraction which subsists among all the particles of matter; but this is a generalization totally unwarranted by the phenomena. Others have maintained that contractility is to be ascribed to the attraction of life, and to be merely a modification of vitality. Thus, Girtanner imagined that this property resided even in the living fluids, and was co-extensive with organized nature. This, however, is equivalent to the assertion, that the phenomena requires no explanation at all; for it certainly leaves the question just where it was before. We already knew that the effect of muscular power indicated a peculiarity to the nature of that power, for they appeared different from any other. To say that it is a peculiar modification of the power of life, gives us therefore no new information, unless it be meant that it is similar in its nature to the other powers which the living organs exhibit; but it would, in that case, convey an erroneous idea, because, the phenomena themselves being different, cannot, according to the rules of legitimate induction, be ascribed to the same physical cause. We have already pointed out the fallacy of this mode of reasoning, in which final causes are confounded with physical causes, and substituted for them as philosophical explanations of phenomena.

(224.) There is, unquestionably, a greater degree of cohesion in the particles which compose the fibres of muscles in their living, than in their dead state. This cohesive power, in consequence of the connexions of the muscle in the body, is equivalent to a constant tendency to contraction. Hence, the fibres of muscles are in a constant state of tension, like an elastic substance kept upon the stretch. This property, evidently derived from contractility, has been denominated *tonicity*, a term which has also, as we have seen, been applied to the peculiar state of tension of cellular and membranous structures, derived from a particular condition of their elasticity. (See § 175.) It produces the state of *tone* in a muscle; or that in which it is disposed to contract to a greater degree, than its connexions with the neighbouring parts will allow. This explains why, on cutting a muscle across, the cut edges retract to a considerable extent, leaving a wide gap at the place of section: when, by a sudden effort, the tendo achilles is ruptured, the muscles in the calf of the leg to which that tendon had been attached, being released from this stretching force, retract to a great extent, and form a large and hard swelling high up in the leg.

(225.) On minutely examining the phenomena of muscular contraction, it will be found, even in those instances in which the contractile power appears to be exerted with undiminished vigour for a certain time, that each individual fibre undergoes, during the interval, a succession of changes of condition, contracting and relaxing alternately. It is only a certain number of the fibres that are in action at the same moment; their power is soon exhausted; and until recruited by repose, other sets of fibres are thrown into contraction, so as to supply their place. They thus relieve one another in succession, until by frequent action the exhaustion becomes more general, and the restoration less complete. In this state, the whole muscle is fatigued, its contractions become irregular and unsteady in proportion as they are more feeble, and the whole action is tremulous, and incompetent to the production of the desired effect. These tremulous movements are very obvious when the muscles are weakened from any cause, as well as when exhausted by excessive action. Dr. Wollaston[1] with his usual acuteness, detected, by a very simple experiment, the minute oscillations consequent upon these continual and rapid alternations of contraction and relaxation in the fibre. When the finger is inserted in the ear with a moderate degree of force, and the pressure is continued with as much steadiness as possible, a peculiar vibratory sound is heard, similar to that of a carriage rolling on the pavement. This must evidently proceed from a corresponding vibratory action of the muscular fibres. It appears, therefore, as Dr. Wollaston remarks, that the voluntary effect in this case, although it may seem to us to be perfectly continuous, consists in reality, of a great number of vibrations repeated at extremely short intervals.

(226.) There is a peculiar kind of contractility possessed by membranous structures, which has often been supposed to bear an analogy to muscular contractility, or even to be some modification of this property. It is called into action by the application of a certain degree of heat, and also by some powerful chemical agent, such as the concentrated mineral acids; and the effect produced is a sudden corru-

[1] *Philosophical Transactions* for 1810, p. 2.

gation, or curling up of the membranous part. This phenomenon was noticed by Haller, and was termed by Bichat *racornissement*. Alcohol, and many of the neutral salts produce, but more slowly, effects which are similar in kind, though much inferior in degree; but in this case the corrugation continues to increase, if the agent continues applied, which does not happen when the more powerful agents, as the acids, or boiling water are employed; for the continued operation of these latter agents is to dissolve and disorganize the animal substance. Bichat took considerable pains to investigate these phenomena, and has pointed out[1] several circumstances by which this property may be distinguished from mere membranous elasticity. From muscular contractility, indeed, it differs much more considerably, and depends, therefore, in all probability, on principles totally different from that remarkable animal property.

SECT. V.—FUNCTIONS OF THE OSSEOUS FIBRIC OR SKELETON.

(227.) The general basis for the mechanical support of all the softer organs of the body, both in their states of quiescence and of motion, is the osseous fabric, or *skeleton*; composing a connected frame-work of solid and unyielding structures, fitted for the threefold purposes of giving protection to the more important organs which perform the vital functions, of sustaining the weight of the several portions into which the body may be conceived to be divided, and of furnishing fixed points of attachment to the muscles or moving powers, and thus supplying them with the mechanical advantages of levers in the execution of the more power-

[1] *Anatomie Générale.*

ful movements of the frame, and especially in the progressive motion of the whole body from place to place.

(228.) The organs more especially defended from external injury by a bony covering, are the *brain*, the principal organs of the *senses*, and the organs of *circulation and respiration.*

1. *The Cranium.*

(229.) The bones of the skull are contrived with singular artifice and skill to afford protection to the brain, an organ, as we have seen, of peculiarly soft and delicate texture, and of which the functions are so refined as to require for their accomplishment the most perfect freedom from external pressure, and even from any harsh vibration or concussion of its parts. It is evidently with this view that the bony covering of the brain, or skull-cap, as it has been called, is constructed in the form of a vault or dome, as being the best calculated to resist external pressure, on the well-known mechanical principle of the arch. But pressure applied vertically to an arch necessarily gives rise to an outward horizontal thrust at the two ends of the arch. In architecture, various expedients are resorted to for opposing this force. In a bridge it is resisted by the solid abutments where the arch takes its rise on each side. In the higher arches of ornamental architecture it is counteracted by the weight of a buttress placed over the origin of the arch, and in harmony with the design of the whole. For the support of the roof of a building, which has to rest upon perpendicular walls, either these walls must be built of a strength equal to withstand this horizontal pressure, or, what is generally resorted to, a tie-beam must be attached to the base of the roof, which tie-beam will resist by its cohesive strength the force which tends to stretch it, derived from the outward pressure of the roof.

(230.) In the architecture of the skull we find the exemplification of these methods, and their strict conformity with the refined principles of mechanics. The two parietal bones on the sides, the frontal bone before, and the occipital bone behind, may be considered as the four great stones which compose the convex part of the dome. If we first consider the parietal bones, viewing them as constituting a single arch, we find that the r lower edges are bevelled off at an acute angle, so as to be overlapped on each side by the upper edge of the temporal bone, which continues the curvature as far as the basis of the skull. Thus the two parietal bones are effectually wedged in between the two temporal bones, and any pressure applied on the top of the head, which would of course tend to thrust their lower sides outwards, is resisted by the temporal bones. But these temporal bones are themselves locked into the irregularly-shaped sphenoidal bone, which, as we have seen, forms the central piece of the basis of the skull, being in actual contact with every one of the bones which compose it, as well as the face, in which the organs of all the senses, except that of touch, is contained. The os sphenoides thus performs the office of a great tie-beam to the lower part of the arched roof of the skull: and the same principles will be found to hold good when the section of the skull is taken in the longitudinal direction; the os frontis before, and the os occipitis behind, which sustain their share of any pressure made on the upper parts of the head, being so locked in, by the bending inwards of their lower processes, with the sphenoid bone, as effectually to prevent their starting outwardly.

(231.) Another circumstance in the architecture of the skull is particularly deserving of notice, as it exhibits the most marked instance of provident design. It relates to the structure of the bones themselves, which is that best calculated to resist fracture on the one hand, and on the other to prevent the transmission of vibrating concussions to the brain. It is manifestly with this view that it is composed of two plates of bone, the external one fibrous, tough, and not easily broken; the inner one more dense and rigid, offering the most poweful resistance to simple direct pressure; yet, on that very account, more fragile in its nature, and partaking therefore in the quality of brittleness, which belongs to all the harder bodies, such as glass or flint. It was on account of its possessing this property that it was named the *tabula vitrea* by anatomists. But while it is evident that such an accident would have been of frequent occurence if that part of the bone had been directly exposed to every casual blow, this evil has been carefully guarded against by the interposition of a spongy intertexture of bony fibres, the *cancellated structure*, as it is termed, which forms a thick layer between the two laminæ of bone, or as they have been called, the outer and the inner *tables* of the skull. This intervening layer operates as a cushion, arresting the progress of the vibrations from the external to the internal plate of bone, and preventing fracture.

(232.) Even when the impetus is so great as to penetrate through this resisting medium, still the force with which it impinges on the subjacent parts must be very considerably moderated, and the danger of injury to the brain diminished. It is with a similar design of giving protection that a soldier's helmet is lined with leather or covered with hair; a provision which we even find in the head-piece of the Roman soldiers, in whose equipment utility alone was consulted, and nothing was admitted that served the purpose of mere ornament. Wherever the bones of the skull are more particularly exposed to blows, we find a greater thickness of bone provided for the sake of additional power of resistance.

(233.) The *sutures*, or joinings of these bones, are also admirably contrived to stop the transmission of vibrations arising from percussion from extending to any distance round the skull. These sutures, externally, where the tough and fibrous plates of bone are united, present a serrated line; the fibres at the edges of each being mutually inserted between those of the contiguous bone. But this dove-tailed joining is not met with in the inner table; there the edges of the bone are smooth and placed in simple contact. This is evidently done in order to prevent the chipping off of the minute parts of a brittle structure, had they been interlaced together as the fibres of the outer table are. But still the interruptions afforded by the suture tends in a great degree to check the progress of fracture.

2. *The Face.*

(234.) The organs of the principal senses, the eye, the ear, the nostrils, and the mouth, are protected by the bones of the face, which likewise form part of the skull. The eyes are exceedingly well defended by the superciliary ridge of the frontal bone above, and also by the orbital plate which supports the anterior lobes of the brain; anteriorly they are protected by the projection of the nasal bones, and outwardly by the arched process which divides them from the temples: while the prominent cheek bones below guard them from injury in that quarter. No part of the body has so effectual a protection from bone as the internal organ of hearing: nor is there any part of the osseous system so hard as the portion of the temporal bone in which this organ is lodged. The nasal cavities, in like manner, which are occupied by the membranes receiving impressions from odorous effluvia, are formed in deep recesses of bone. The organ of taste is also protected by the jaws, though less completely, because the same parts are required to enjoy extensive power of motion.

3. *The Thorax.*

(235.) The heart and lungs, which are lodged in the cavity of the thorax, are defended before and behind by the spine and sternum; and laterally by the ribs, which form bony arches, the shape best calculated for resisting pressure applied externally. They are formed of separate pieces, with intervals between, in order to admit of motion: for the cavity of the chest requires to be alternately enlarged and contracted in the performance of respiration, which is a function of primary importance in the animal economy.

4. *The Spine.*

(236.) The support of the trunk and upper parts of the body, including the head, is entrusted to a column of bones, the assemblage of which constitutes the spine. The spine is that part of the skeleton of all animals composing the four superior classes, namely, the mammalia, birds, fishes, and reptiles, which is most constantly found, and which exhibits the greatest uniformity of structure. The individual bones which compose the spine are so intimately united and so firmly secured by ligaments on every side, that they appear in the living body as one continued bone, and the whole assemblage is known, in ordinary language, by the name of the *back-bone*. The purposes answered by this complex fabric are numerous and important. It is the great central beam of the fabric, and furnishes the basis of support to all other bones of the skeleton. It serves, in particular, to unite the bones of the limbs with the trunk, so that they form with the latter one connected frame-work. It is the axis of their principal motions, the common fulcrum round which they all revolve. It has an intimate mechanical relation with all the parts of the body. It affords attachment to the great muscles which move the trunk and the principal joints of the extremities. It contains and gives protection to that important organ, the spinal cord, from which, as we have seen, almost all the nerves of the body take their origin, and which is unquestionably, next to the brain, the most essential organ in the economy. Whilst the spinal column performs these offices, it is at the same time capable of considerable flexion, both laterally and longitudinally; and admits also of some degree of twisting motion, in a plane perpendicular to its axis.

(237.) No where has art been more conspicuously displayed than in the construction of an apparatus adapted to fulfil such opposite and apparently imcompatible functions. To secure the firmness and strength which are required in the basis of support to the whole body, in the key-stone, as it were, of its various arches, whilst it is at the same time rendered capable of so great a variety of motions, objects which seem utterly at variance with its also affording protection to a tender and delicate organ, in which the least pressure would be attended with fatal consequences, must be allowed to be a most difficult problem of mechanism. And yet these various, complicated, and apparently inconsistent offices, we find executed by one and the same instrument. Flexibility is obtained by subdividing it into a great number of small portions, each of which is separately allowed but a small degree of bending upon the next; and thus a considerable motion is obtained in the whole column, with but a very inconsiderable one at each joint. Each bone, as was described in the account of its anatomy, is connected with its neighbour by a broad basis of attachment; and the slight relative motions of which they are susceptible are chiefly entrusted to the lateral articulations. Whilst these broad bones give the whole chain its requisite firmness and stability, they are so constructed as to afford a passage, without any diminution of their strength, to the substance of the spinal marrow. For this purpose each of the bodies is hollowed out so as to form a continued groove all down the back; and over this groove a broad arch is thrown from each side, converting it into a complete canal. In order to preserve the continuity of this canal, and prevent the vertebræ from shifting upon one another so as to press upon the spinal cord within, during the various movements of the body, further securities are provided. They are severally connected together by their projecting processes, which lock into one another, and are still more firmly secured by the ligaments that bind them down on every side. Thus, the bodies of the vertebræ are guarded against the danger of accidental slipping, but they are defended also from displacement by any force short of what would break the bone.

(238.) But besides all these provisions the vertebral column is protected from injury arising from violent jolts or jars, by having interposed between each adjoining vertebræ, the peculiar springy substance known by the name of the *intervertebral cartilage or ligament;* for it in reality partakes of the nature of both these textures. It is a substance quite peculiar to this part of the frame. Its compressibility and the elastic force with which it recovers its shape when relieved from the compressing power, must greatly lessen the quantity of motion required of each bone during the flexion of the column, as well as soften all the concussions incident to violent motion. No chasm is left by their separation when the spine is bent; and the unity of the whole column, and of the channel in its centre, is preserved unbroken. A passage is at the same time allowed between each contiguous vertebræ for the nerves which issue in pairs from the spinal cord, to distribute their branches and filaments to every part of the body.

(239.) The natural curvatures in the line of the vertebral column also contribute materially to the elasticity of the whole framework. On receiving any shock in the direction of its length, the impulse, instead of being propagated the whole length of its line, is diverted from its course and taken off by the flexures of the column; and the maintenance of its natural position is effected more by the power of the muscles attached to the spine, than by its inherent elasticity.

5. *The Pelvis.*

(240.) The broad expansion of bone which extends on each side of the pelvis, and the extremities of which form the hips, are evidently designed as a basis of support for the viscera of the abdomen. The lower portion of the bones of the pelvis is at the same time rendered light by being formed into several arches; strengthened at the points where it is exposed to the greatest pressure, and at the same time affording room for the articulations of the thigh bones.

6. *The Limbs in General.*

(241.) The third office of the skeleton is to furnish levers for accomplishing the progression and other movements of the body, which require great force, great extent, and great precision of motion. These objects are attained by the limbs, which, as is well known, are divided into separate portions, obviously for the purpose of increasing the facility of adaptation to a great variety of movements and of actions which the individual may be called upon to perform.

(242.) The principal bones of the extremities have the shape of lengthened cylinders, and compose a system of levers adapted to the regular and accurate application of the moving force, and for the execution of rapid, extensive, and powerful movements. The circumstance of their hollow and cancellated structure is a palpable instance of provident adaptation to the office for which they are framed. It may be mathematically demonstrated, that if the quantity of materials assigned for the construction of the bone be given, there is no mode in which those materials could have been more advantageously disposed for resisting a transverse force, that is, a force tending to break it across, than the form of a tube, or hollow cylinder, which is that actually given to them by nature. If, for instance, the same quantity of matter had been collected into a solid cylinder of the same length, it would have been subject to fracture by a much smaller force than that which it bears without injury in its actual tubular form. This remark was long ago made by the elder Dr. Monro,[1] who observes that the resistance opposed by a body of cylindrical shape to a force applied transversely is in the direct ratio of its diameter; hence the same number of fibres disposed round the circumference of a circle in such a way as that their sections would present the appearance of a ring, will resist with greater force than if they had been united at the centre, so that their section would present a circle of much smaller diameter than the ring. The hollow cylindrical bones are accordingly found in those situations where the power of resisting external force is principally wanted, while it s at the same time an object of importance not to add unnecessarily to the weight. A simple experiment will illustrate in a very striking manner this proposition. Let a cylindrical glass rod and a glass tube be taken of the same length and also of the same weight, so that they may both contain the same quantity of materials. If each be then supported at their two ends, on a frame adapted to the purpose, it will be found that the same weight which, when hung from the rod, will break it asunder, will, when transferred to the tube, be sustained without even bending it in any sensible degree. Dr. Porterfield has given an elaborate mathematical demonstration of the general proposition.[2]

(243.) There are few subjects in physiology which present so many interesting points of inquiry, or afford more abundant proofs of intelligence and design than the mechanical properties of the osseous fabric. From the account we formerly gave of the composition of bone, it appears that it is constructed of two principal materials, an earthy basis, which is the phosphate of lime, and an animal or membran-

[1] *Anatomy of the Bones and Muscles*, p. 21.
[2] *Edinburgh Medical Essays*, vol. i. p. 95.

ous substance, which possesses considerable tenacity. To the first of these ingredients the bones owe their solidity and hardness. No inorganic matter, not even the metals, has so great a cohesive power, with a given weight of materials, as the earthy bodies; and this is probably the reason why the phosphate of lime has been selected as the substance employed to give the necessary solidity and hardness to bones. But these qualities, if carried to excess, would be accompanied with brittleness. To guard against this evil, the cohesion of the inorganic earth is tempered by the interposition of an elastic organic material; this is the cellular tissue, within the cells of which the bony matter is deposited, and which acts the part of a cement, binding them more strongly together, and at the same time obviating the excessive brittleness which a substance of more uniform hardness would have possessed. Thus, by the admirable blending of these two elements, two qualities which, in masses of homogenous and unorganized matter are scarcely compatible with one another, are happily united.

(244.) The manner in which the cylindrical bones are connected together is also highly deserving of attention. There are, indeed, few parts of the mechanism of animals more peculiarly fitted to excite our admiration than the structure of the joints. Every provision seems to have been made for facilitating their motion, and every precaution taken to enable them to act with safety. Their ends are enlarged for the purpose of affording a broader surface of junction, and for procuring greater firmness and security of connexion. The rough and hard substance of bones would have been particularly exposed to injury if they had been allowed to grate upon one another without some intervening smooth surface. In all the joints, at the places where the ends of the bone would have suffered from this cause, we find them tipped with a white, smooth, and elastic cartilage. Dr. Paley[1] has very aptly compared this expedient to the plating of a metallic instrument with a different metal. Detached portions of cartilage, are, as we have seen, frequently placed between the bones, which thus, instead of working upon each other, work upon the intermediate cartilages. This is analogous to the contrivance practised by mechanics, who interpose a loose ring where the friction of the joints of any of their machines is great, and who particularly resort to it where some strong and heavy work is to be done. It is precisely under similar circumstances that the same contrivance is employed in the human body; and the analogy is a striking evidence of that art and foresight which are manifested in the plan of its conformation. The lubricating quality of the synovia is also an exquisite provision designed to diminish friction.

(245.) The ligaments which bind the ends of the bones together, and restrain the direction of their motions, are admirably calculated to perform the offices assigned to them. Like the bones, they unite qualities which are rarely met with in conjunction. They have all the properties we can desire in a rope; namely, perfect flexibility, with great power of resisting extension. It is hardly imaginable how great a force is required to stretch, or rather to break asunder a ligament, for it will not yield in any sensible degree until the force is increased so as at once to tear it to pieces. Yet with all this toughness, it is so flexible as to oppose no impediment to the suppleness of the joint. "Every joint," says Dr. Paley, "is strictly a mechanical instrument, and as manifestly contrived, and as accurately defined as any

[1] *Natural Theology*.

that can be produced out of a cabinet maker's shop. Their durability is no less astonishing. A limb shall swing upon its hinge, or play in its socket, many hundred times in an hour, for sixty years together, without diminution of its agility."[1]

7. *The Lower Extremities.*

(246.) The three portions into which the lower extremities are divided, namely the *thigh*, *leg*, and *foot*, being united by joints, and moveable upon one another, are calculated to serve the double purpose of firm columns of support to the body while standing, and of facilitating and regulating its movements while advancing. It might, on a superficial view of the subject, be supposed that, in standing in the erect posture, the weight of the body would be more firmly and effectually supported had the whole limb consisted of a single straight column. But independently of the greater strain to which such a structure would be exposed, in consequence of the great length of bone required, it would, in fact, have had less stability than it now possesses. A marble statue of a man resting merely on the feet in a natural attitude, would be overthrown by a small impulse; and even in the living body, it is an infallible consequence of the laws of mechanics, that if ever the perpendicular line drawn from the centre of gravity happen to pass beyond the base of support, the body must inevitably fall in spite of every muscular exertion that can be made. The only way to prevent such an accident is to bring back the centre of gravity nearer to a point above the centre of the base before it has actually passed it; and this we instinctive-

[1] *Natural Theology.*

ly do when we feel ourselves in danger of falling to one side, by extending the arm horizontally on the opposite side.

(247.) But the limb being divided into joints, these joints would give way under the weight of the body, were they not prevented from bending by the constant action of the muscles. The continual muscular effort required in standing is nearly as great an expenditure of muscular power as the act of walking. Soldiers on parade remaining in the same attitude, experience even more fatigue than they would suffer by a march during an equal time, because the same muscles are constantly in action. The posture of a soldier under arms, with his thighs and legs in the same straight line, is one which requires a painful effort to preserve. The moment the word of command is given him to "stand at ease," the muscles on one side immediately relax, the right knee is slightly bent, the tension of the ankle-joint is relieved, and the body, sinking upon the left hip, has its height diminished by above an inch and a-half. The weight of the trunk is sustained more directly by the column of bones of the left limb, which support that weight at a greater mechanical advantage than before; for the oblique direction of the neck of the thigh bone, with regard to the bones of the pelvis, which is very great in the perfectly erect position, is now diminished. But the great source of relief is that a different set of muscles is called into play on every change of posture; those which were before fatigued have time to recruit their energies, and become prepared afterwards to afford in their turn the same relief to others by resuming their exertions.

(248.) Strictly speaking, it is quite impossible for even the strongest man to remain for even a very short interval of time in precisely the same position. The fatigue of the muscles which are in action soon become sensible, and relief is instinctively given to them by varying the points of support. Thus we may observe that in standing, the weight of the body is naturally thrown alternately from one foot to the other. The action of standing must be considered as a series of perpetual, but obscure movements, by which the centre of gravity is continually shifted from one part of the base to the other; the tendency to fall in any one direction being perpetually counteracted by small and insensible movements in the contrary direction. Long habit has rendered us unconscious of these exertions, and inattentive to the sensations which prompt them. But a child, when acquiring the art of walking, is sensible of all these difficulties, and does not learn to walk but by reiterated lessons, and by the experience of many falls. It is by a practice of the same kind, and continued during a longer period, that the rope-dancer learns to support himself on a narrower or more unstable base than that which nature has provided. This he effects, not by keeping his centre of gravity precisely in the mathematical perpendicular to the rope, but by continually shifting it from side to side; never allowing it to fall above a certain very minute distance, and immediately correcting the vacillation by a movement which gives it an impulse in the contrary direction.

(249.) The flexures of the joints of the lower extremities, it may be observed, take place alternately in opposite directions. Thus, the thigh is bent forwards upon the pelvis; the leg is bent backwards upon the thigh; and the foot, again, is bent forwards upon the leg. This arrangement is obviously the one best adapted to convenience, both as regards the folding the parts when bent, and the commodious disposition of the muscles, which perform the opposite motions of flexion and extension. As the weight of the body occasions the flexion of the joints, so it is that flexion which the muscles are chiefly required to counteract; and this is the duty of the extensor muscles. We accordingly find, that in each joint, the latter are much larger, and more powerful than the flexors. They are enabled also to act with greater mechanical advantage, in consequence of their being inserted into projecting processes of the bones, evidently provided with this express intention. This is the purpose of the trochanter of the thigh bone, and the projecting bone of the heel. The same object is accomplished, in a still more artificial manner, in the knee-joint, by an additional bone, the *patella*, or knee-pan, into which the great extensor muscles situated in the fore part of the thigh are inserted, and which renders their action much more efficient, both by diminishing its obliquity, and by removing it farther from the centre of rotation. It acts, therefore, as a pulley, which is a species of lever; and it is so contrived, that while the knee is bent, and the muscles at rest, as when we are sitting, this bone sinks down, concealed in a hollow of the knee. When the extensor muscles begin to act, they draw out the patella from this hollow; and in proportion as they contract, and their strength diminishes, the patella gradually rising, gives greater mechanical advantage to their action, which is greatest of all when, by their complete contraction, their power is most expended.

(250.) The structure of the feet is also admirably contrived, as a secure basis for the support of the whole superincumbent weight of the body, and of all the additional burdens which the body may be made to sustain. The arrangement of the bones is in as strict conformity to the principles of the arch as those of the skull. The bones of the tarsus constitute what may be called a double arch; that is, an arch in two different planes, at right angles to one another. There is, in the first place, one great longitudinal arch, springing from the point of the heel to the ball of the great toe: and there is, in the second place, a transverse arch formed among the tarsal bones themselves, one within another. Near the heel this arch is composed of the astragulus, os calcis, and naviculare; and farther on, by the cuneiform or wedge-like bones, the name of which expresses their office, analogous to that of the stones at the crown of an arch of masonry. The elasticity, as well as security, resulting from all these arches, imparts that ease and spring so remarkable in the step, and obviates the injurious jar that would be otherwise inevitably communicated to the body by leaps, by falls, or other accidents.

(251.) In walking, the first action consists in fixing one foot firmly on the ground, by transferring to it the whole weight of the body; the other foot being then at liberty to move, is with the leg carried forwards. This projection of the limb is necessarily attended with a corresponding advance of the centre of gravity, which proceeds to move forwards till it arrives beyond the basis of the foot on which the body is resting. Whenever this happens, the body, being unsupported, begins to fall, and would continue to fall, were not the other foot in advance, and ready to receive it, and stop its further descent. This is the reason why we experience so disagreeable a jar, if in walking inattentively, the foot we had advanced happens to arrive at a lower level on the ground than had been expected; as when, for instance, we meet with a descending step for which we were not prepared. The body on these occasions, falling through greater space than usual, acquires a certain velocity of descent, and this unusual velocity being suddenly checked, communicates a shock to the whole system.

(252.) While the weight of the body is thus transferred alternately from one foot to the other, the centre of gravity of the body, while it is continually carried forwards, is at the same time alternately raised and lowered, so as to describe at each step a small arch; and its whole motion may be represented by a waving line, having lateral as well as longitudinal inflexions, and composed of a succession of short curves. In taking long steps, we are obliged to raise the centre of gravity through a longer arch, and therefore to a greater height. This is consequently more fatiguing than a shorter step. If, however, we go into the contrary extreme, and take too short steps, the advantage obtained in lessening the height of the arches described by the centre of gravity, is more than compensated by the greater quickness required in the motions necessary for keeping up the same rate of walking.

(253.) The lateral undulation of the body during walking is never performed with precise equality on both sides; and the amount of the accumulated deviations would be considerable, did we not avail ourselves of the assistance of the sense of sight in counteracting it. This will appear from the well-known fact, that it is impossible for a person who is blindfolded to continue to walk in a straight line for any considerable distance. Even on a perfectly level plain, we unavoidably incline to the right or to the left; and the want of consciousness that we are doing so, prevents us from rectifying the error; so that while we imagine we have undeviatingly pursued a straight course, we may perhaps, when the bandage is removed from our eyes, find ourselves near the very spot from whence we had commenced our circumambulatory excursion.

8. *The Upper Extremities.*

(254.) The upper extremity, though exempt from the office of supporting any part of the weight of the trunk, and intended for a variety of very different uses, presents us with exactly the same number of divisions as the lower extremities; excepting that in the skeleton, if we compare the scapula to the bones of the pelvis, there is an additional bone provided in the clavicle, or collar bone, by means of which the bones of the arm are articulated with those of the trunk. The extremity of the clavicle, indeed, by which it joins the sternum, is the pivot on which all the great motions of the arm are performed. The interposition of the scapula is evidently for the purpose of giving a more extended surface for the attachment of the strong muscles destined to act upon the arm and upper part of the trunk, and which also lend their aid in performing the movements necessary for respiration. It also contributes its share in the defence of the back part of the chest.

(255.) The joint of the shoulder is of the ball and socket kind, and admits, therefore, of the greatest latitude of motion. That of the elbow is a simple hinge-joint, and restricted consequently to mere flexion and extension. A rotatory motion was here unnecessary; for the free rolling of the arm at the shoulder answers every purpose that can be desired, and the elbow-joint is rendered more secure by this limitation of its motion; for it will always be found, that whenever a hinge-joint is sufficient for the purposes required, it is employed in preference to that of the ball and socket, which, from its very extensive range of motion, must necessarily be looser in its structure, and more liable to dislocation.

(256.) In the wrist, which is the great centre of all the motions of the hand, a construction was called for which might allow of the utmost latitude of motion. The following were the three kinds of movement required; first, simple flexion and extension; secondly, lateral flexions; and, thirdly, twisting, or rotation of the hand, as when it is employed in turning a screw. If all these different motions had been entrusted to a simple ball and socket joint, they could not have been well performed without great strains and hazard of dislocation. This danger is admirably obviated by distributing the motions among several articulations. No part of the bony system is more complex than the wrist, which consists of eight small bones crowded into a very narrow space, and lashed together by many strong ligaments, that form bands crossing one another in every possible direction. While they are together fitted to the bones of the fore-arm in the manner of a hinge-joint, their mutual connexions allow at the same time of considerable lateral flexion.

(257.) But still the rotatory or twisting motion of the hand, which is perhaps the most useful of all, is not provided for by this mechanism. For the accomplishment of this object there is employed a contrivance to which the rest of the system presents nothing similar. The wrist is connected not so much with the principal bone of the fore-arm, as with a subsidiary bone of equal length with it, and placed in a parallel position, termed the *radius;* and its peculiar mode of junction is such as to enable it to describe round the former a complete semicircle. In these rolling motions the radius carries along with it the hand, which thus turns in perfect security; for it is difficult to conceive how a force could well be applied, so as to separate bones having so long a lever of resistance. Thus, while the wrist is exempt from the weakness incident to circular joints, it possesses all the properties which we find in the most moveable.

(258.) The manner in which the fingers are disposed in the hand, like radii from a common centre, is such as to allow them very free play, and to extend their sphere of action. But the chief perfection of the hand, as a mechanical instrument of prehension, consists in the structure of the thumb, which is furnished with muscles of so great a strength, compared with those of the fingers, as to enable it to oppose and balance their united power. Hence the hand is capable of grasping a spherical body, and of keeping firm hold of a variety of objects, which it would otherwise have required the concurrence of both hands to retain.

(259.) The passage of the tendons, by which the fingers are bent, is particularly deserving of notice, and has often been appealed to as a signal instance of express contrivance. As the uses of the hand require the bending of each joint of the fingers independently of the others, it was necessary that separate muscles and separate tendons should be provided for each. The muscles are most advantageously placed high up in the arm, and convenience requires that those muscles which bend the last joints should lie beneath those that bend the middle joints. Had the tendons proceeding from the latter been directly inserted into the middle of the second bone of the finger, they would have been exactly in the way of the tendons which are underneath, and which are proceeding to a more distant insertion. They are therefore split into two branches, each being inserted into the side of the bone; and the lower tendon is thus allowed to pass on securely between them. This structure has also this further advantage, that it procures a more ready flexion of the last joint than of the other joints; a provision, the purpose of which is manifest, since it tends effectually to prevent the escape of the object we wish to lay hold of. "There is nothing," says Dr. Paley, "in a silk or cotton mill, in the belts, straps, or ropes, by which motion is communicated from one part of the machine to the other, that is more artificial, or more evidently so than this perforation." "Let a person observe his own hand while he is writing, the number of muscles that are brought to bear upon the pen, how the joint and adjusted operation of several tendons is concerned in every stroke, yet that five hundred such strokes are drawn in a minute. Not a letter can be turned without two or three tendinous contractions, definite both as to the choice of the tendon, and as to the space through which it moves. Yet how correctly does the work proceed; how faithful have the muscles been to their duty; how true to the order which endeavour or habit has inculcated. Let us watch the hand while playing upon a musical instrument. All the changes produced, though extremely rapid, are exactly measured, even when most minute; and display on the part of the muscles an obedience of action alike wonderful for its quickness and its correctness."

(260.) To specify all the instances of express contrivance in the mechanical conformation of the hand would fill a volume. As an organ of touch it is admirably formed. No instrument is better adapted to the practice of the mechanical arts; none could be better fitted for examining the properties of bodies, and the laws of the material world, of which none of the other senses, unassisted by that of touch, could impart to us any accurate knowledge. So great are the advantages which the possession of this organ has conferred upon the human race, that many philosophers, prone to paradox, have ascribed to this circumstance alone the whole of the intellectual superiority which he enjoys over the brute creation.

CHAPTER VI.

ASSIMILATION.

SECT. I.—CHEMICAL CONSTITUTION OF ORGANIZED MATTER.

1. *Necessity of Aliment.*

(251.) A constant supply of nutritive matter is necessary for the continuance of life, a necessity arising from a variety of causes. In the first place, the substance of which the body is formed is exposed to various sources of waste and dissipation, and is continually verging to a state in which the organs become unfit for the performance of their functions. The chemical affinities by which the elements of organized substances are retained in that peculiar mode of combination which constitutes their living state, are, as we shall presently see, very nicely balanced, and would be unable to preserve them in that condition were not some means provided for counteracting their natural tendency to decomposition. By the active exercise of their respective functions all the organs, but more especially the muscular and nervous systems, experience a deterioration of their component parts, and suffer decay and waste. Fresh materials are required for supplying this continual expenditure. A certain degree of temperature must also be kept up, otherwise the muscles would lose their faculty of contracting, and the nerves their power of conveying impressions to and from the sensorium. Materials are therefore necessary to be employed as fuel for keeping up the vital warmth. The daily consumption of combustible materials, apparently used for this purpose in the animal economy, is, we shall afterwards find, very large, and forms a considerable proportion of the food received into the body.

(262.) All that we have now said refers to the body in its adult or mature state, when it has attained its full dimensions, and when all that is required is its preservation in that state. But during all that period of life when the body is increasing in its size, it is evident that its growth can only take place in consequence of the addition of new particles to those already composing the substance of the body; and some parts, such as the hair and nails, continue to grow even to the latest period of life. At every age some part is liable to be injured or destroyed, and a provision is in most cases made for the reparation of that which has been injured, or even for the replacement of that which had been destroyed. These objects can be effected only by the supply of new materials derived from external sources.

The changes effected by the long series of assimilatory processes being essentially chemical, it becomes necessary to institute a particular inquiry into the chemical constitution of organized substances in their successive stages of mutation, from the most simple to the more complex conditions in which they are found to exist in the composition of an animal body.

2. *Chemical conditions of organized matter.*

(263.) The parts, which by their assemblage constitute an organized body, when compared with unorganized matter, exhibit in their chemical, as well as in their mechanical characters, the most well marked and striking contrast. Complexity, variety, and difficulty of analysis, are the leading features as much in the former, as in the latter of these subjects of consideration. Combinations equally artificial, equally the result of design, and of refined elaboration, are exhibited both in the mechanism of organic structures, and also in the chemical constitution of organic substances. Compared with the latter, all the bodies which are presented to us in the mineral kingdom, are extremely simple; and their study presents no difficult es of an insurmountable nature. The number of primary or elementary substances, or of those at least which we regard as simple, is, indeed, greater in the mineral kingdom, than that of those which enter into the composition of animal or vegetable bodies; but they are for the most part found united in binary combinations, or are, at least, easily resolvable into a small number of such binary compounds. In the products of animal or vegetable systems, we find a less variety of ultimate principles; but this is more than compensated by the infinitely greater diversity of modes in which they are combined. The same elements, instead of forming with each other mere binary combinations, generally exist in more complicated states of union; there, four, five, or even a greater number of constituent substances, having their affinities nicely balanced, and harmonized into one individual combination.

(264.) From this diversity in the mode of union, there arise remarkable differences in the properties of different organized products, formed from the same ultimate principles: nor can we, as in bodies belonging to the mineral kingdom, with an exact knowledge of the nature and proportions of the component substances, proceed, by any artificial arrangement, to the actual formation of the compounds themselves. No approach has yet been made by human ingenuity, to the imitation of nature in these refined operations of vitality.

(265.) Another consequence resulting from this difference in constitution between organized products and the inorganic bodies of the mineral kingdom, is that the affinities by which the elements of the former class of bodies are held in union, being nicely balanced, are more subject to change. The equipoise is easily disturbed and subverted. The principles have a constant tendency to react on each other, so as to give rise to a new order of combinations; which readily take place by slight alterations of circumstances. All organic products are susceptible of decomposition by heat alone; they are readily acted upon by various agents, as water or atmospheric air; and they are generally liable to spontaneous changes, to fermentation, and putrefaction.

(267.) Such, then, are the distinguishing features of the chemical properties belonging to the products of organization; simplicity as to the number of ultimate elements; complication in the mode and order of combination; unsteadiness in the balance of affinities retaining them in union, and consequent proneness to decomposition, and impracticability of their artificial formation by a reunion of their principles.

(268.) Whilst the products of the animal kingdom participate with vegetable bodies in these common characters, which distinguish them from inorganic materials, they differ from the former in several subordinate circumstances of chemical relation. The constituent principles of animal substances are somewhat more numerous, and their affinities more nicely adjusted, and more easily disturbed. Their chemical constitution is the result of still more delicate processes, and of a more elaborate organization. The three great component elements of all vegetable bodies, are *oxygen*, *hydrogen*, and *carbon;* but animal substances generally contain, besides these, a considerable proportion of a fourth element, namely *nitrogen*, the presence of which has a considerable influence on the changes they undergo when subjected to the operation of foreign agents, or left to the spontaneous operation of internal causes of decomposition. *Phosphorus* and *sulphur* must also be enumerated among the component parts of the greater number of animal substances; and the affinities exerted by these elements also tend to modify the results produced by these various causes. The greater the number of elementary ingredients present in any assemblage, the greater will be the tendency to form binary or ternary combinations; and the more will the affinities be divided between different elements, and pass easily from one mode of arrangement into another. Hence the greater susceptibility to decomposition which characterises animal products, when compared with vegetable.

(269.) In addition to the substances already mentioned, we must also reckon among the constituents of animal substances, *lime*, *potash*, *soda*, and *iron;* but these exist only in small quantities.

(270.) Some of the most important qualities distinguishing animal substances are owing, in particular, to the predominance of nitrogen in their composition. This substance is disengaged from them in large quantities by the action of the nitric acid. This acid, indeed, itself contains nitrogen; but it has been ascertained, that in producing this effect, the acid does not undergo any decomposition; so that the nitrogen is furnished not by the acid, but entirely by the substance subjected to its action. *Ammonia* is evolved both during the putrefaction of animal substances, and also by the application of a heat sufficient for their decomposition; and this ammonia results from the combination of the nitrogen with hydrogen during these processes. *Cyanogen*, or *prussic acid*, is also a frequent product of these operations; and is known to consist chiefly of nitrogen. Under these circumstances, also, the phosphorus enters into new combinations, particularly with the hydrogen and azote, and forms compound gases, which are extricated both during the putrefaction and destructive distillation of animal substances. By becoming acidified by its union with oxygen, it enters into combination with earths, alkalies, and oxide of iron, and forms a variety of neutral salts. The same observations also apply to the sulphur which is found in certain quantities in several animal substances.

(271.) Another general difference in the chemical composition of animal and of vegetable substances, is that the former contain a smaller proportion of carbon, and a greater proportion of hydrogen than the latter. Carbon may be regarded as the base of vegetable matter, to which oxygen and hydrogen are attached; while hydrogen appears to be the principal component part of animal matter, and is there combined with nitrogen, oxygen, carbon, and phosphorus. Hence during the decomposition of animal substances by heat, the chief products are ammonia and empyreumatic oil, in both of which hydrogen is a principal constituent. In general animal matters contain less oxygen than vegetable, and hence afford less acid by their decomposition; and the coal which remains differs from vegetable charcoal in being much less combustible.

3. *Proximate Animal Principles.*

(272.) In the numerous and diversified products of the animal kingdom, we may trace different degrees of complication in the composition of their elements. Several substances present the appearance of greater simplicity, and appear to result from the more direct union of a few elements, and to preserve among various shades of modification the same general properties, and the same distinctive characters. The more compound products often admit of an intermediate analysis into these comparatively simpler constituents, which are distinguishable from each other by a certain uniformity of character, and which we may presume are obtained in the same state as that in which they existed in the compound subjected to the analysis. These form what are termed the *intermediate* or *proximate principles of animal bodies,* in contradistinction to the *elementary principles,* which are the result of the ultimate analysis of the substance. These proximate principles may be considered as forming by their mixture, or combination, all the varieties of animal matter; and they are therefore the more immediate object of attention to the chemist in his analysis of animal substances.

(273.) The only method resorted to by the earlier chemists, in the infancy of science, for ascertaining the composition of animal substances, was that of subjecting them to the process of distillation at a high temperature, by which their proximate principles were entirely destroyed, and either converted into new compounds, or resolved into their ultimate elements. Many of these being gaseous, were suffered to escape, and were totally disregarded. Scarcely any light could be thrown upon the composition of animal bodies by such an imperfect mode of examination. Successive improvements were afterwards introduced into this branch of chemical research, consisting chiefly in the application of various re-agents, from which instructive results were derived.

(274.) The modern art of animal analysis may be considered as comprising three different kinds of operations, which, however, admit of being variously combined. The first consists in observing the spontaneous changes resulting from various natural circumstances in which the substances may be placed; the second depends on the application of chemical agents, employed either as tests to indicate the existence of particular elements or proximate principles, or as menstrua, which, by their specific affinities, may separate the elements or primary compounds from each other; while the third set of operations, reverting to the original plan of destructive analysis, effects the complete decomposition of the substance, but carefully collects all the volatile and gaseous matter, and deduces an accurate estimate of the nature and proportions of the ultimate elements. We obtain, for example, a certain quantity of water, carbonic acid, and ammonia; and knowing the proportions of oxygen, hydrogen, and carbon, which they respectively contain, we are able to ascertain the precise amount and relative proportion of the elements which entered into the constitution of the substance analysed.

(275.) The general result of the investigations which have been conducted by the last of these methods is, that the simple bodies of which animal substances consist are comprised in the following list:

1. Oxygen	8. Soda
2. Nitrogen	9. Potass
3. Carbon	10. Chlorine
4. Hydrogen	11. Magnesia
5. Lime	12. Iron
6. Phosphorus	13. Silica
7. Sulphur	14. Manganese.

(276.) Of these, the first six may be considered as the principal elementary ingredients of animal substances. Magnesia and silica are found only in very minute quantities, and may therefore be in a great measure considered as foreign bodies. The soft parts of the body are composed almost entirely of oxygen, nitrogen, carbon, and hydrogen; while lime and phosphorus form the basis of the hard parts.

(277.) The proximate principles most generally met with in animal substances are,

1. Gelatin	3. Fibrin
2. Albumen	4. Mucus.

(278.) To these have been added some others, such as *urea*, *picromel*, *stearin*, *elain*, *osmazome*, and several *saccharine* and *acid principles*, which being more limited in their extent, will fall more properly under consideration in the review we shall give of the substances which chiefly contain them. We shall first then present an account of the properties of the four essential principles above enumerated.

4. *Gelatin.*

(279.) Gelatin may be extracted by long continued boiling in water from almost all the hard and solid parts of the body, such as the skin, membranes, ligaments, cartilages, and even the bones themselves. By the slow evaporation of the water which thus holds it in solution, the gelatin may be obtained in a state of purity, when it appears as a hard, brittle, and semi-transparent substance, which breaks with a glassy fracture. It varies somewhat in its appearance, according to the source from which it has been obtained. Glue may be taken as an example of dried gelatin, in which, however, a few impurities are contained. Isinglass may be considered, on the whole, as the purest form under which gelatin is met with, and it exhibits most completely the characteristic properties of that proximate animal constituent.

(280.) One of the most striking characteristics of gelatin is the property it exclusively possesses, when united to a quantity of water, of dissolving slowly, but completely, forming a solution of an opaline colour, which is perfectly fluid when warm, but becomes concrete on cooling, assuming the tremulous appearance so well known as belonging to jelly. In this state it readily again becomes liquid, by the application of a gentle heat, and may, by the continuance of that heat, be brought back to the state of dryness. These alternate solutions and desiccations may be repeated for any number of times, without any change being produced in the chemical constitution of the gelatin. The proportion in which gelatin forms a solution capable of concreting by cooling, has been ascertained by Dr. Bostock in the following manner. One part of dry gelatin to 100 parts of water gave a solution which completely stiffened by cooling. But when the proportion of water was 150 parts to one of gelatin, a compound was produced, which though evidently gelatinous, did not assume the concrete form.

(281.) Solid gelatin undergoes no change if it be kept perfectly dry; but when united with water, either in the form of solution or of jelly, it very soon becomes putrid; an acid first makes its appearance, a fetid odour arises, and ammonia is afterwards formed.

(282.) The most ready and convenient test of the presence of gelatin in any fluid, is a solution of tannin; the addition of which immediately occasions, by the combination of these two principles, a copious precipitate, which assumes a solid form. This precipitate collects into an elastic adhesive mass, which soon dries in the open air, and forms a brittle resinous-like substance, very similar in appearance to over-tanned leather. It is perfectly insoluble in water, and is not susceptible of putrefaction. It is this combination of tannin with gelatin that constitutes the preservative part of tanned leather, and which enables it to resist the transmission of moisture. The solutions of tannin most conveniently applicable as tests of gelatin, may be prepared by an infusion of an ounce of gall-nuts in a pint of water; or, as Dr. Bostock has proposed, the extract of rhatania, digested in hot water, and filtered after it becomes cold. A considerable precipitate is produced by these infusions, when the proportion of gelatin to the water is so small as to compose only the five thousandth part of the solution. The precipitate afforded by tannin is not, however, to be considered as a decisive test of the presence of gelatin; for, as we shall presently find, it also occurs in consequence of the presence of albumen. In order to prevent any confusion from this cause, it will be necessary to have recourse also to another test, that of corrosive sublimate, which is found to precipitate albumen, but not gelatin. If, therefore, by adding corrosive sublimate, we obtain no precipitate, we may be certain of the presence of albumen.

(283.) Gelatin is insoluble in alcohol, but when already in solution in water, it is not precipitated by that fluid Acids dissolve it with great facility, even when much diluted, especially when aided by heat. The nitric acid effects its decomposition, during which nitrogen, and then nitrous gas, are disengaged in considerable quantities; and oxalic and malic acids are evolved, and may be obtained from the residuum. Sulphuric acid, with the assistance of heat, partly converts it into a substance resembling sugar. Chlorine combines with gelatin, forming a white substance, which assumes the form of filaments.

The pure liquid alkalies dissolve gelatin very readily. The solution is a brown viscid substance, which possesses none of the properties of soap, and is not precipitated by acids. This property of remaining dissolved after acids are added to the alkaline solution, distinguishes gelatin from albumen, fibrin, and other animal products, and is therefore a valuable mode of discriminating its presence, and of separating it from them in analysis.

(284.) Gelatin is precipitated by several of the metallic salts and oxides, but not so unequivocally as to afford satisfactory tests of its presence. Like all the other constituents of animal bodies, gelatin, while it preserves its essential properties, is susceptible of many shades of variation, and appears therefore under a diversity of forms, such as glue, size, isinglass, &c; but although many valuable remarks on this subject are contained in Mr. Hatchett's *Observations on the Component Parts of Animal Membrane*, published in the Philosophical Transactions for 1800, we are still very much in the dark as to the circumstances which occasion the differences in the several kinds of animal gelatin.

5. *Albumen.*

(285.) The proximate principle which, from its composing the greater part of the white of the egg has been termed *albumen*, is most abundantly met with in almost all the parts of animals, whether solid or fluid. It is the chief basis of several of the more solid textures of the body, such as the membranous and fibrous structures, and the parenchymatous substance of the glands and viscera; and it also forms a large proportion of the blood and of the secreted fluids.

In the white of the egg, albumen exists in a state of solution in water, and combined with a small quantity of soda. By agitation with a still larger quantity of water, the two fluids unite, and form a viscid liquid, the component parts of which do not separate by standing.

(286.) The characteristic property of albumen is its capability of coagulating, or passing from a liquid to a solid form, by the action of heat, of acids, and of alcohol, and several metallic salts and oxides. This change takes place in undiluted albumen, at a temperature of about 160° of Fahrenheit. After it has been once coagulated, albumen is no longer soluble in water, unless by long boiling, aided by pressure. By a long continued gentle heat, coagulated albumen gradually has its moisture dissipated, and the solid matter, amounting to about one-fifth of the original weight, is left behind, in the form of a hard brittle transparent substance.

(287.) If the albumen be much diluted, it appears to be incapable of coagulation by the usual means; but still it was found by Dr. Bostock, that a solution containing only one thousandth of its weight of albumen, although not properly coagulated, was rendered perceptibly opaque by a boiling temperature; so that heat may be considered, for all practical purposes, as a sufficiently accurate test of its presence in any fluid. During coagulation there is no absorption of oxygen; nor is any gas extricated: and hence there appears to be no reaction of the principles of the albumen upon each other. The nature of the change which takes place during this transition from the fluid to the solid form, is by no means well ascertained. Dr. Thomson supposed the fluidity of albumen to depend on the presence of alkaline matter; and its coagulation to the removal or neutralization of this alkali; and some experiments which were devised by Mr. Brande tend strongly to support this theory. He found that a rapid and abundant coagulation took place in the white of an egg subjected to the action of a galvanic battery, around the negative pole, where the alkali must have been separated; while a thin film only collected round the positive pole. He discovered also, by these experiments, that galvanic electricity may be applied successively to the detection of very minute quantities of albumen, which would not be rendered sensible by any other test.

(288.) Another agent which immediately effects the coagulation of albumen, unless it be previously much diluted, is alcohol. Ether also produces the same effect.

(289.) Acids in general occasion the coagulation of albumen; but several of them afterwards redissolve the coagulum if assisted by heat. This is at least the case with the three mineral acids. The coagulum formed by acids always retains in combination a portion of the acid which has been employed. That produced by nitric acid is the least soluble; and hence nitric acid occasions a precipitate from solutions of albumen, which are so dilute as not to be affected by other acids. Thenard remarks that the coagulum produced by acids, is re-dissolved by pure alkalies, and even by ammonia, which does not dissolve albumen that has been coagulated by heat. Nitric acid, when concentrated, decomposes albumen, extricating from it azotic gas, and during its solution, nitrous gas. Oxalic and malic acids are formed, and a thick oily matter, soluble in alcohol, appears on the surface. On the other hand, when coagulated albumen is subjected to the action of dilute nitric acid, it is after some time converted into a substance having the properties of gelatin. For this highly curious fact we are indebted to Mr. Hatchett.[1] Alum, probably in consequence of its excess of acid, coagulates albumen, provided the solution be not very dilute. One part of albumen in five hundred of water is rendered slightly turbid by a solution of alum, but without any *formation of a precipitate.*

(290.) The triple prussiate or ferrocyanate of potass is, according to Dr. Henry, an extremely delicate test of the presence of albumen, and may be used to discover it in fluids to which other tests are inapplicable. To enable it, however, to produce a precipitate, a very slight excess of acetic acid should be previously added, either to the test, or to the liquid suspected to contain albumen.

(291.) Another delicate test of the presence of albumen is a solution of corrosive sublimate; and it is the more valuable, inasmuch as it has no effect on solutions either of gelatin or of mucus. Dr. Bostock found that a single drop of a solution of corrosive sublimate added to a liquor containing one-thousandth of its weight of albumen, renders it visibly milky, and at the end of some hours a flocculent precipitate

[1] See his paper already quoted from the *Philosophical Transactions* for 1800.

falls to the bottom of the vessel. The same re-agent produces a sensible effect on a liquid, containing only half that quantity, or one two-hundredth of albumen.

(292.) Many other metallic salts, throw down a precipitate from solutions of albumen, as the acetate of lead, the nitro-muriate of tin, the nitrate of silver, and the nitro-muriate of gold; but as they produce a similar effect on other species of animal matter, they are scarcely deserving of confidence as tests of any one in particular. A solution of tannin, which, when added to albumen, occasions, after some time, a precipitate, may sometimes afford useful indications in analytical inquiries, for it may be distinguished from that produced from gelatin by its want of density and cohesion.

(293.) Albumen is readily dissolved by the pure liquid alkalies, which disengage ammonia from it, and form with the residue a saponaceous compound. This soap, when dissolved in water, is precipitated by acetic or muriatic acids.

6. *Fibrin.*

(294.) The proximate animal principle, known by the name of *fibrin*, or *animal gelatin*, exists in large quantity in the blood, and forms the basis of the muscular flesh of animals. When properly prepared, and freed from the admixture of extraneous matter, it presents a substance of a white colour, destitute of taste or smell, of a fibrous texture, and of a soft and elastic consistence. When dried it is brittle, and has a certain degree of transparency; it undergoes no change from the action of either air or water.

(295.) When exposed to heat, it contracts very considerably, and exhibits movements like horn, exhaling at the same time the smell of burned feathers. When subjected to great heat, it yields the usual animal products of water, oil, ammonia, carbonic acid, and carburetted hydrogen, with a large carbonaceous residuum. This charcoal is very difficult to incinerate, owing to the presence of phosphoric salts. which are fused by the heat employed for that purpose, and form a glassy coat on the surface. A considerable quantity of carbonate of lime is found in the residual ashes.

(296.) The acids exert a considerable action upon fibrin. Concentrated acetic acid renders it soft and transparent; and the whole mass is converted by heat into a tremulous jelly. By the addition of water, and the continued application of heat, a complete solution is effected, attended with the evolution of nitrogen. Fibrin combines with muriatic acid in two proportions; the one gives a neutral compound soluble in water; the other, containing an excess of acid, is insoluble, but becomes soluble by the action of pure water. Concentrated sulphuric acid decomposes and carbonizes fibrin. Diluted with six times its weight of water, this acid acquires a red colour by being digested with fibrin, but scarcely dissolves any sensible portion; but part of the acid is absorbed by the remaining mass, which becomes a compound of fibrin and an excess of sulphuric acid. Water deprives it of this excess, and a neutral combination is obtained, which is soluble in water, and has the same characters as neutral muriate of fibrin. The action of nitric acid upon fibrin is much diversified, according to its dilution or state of concentration. When the acid is diluted with a large quantity of water, a great abundance of nitrogen gas is disengaged. This gas is entirely derived from the fibrin, and not from the acid, which, as Berthollet ascertained, has suffered no decomposition during the process. The residuum, in this case, is principally oxalic acid, with a small quantity of malic and acetic acids, and a portion of fatty matter.

When the nitric acid is undiluted, on the other hand, it undergoes decomposition, and nitrous gas, mixed with nitrogen gas, is disengaged. When fibrin is digested for twenty-four hours in nitric acid of the specific gravity 1.25, it is converted into a pulverulent mass, of a pale citron colour, which is deposited at the bottom of the liquid. By washing it in water, the excess of acid is carried off, and the colour gradually becomes of a deep orange. Fourcroy and Vauquelin considered this yellow matter to be a peculiar acid, which they distinguished by the name of the *yellow acid.* But Berzelius has shewn that it is merely fibrin combined with nitric and malic acids. When the action of nitric acid on fibrin is very slow, it is gradually converted into a state somewhat analogous to gelatin.

(297.) Fibrin, when subjected to the action of caustic alkali, increases in bulk, becomes transparent and gelatinous, and at length is entirely dissolved, forming a yellowish green solution. From this solution it is precipitated both by acids and alcohol, but seems to have undergone some change; for it is not, as before, soluble in acetic acid. Fourcroy had asserted, that the compound of fibrin and alkali resembles soap; but it does not, in fact, appear to have any analogy with saponaceous bodies.

(298.) Alcohol of the specific gravity of 0.81, converts fibrin into a kind of adipocirous matter, which is soluble in alcohol, and precipitated by the addition of water. It has a strong and unpleasant odour. The alcoholic solution leaves, on evaporation, a fatty residue, which did not pre-exist in the fibrin, but which, like the original substance, is soluble in acetic acid. By the action of ether, fibrin is converted into the same kind of adipocire, but which has a more offensive odour, and is in larger quantity.

(299.) After the account we have given of the three proximate principles which enter so largely into the composition of animal matter, namely, gelatin, albumen, and fibrin, it will be useful to take a comparative view of the analogies they present, and of the differences by which they are distinguished, both in their properties and composition. They are apparently composed of the same ultimate elements, combined in proportions which are not widely different. They admit accordingly of mutual conversion into one another, by processes which produce a slight alteration in the proportion of their constituents. By the . ction of the nitric acid fibrin is converted into a kind of gelatin, and a similar change has been effected on albumen by the same re-agent. All these substances are presented both in the liquid and solid forms, and pass readily from the former to the latter of these states, without any apparent change in their chemical constitution. They are all of them indestructible when perfectly dry, but readily undergo putrefaction when united with water. Yet the modes in which they are respectively acted upon by water are different, and affords an easy character of distinction between them. Gelatin is soluble in cold water; the solution when evaporated becomes gelatinous; and if this jelly be dried, it is still again soluble. Albumen is likewise soluble in water; but whenever the temperature is raised to 170°, it separates by coagulation, and this coagulum is not again soluble. Fibrin is clearly distinguished by its total insolubility in water at any temperature, at least under the common atmospheric pressure.

(300.) Then these principles likewise differ in their composition; for though they seem to consist of some ultimate principles of nitrogen, hydrogen, oxygen, carbon, phosphorus, and sulphur, yet these differ somewhat in their proportions. The most accurate analysis of these substances into their ultimate elements are those of MM. Gay Lussac and Thenard, the results of which are exhibited in the following table:

	Gelatin.	Albumen.	Fibrin.
Carbon,......	47·881	52·883	53·360
Oxygen,.....	27·207	23·872	19·685
Nitrogen, ...	16·988	15·705	19·934
Hydrogen,...	7·914	7·540	7·021
	100.	100.	100.

It appears from the above analysis, that the principal difference of composition occurs in the proportion of nitrogen. Gelatin contains the least of this element; albumen more; and fibrin a quantity considerably larger than either of the others. The latter substance appears therefore to be the most animalized product. It also contains the largest quantity of carbon, as appears indeed from the greater residuum of charcoal which it leaves after destructive distillation. Sulphur is perhaps peculiar to the composition of albumen. On the other hand, the proportion of oxygen is considerably greater in gelatin than in either of the other two substances. This predominance of oxygen, together with the less compactness of its mechanical composition, are probably the causes of the greater tendency which gelatin shows to pass into the acid fermentation. In this respect also, gelatin shows itself to be less completely animalized than the other proximate principles, and to partake more of the chemical character of vegetable substances, which are well known to evolve an acid in the progress of spontaneous decomposition. There are indeed some vegetables, as the tribe of fungi, that become alkaline by their putrescence;

and these are found to contain nitrogen ; so that gelatin on the one hand, and the fungi on the other, may be regarded as forming, on each side, the connecting links between these two great kingdoms of nature.

(301.) It is a curious subject of speculation to reduce the proportions resulting from the analysis of the French chemists, to those which are most reconcileable to the atomic theory. They will then stand as follows :

Number of atoms of	In Gelatin.	In Albumen.	In Fibrin.
Carbon, ...	15	17	18
Oxygen, ...	6	6	5
Nitrogen, ...	2	2	3
Hydrogen, ...	14	13	14

The weights, both absolute and relative, of the atomic elements, are shewn in the following table :

	Gelatin.		Albumen.		Fibrin.	
	Absolute.	Relative.	Absolute.	Relative.	Absolute.	Relative.
Carbon,....	90	50·00	102	53·40	108	52·94
Oxygen,...	48	26·67	48	25·13	40	19·61
Nitrogen,.	28	15·55	28	14·67	42	20·59
Hydrogen,	14	7·78	13	6·80	14	6·86
	180	100·	191	100·	204	100·

In the conversion of albumen into jelly, by the slowly continued action of nitric acid, we may conclude that the acid imparts a portion of its oxygen to the albumen, and perhaps adds also a small quantity of nitrogen ; thus constituting the proportions assigned to gelatin by Gay Lussac and Thenard.

7. *Mucus.*

(302.) The term *mucus* has been employed in very different senses by different writers. Some have applied it vaguely to almost every animal substance which was not referable to any other class. Fourcroy and Vauquelin, while they include under this term the viscid secretions which lubricate the alimentary and other passages that open at the surface of the body, they have admitted its claim to be considered as a peculiar proximate principle, but regard it as analogous to vegetable gum, from which they suppose it to differ only by containing a proportion of nitrogen. Their descriptive account of its properties, however, are deficient in the precision which the subject seems to require, and which have been aimed at by subsequent chemists. Berzelius, it is true, refuses to allow that there is any such common principle as mucus, and founds his opinion on the ground that the chemical characters of the fluids which bear that name, are very various in different parts of the body, and are modified in different situations, according to the particular purposes they are intended to fulfil. Mr. Hatchett, in his interesting paper on *the Component Parts of Animal Membrane*, has attempted to fix the meaning of the term more definitely. Viewing mucus as extremely analogous in its properties to gelatin, he considers these two substances as merely modifications of each other; the former characterized by its incapability of being gelatinized; the latter by possessing that property; while both are soluble in water.

Dr. Bostock, in his excellent papers on *the Analysis of Animal Fluids*, has endeavoured to establish definite characters as belonging to this fluid, when existing in a state of purity. He states that if the solid matter obtained from the evaporation of saliva to dryness, be re-dissolved in water, and filtered, the solution will consist of mucus alone, or with scarcely any extraneous substance. By a careful evaporation he found that the solution contained one two-hundredth part of its weight of mucus. He also obtained a similar principle by macerating an oyster in water, and evaporating the liquid. It thus appeared that the water had dissolved about one-fiftieth of its weight of animal matter. Mucus thus obtained resembles gum-arabic, excepting that it is somewhat more opaque. Like it, it has scarcely any taste, dissolves readily in water, and forms an adhesive solution. Alcohol added to this solution has no tendency to coagulate it. No appearance of coagulation is produced by exposing the fluid for some time to the heat of boiling water; nor is there any tendency to gelatinize, by evaporating and afterwards cooling the fluid. No distinct effect is produced on the solution of mucus, either by the nitro-muriate of tin, corrosive sublimate, or the infusion of galls. The subacetate of lead, or Goulard's extract, occasions an immediate opacity, and after some time, a flaky precipitate.

(303.) Dr. Bostock concludes that a decided and essential difference is thus established between mucus and jelly, by the different effects produced by tannin, and by subacetate of lead. Tannin is a most delicate test of jelly, but does not in any degree affect mucus. Goulard's extract, on the other hand, is a delicate test of mucus, but does not in any degree affect jelly. The bichloride of mercury, (corrosive sublimate), on the contrary, which is one of the most accurate tests of albumen, does not appear to affect either jelly or mucus.

Notwithstanding the attempts which Dr. Bostock made to devise a method of directly determining the proportion of mucus in a compound fluid, he was not able to succeed, in consequence of the facility with which Goulard's solution decomposes the different extraneous ingredients, both animal and saline, which are almost always present in substances that contain mucus, even in a state the nearest approaching to purity. The salts are particularly liable to act upon the metallic solutions employed as tests; so that it is impossible to say how much of the effect is owing to each of these separate causes. The precipitates thrown down from mucus by subacetate of lead, and nitrate of silver, were found by Mr. Brande to consist both of the muriates and phosphates of those metals. Mr. Brande also attempted to obtain mucus free from neutral salts, by subjecting it to the action of galvanic electricity. He thus detected a small quantity of albumen in saliva, which was not discoverable by the ordinary tests.

(304.) A great resemblance has frequently been noticed between the mechanical properties of animal mucus and vegetable gum; and Dr. Bostock found that they strongly resemble each other also in their chemical qualities. A solution of gum-arabic, containing one grain of gum to two hundred grains of water, was not affected either by the bichloride of mercury, nor by tannin. With the nitro-muriate of tin, and with the nitrate of silver, there was only a slight degree of opacity; but with the subacetate of lead there was a dense precipitate instantly formed.

(305.) On the whole, however, animal mucus in its chemical relations appears to be most nearly allied to albumen; and the constituent upon which its characteristic properties principally depend, would seem, as Dr. Bostock remarks, to be a mere modification of this substance.

(306.) We shall conclude our account of this substance by the following direction as to the order in which it will be most convenient to conduct our analytical inquiries of a fluid, which may be supposed to contain either albumen, jelly, or mucus. The first step is to observe the effect of the bichloride of mercury; if this produce no precipitate, we may be certain that the fluid in question contains no albumen. We should next employ the infusion of galls, and if this also occasion no precipitate, we may conclude that the animal matter held in solution consists of mucus alone. Such being the chemical properties of the chief proximate principles of animal organization, we have next to examine the mode in which these substances are produced in the economy.

SECT. II.—ARRANGEMENT OF THE FUNCTIONS OF ASSIMILATION.

(307.) The means provided by nature for meeting the various demands of the system, by converting materials derived from without into the proximate principles of animal organization, the properties of which we have now examined, constitute a separate class of functions distinct from all the others. They might not unaptly be termed the *reparatory functions;* but as the changes which are effected in the materials received into the body for its conversion into nutriment are wholly of a chemical nature, we thought they might, with still greater propriety, be termed the *chemical functions*, in contradistinction to those the objects of which are entirely of a mechanical nature, and which have already passed under our review.

(308.) The reparatory, or chemical functions, may be divided into two great orders; the first consisting of those which effect all the changes that the food undergoes during its conversion into blood; the second, of those which apply the blood, or nutriment thus properly prepared, to the various purposes for which it is wanted, and which effects in it those chemical changes that are required for those objects.

(309.) The first order may again be subdivided into several subordinate processes, including, 1st, The preparation which the food undergoes in the mouth by *mastication*, or mechanical division. 2d, Its admixture with saliva and other secretions, which is generally termed *insalivation*. 3d, Its *deglutition*, or conveyance into the stomach. 4th, Its *digestion* in that cavity, and conversion into chyme, which may properly be termed *chymification*. 5th, The subsequent changes it undergoes in the intestines, by the influence of various agents, such as the bile, the pancreatic and intestinal secretions; and its ultimate conversion into chyle, and separation from the excrementitious portion, comprising the processes of *chylification*. 6th, Its *absorption* by the lacteals, its transmission to the heart, and its *sanguification*, or conversion into blood. To the above functions the title of *natural functions* was given by the older physiologists, and the name is retained in many modern works in medicine.

(310.) The second order comprehends, in like manner, a number of most important functions, which, from their immediate influence on the continuance of life, have been emphatically denominated the *vital functions*. They consist, 1st, of the *Circulation* of the blood, by means of the heart, arteries, veins, and capillary vessels. 2d, *Respiration*, by which every portion of the blood is subjected in its turn to the chemical action of the air respired; is freed from its excess of carbon, and becomes oxygenated, or arterialized, and fit to be applied to the purposes of the system. 3d, *Secretion*, a term which expresses a variety of changes effected in the blood, by passing through glands and other secreting organs, adapting it to different purposes in different cases. Closely allied in its object to secretion is the function of (4th) *Nutrition*, whereby the several parts of the body receive accessions to their growth, and are maintained in the condition requisite for the perfect performance of their requisite offices. 5th, *Absorption* by the lymphatics, for the removal of all superfluous or decayed particles in the body. 6th, The last function in this order, which completes the series of chemical changes going on in the living laboratory of the body, is *Excretion*, or the separation of useless or noxious materials from the blood, and their rejection from the system. We shall proceed to the consideration of these functions in the order in which they have been enumerated. But for the proper understanding of the subjects they involve, it will be necessary to premise an inquiry into the chemical nature of the substances which are received into the body as food.

SECT. III.—PROPERTIES OF FOOD.

(311.) The food of man is more various in its kind than that of any other animal; for it comprehends a great multitude of articles both of an animal and vegetable nature. Hence man has been regarded as entitled to the appellation of an omnivorous animal. His powers of digestion, however, though capable of being exercised upon a great variety of materials, are yet inadequate to the assimilation of many substances, which form the exclusive food of several of the larger quadrupeds whose structure and economy are not very remote from those of man. The human stomach and intestines are incapable of extracting nourishment from the fibrous or membranous parts of vegetables, like the ox, the sheep, and other herbivorous animals; nor have they the power of digesting hard and solid bones, like the hyæna, the dog, and other highly carnivorous quadrupeds. Neither the leaves of trees nor the grasses, have ever, in any age or country, been used as the food of man. Many savage races of the American continent, though possessing vast tracts of country abounding in trees and grass, have frequently been visited by the extremes of famine, by which whole districts have been depopulated. When Australia was first visited by Europeans, the native inhabitants were found only occupying the sea-coast, gathering up a scanty and precarious subsistence from the shell-fish casually thrown upon the shore; but the settlements which have since been made have occasioned their retirement into the interior, and their numbers have rapidly diminished. It is obvious that, had the leaves of the vegetables which grow wild in those regions been capable of affording the smallest sustenance, they would have necessarily been resorted to in these extremities of hunger. But no authenticated instance of the kind occurs in the history of the human race.

(312.) Man, however, seems to enjoy the exclusive privilege of having organs of digestion equally adapted to the assimilation of both animal and vegetable aliment of certain kinds; and the range which is allowed him in this respect is most extensive. Hence we find, that in most countries where there prevails a high degree of civilization, and where religious scruples do not interfere, both animal and vegetable food is indiscriminately employed by all who can procure them. In many parts of the globe, indeed, necessity compels a restriction to certain kinds of diet; and in some the same restriction is imposed as a religious duty. Thus the Gentoos live entirely on the vegetable produce of the earth, to which, however, they add the highly nutritious article of milk. The Birmans, who are a remarkably active and robust race, are said to live exclusively upon vegetable food. On the other hand, the inhabitants of the mouths of many of the African rivers, live wholly upon the produce of the ocean. The flesh of the rein-deer constitutes the principal food of the Laplander. In general it would appear that the inhabitants of cold climates consume a larger proportion of animal food than those of the torrid zone. Whence it has been, with much probability, inferred, that less combustible matter is required b' the system in situations where the external temperature is habitually high; a remark which, if well founded, is conformable to the principle already laid down in our statement of the purposes to which a portion of the food is applied, namely, that of keeping up the animal temperature. In the ruder periods of society, when the arts of civilization had not yet diffused their beneficial influence over mankind, it is probable that men were more carnivorous than in the present state of the world. The introduction of the use of corn, and other grains of the same class, has effected in this respect an important change in the condition of the species; but it would appear that the introduction of this great benefit was very gradual, and must have required a long succession of ages before the cultivation of the gramina had attained any degree of perfection.

1. *Animal Food.*

(313.) The parts of animals which are chiefly consumed as food is the muscular flesh; but milk, and the different products obtained from milk, together with eggs, also compose articles of diet. The animals from which these aliments are derived, are principally the herbivorous mammalia, different tribes of birds and fish, a small number of the class of reptiles, and several species of mollusca and crustacea. The flesh of the mammalia and of birds consists principally of fibrin and gelatin, intermixed also with fat. Milk may be considered as an emulsion of albumen, oil, and sugar, suspended in a large quantity of water. The two former ingredients, when obtained separately, constitute respectively cheese and butter. The eggs of birds chiefly contain albumen, together with a small quantity of oil. Fish contains less fibrin, but a larger proportion of albumen and gelatin than the flesh of either quadrupeds or birds ; and in some fish there is joined to these constituents a large quantity of oil. This also is the case with those crustacea and mollusca which are used as articles of diet. When we come, therefore, to analyze the proximate principles from which animal nutriment is derived, we find them reducible to the following: namely, fibrin, albumen, oil, gelatin, and sugar ; together with a few others, such as ozmazome, which are of minor importance.

2. *Vegetable Food.*

(314.) The parts of vegetables most frequently consumed as food, are the seeds, seed-vessels, fruits, stalks, roots, and tubera, and more commonly the leaves. The most nutritious amongst the proximate principles resulting from the analysis of these vegetable materials, are gluten, farina, mucilage, oil, and sugar. The seeds of the cerealia or of rice constitute the chief bulk of the food in those countries where civilization has made any considerable progress. Of all these kinds of grain, wheat appears to contain, in proportion to its bulk, the greatest quantity of nutriment ; and this arises from its abounding in gluten, which of all the vegetable principles appears to be best adapted to the human organs of digestion. In its properties it bears a strong resemblance to animal substances; and it appears, indeed, by chemical analysis, to contain a large proportion of nitrogen. Hence it may be considered as the most animalized of the vegetable products. Gluten is contained in most vegetables which afford farina, and is also found in the leaves of many esculent vegetables, such as the cabbage.

(315.) *Farina* is found in great abundance in wheat and other grains, and also forms a large proportion of the nutritive portion of rice, and of certain tubers, among which the principal is the potatoe. The leaves, stalks, and seed-vessels of plants are rendered nutritious by the mucilage which they contain, which is generally united with a portion of sugar.

(316.) The saccharine principle contained in vegetables, and blended with their other elements, contributes greatly to render them nutritious; though in its pure state, as extracted from the sugar-cane, or the beet, it is rather used as a grateful addition to other articles of diet than as a separate source of nutriment. Sugar may be extracted from a great variety of plants besides those above mentioned. The maple, the birch, the parsnip, the cocao-nut, walnut, maize, and carrot, contain it in great abundance, as is the case, indeed, with every species of grain used as food. Almost all fruits are more or less saccharine. Figs, grapes, and dates, which contain it in large quantity, form a very considerable proportion of the food of the inhabitants of the south of Europe, and the African nations on the borders of the Mediterranean. All fruits contain a basis of mucilage, and in many this mucilage is combined with oil as well as with sugar.

(317.) Attempts have frequently been made to reduce all nutritious substances to a single principle common to all of them, and to establish accordingly a scale of nutriment, the place which any substance should occupy on that scale being regulated by the proportion in which this essential principle existed in it. Haller conceived that jelly might be considered as fulfilling this condition, and as being the essentially nutritive substance in nature.[1] Cullen thought that this property appertains to two substances, the nutritious matter being either of an oily or saccharine nature, or consisting of these two qualities combined.[2] Richerand considers alimentary matter as either gummy, mucilaginous, or saccharine.[3] Dr. Fordyce referred all nutriment to the presence of mucilage.[4] All these, and many other attempts at generalization, made by different physiologists at different times, are premature and unphilosophical, since they associate in the same class substances having properties totally dissimilar, although they concur only in that of affording materials for the support of the animal system. Perhaps the most exact classification of the kind is that of Magendie, who refers all alimentary substances, whether animal or vegetable, to the following heads, namely, farinaceous, mucilaginous, saccharine, acidulous, oily, caseous, gelatinous, albuminous, and fibrinous.

(318.) Prout, in a paper published in the *Philosophical Transactions*,[5] thinks that all the articles of food used by man may, according to their chemical relations, be arranged under three heads, namely, the saccharine, the albuminous, and the oily. Sugar, the basis of the first class of ali-

[1] *Elementa Physiologiæ*, xix. 3, 2. [2] *Physiology*, § 211.
[3] *Elémens de Physiologie*, § 3, p. 82. [4] *Treatise on Digestion*, p. 84.
[5] For the year 1827, p. 355.

mentary substances, he finds to consist of carbon in different proportions, from thirty to fifty per cent. chemically combined with water. The basis of albumen and oil are more compound, but are also united with water, the proportion of carbon existing in some of the oils being nearly eighteen per cent. He is of opinion that two at least of these elements must be blended together in our food in order to render it either nutritious or digestible. Milk, the food provided by nature for the young animal, exhibits the most perfect union of these three elements.

(319.) It must be evident, however, upon a slight consideration, that notwithstanding all the attempts that have been made to establish an accurate scale of nutriment, more must depend upon the powers possessed by the digestive organs to convert the particular kind of food into nutritious matter, than upon its being able to supply the elements requisite for composing nutriment. Thus there are many substances, such as oil for example, which contain a very large proportion of the elements which compose the blood, but which are extremely difficult of digestion, and consequently cannot of themselves be considered as nutritious, although when blended with other substances which contain fewer of these elements, but which enable the stomach to exert a proper action upon the compound, they become highly nutritive. This remark applies also to sugar, which, although adding considerably to the nutritive qualities of those vegetable products which contain it, would not, if used alone, be capable of supporting life. Magendie found, that dogs fed upon sugar alone soon became unhealthy, and if that diet was persisted in, perished from inanition.[1] Dr. Stark made

[1] *Physiologie*, tom. ii. p. 390.

numerous experiments upon himself, to which, indeed, he ultimately fell a victim; from these it appears, that substances which afford most nutriment, if their use be persevered in for any length of time, to the exclusion of other diet, soon produce derangement of the stomach, and failure of its digestive power. Peculiarities are often met with in the stomachs of different individuals with respect to the power of digesting particular kinds of food. In this respect much depends upon previous habits; so that it is scarcely possible to establish any general rules with regard to the nutritious qualities of different species of aliment, that are not invalidated by innumerable exceptions. The quantity of liquid that is taken in along with the solid food is also exceedingly various in different individuals; that which is suited to the digestion of the one being found to disagree with another. If we except soups, which of course consist of the soluble parts of materials out of which they are prepared, and also milk, the liquids received into the stomach rarely contain any notable proportion of nutritious matter, but seem rather to aid the digestion of more solid food, either by supplying the place of a solvent, or by acting as a stimulus to the stomach. They are also in many cases necessary for supplying the loss occasioned by perspiration, which in hot climates, by regulating the temperature of the body, is essential to the preservation of health. These purposes are answered by many vegetable infusions, such as tea and coffee, and also by fermented liquors, although the latter contain to a certain extent many of the materials of nutrition, such as sugar and mucilage, besides the stimulant principle of alcohol.

3. *Condiments.*

(320.) With a view to the same stimulant effect, various substances are added in small quantities to our food, which act as condiments. Of these the principal is common salt, a taste for which seems to be natural to a great number of animals, and which, used in small quantity, has the effect of promoting digestion. Other condiments, such as pepper, mustard, garlic, and various other spices and aromatics, are employed chiefly from the agreeable impression they make upon the palate; but they in many cases check the tendency to fermentation which many kinds of food are liable to undergo in the stomach. As a general rule, to which, of course, there are many exceptions, whatever is agreeable to the palate is adapted also to the digestive powers of the stomach. A certain degree of variety in the articles of diet is more conducive to the nourishment of the body than confinement to any single article.

SECT. IV.—APPETITES.

1. *Hunger.*

(321.) Hunger is a peculiar sensation excited in the stomach by the want of food, and by the presence of the gastric juice in that organ conjointly. It is evidently an affection of the nerves of the stomach, for it is a good deal dependent on the state of the nervous system. Its periodical recurrence at stated times shews that it is a good deal under the dominion of habit. Hunger often suddenly ceases upon the occurrence of sudden emotions of grief or anger, and is much influenced by other causes of mental excitation. Literary men deeply absorbed in meditation often forget that they have occasion for nutriment, and are unconscious of the calls of hunger. Hence such persons are often great sufferers from disordered digestion.

(322.) The presence of the gastric juice appears however to be a natural stimulus to appetite, its primary action being probably in the nerves of the stomach. A similar effect may be produced, when the stomach is full, by taking spirituous liquors, or high-seasoned dishes. Those physiologists who were inclined to refer the phenomena of the living body to mechanical causes, ascribed the sensation of hunger to the friction of the surfaces of the stomach against one another, which they supposed took place when it was empty; but the anatomy of that organ, which, from its rounded form, and from the softness of its texture, would seem totally incapable of producing friction by any of its movements, is totally at variance with this hypothesis. Others have conceived that the collapse of the stomach in its empty state, by deranging the position of the liver and spleen, drags down the diaphragm, and thus excites irritation in the nerves of those regions; and they endeavour to support this doctrine by the alleged fact, that hunger is prevented and appeased by wearing a tight girdle, which occasions pressure on the stomach and gives support to the neighbouring organs. But the instances already given of the dependence of hunger on the states of the nervous system, are sufficient to prove that it is not owing to any mechanical cause.

(323.) The chemical physiologists attempted to explain the phenomena solely by the action of the gastric juice on the coats of the stomach, which they imagined it tended to corrode, and hence gave rise to an uneasy sensation. It is much more probable, however, that the impression made by this secretion is exclusively on the nerves of the stomach;

and there is no doubt but that this action is one of the principal causes of hunger; for it has been found, that, if after long fasting, when there is a considerable accumulation of gastric juice, and when the sensation of hunger is extremely intense, it at once ceases if the gastric juice be removed by an emetic; or even if it be much diluted by taking large quantities of hot water.

(324.) The effects of long abstinence from food are, great loss of strength, emaciation, discoloration of the blood and of the secretions, an increase of nervous susceptibility, fever, loss of sleep, painful sensations in the region of the stomach, followed by total loss of appetite, delirium, and death. It has been said, that the exterior of the bodies of those who die of famine has exhibited a shining appearance in the dark, as if they had been impregnated with uncombined phosphorus.

2. *Thirst.*

(325.) Thirst is a sensation somewhat analogous to hunger with respect to its cause and effect, and with respect of its depending on particular states of the nervous system. It is considerably more distressing and intolerable than hunger. The seat of the sensation appears to be in the mouth and fauces, although its origin is generally in the state of the stomach, or general condition of the system. In the healthy condition of the organs it is a natural impulse prompting us to supply the system with the fluids requisite for carrying on its functions. But in the case of fevers, and other morbid states, thirst is sometimes excessive, and, if indulged without restriction, would prove highly injurious. In cases where a preternatural opening has been made into the œsophagus through the neck, the sensation of thirst is found not to be in any degree assuaged by fluids applied to the mouth, or even swallowed, if they escape through the wound, and do not descend into the stomach; whereas, it is immediately relieved when the same fluids are introduced into the stomach.

SECT. V.—PREPARATION OF THE FOOD FOR DIGESTION.

(326.) The preparatory processes to which the food is subjected previous to its introduction into the stomach, are partly of a mechanical and partly of a chemical nature. It is masticated by the teeth and jaws, and at the same time mixed with the saliva and mucous secretions of the membrane lining the mouth, fauces, and œsophagus. The effect produced by these operations is to reduce the food to a soft and uniform pulp, which is more easily acted upon by the solvent powers of the gastric juice than if it had been swallowed entire.

1. *Mastication.*

(327.) During mastication a great number of muscles are called into action. The principal of these are the powerful muscles that elevate the lower jaw, namely, the temporal, the masseter, and the pterygoid muscles, the latter of which are capable of giving at the same time some degree of lateral motion to the jaw, adapting it thereby to effect a grinding action by the medium of the teeth. The lower jaw forms a lever of the third kind with a double angle, the fulcrum being at the condyles, which are curiously articulated with the skull, by means of an interposed cartilage. Its motions are almost entirely confined to those of elevation and depression; but it has also a more limited extent of lateral motion.

(328.) The teeth, which are the great agents in mastication, have already been described and their different classes enumerated, under the head of ANATOMY. The respective purposes served by each class are sufficiently evident from their shape and position in the jaw. The incisor, or front teeth, are employed for cutting or dividing the food like a pair of shears or scissors ; the cuspidati, or eye-teeth, placed a little farther back in the jaw, are particularly adapted to lay hold of, and tear asunder, fibrous textures that afford considerable resistance ; their action may be compared to that of pincers. Mr. Hunter, after reviewing their different forms in the different tribes of quadrupeds, is enabled to trace a similarity in shape, situation, and use of the cuspidati, from the most imperfect carnivorous animal, which he believes to be the human species, to the most perfect carnivorous animal, the lion. The bicuspidati and molares compose what are called the grinding teeth, and their chief office is the trituration of substances already torn off by the cuspidati, or cut by the meeting of the incisors. The molares especially, being placed nearer to the articulation of the jaw, or centre of motion, act with greater power in exerting pressure on whatever is between them. If we wish to break a very hard body, the shell of a nut for example, we instinctively place it between the backmost molares, where the resistance it opposes to fracture acts by the shortest lever.

The bony substance of the teeth is preserved from the injury to which it would be exposed by the friction of hard substances, and by the contact of corroding fluids, and the influence of the air, by being cased in enamel, which, as we have seen, is considerably harder than bone. In consequence of the peculiar mode of its formation, the enamel is incapable of being renewed by a fresh growth when it has been worn away by friction. When, however, the teeth are lost by age, accident, or disease, their alveoli close and are obliterated by absorption; the gums then acquire a degree of hardness, that renders them an imperfect substitute for the teeth in mastication.

(329.) The chief agent in distributing the food so as to place it in proper situations between the teeth for the purpose of mastication, and for transferring it to the fauces, is the tongue. This organ consists almost entirely of muscular fibres, which are variously arranged, and interwoven together in a very intricate manner, so as to render it capable of motion in every possible direction. Its root is affixed to a bone which is peculiar to it, called the *os hyoides*, from its resemblance to the Greek letter υ, which furnishes a basis of attachment to the greater number of the muscles of the tongue, and the extremities of which being extended considerably backwards, serve to keep the palate expanded and always prepared to receive the food. But the tongue also contains a set of muscular fibres, which proceed longitudinally through the centre of that organ, unattached to any bone, and serving to contract its length. The tongue is thrust out of the mouth, not by any power of elongation in the muscles, as might at first sight appear to be the case, but by the contraction of that portion of the radiating fibres proceeding backwards from the inside of the jaw and the os hyoides, and drawing forwards the root of the tongue when they act alone. This complex structure is admirably adapted to the great variety of uses to which the tongue is applied, not only in mastication and deglutition, but also in speaking.

(330.) The muscular actions of the lips and cheeks are also intimately concerned in mastication; and ample provision is made for their varied movements by being furnished with so great a number of muscles as those which cover the face, and are attached more or less to the lips and corners of the mouth.

2. *Insalivation.*

(331.) While the food is under the action of the organs of mastication which effect its mechanical division, it is at the same time mixed up with the saliva. This fluid is found, when chemically examined, to consist principally of mucus and albuminous matter held in solution in water, together with a small proportion of saline ingredients.

(332.) Dr. Bostock considered that he had detected two kinds of animal matter in the saliva, one composing the soft masses, and giving it its consistence and physical characters, nearly similar to coagulated albumen, the other dissolved in the water of the fluid along with the salts, and resembling the serosity of the blood.[1] Berzelius regards the former of these substances as corresponding in its properties to mucus, and states the saline ingredients to be chiefly alkaline muriates, with a small quantity of lactate of soda and of pure soda.[2] Tiedemann and Gmelin state the solid contents of the saliva to vary from one to twenty-five per cent, and to consist of salts, mucus, and ozmazome, to which are added, in some cases, a little albumen and a little fatty matter, containing phosphorus. The soluble-salts consist of alkaline carbonate, which gives an alkaline character to the fluid, acetate, phosphate, sulphate, muriate, and sulpho-cyanate. The alkali in man is almost solely potass; while, in the dog and

[1] *Edin. Med. Journal*, ii. 44.
[2] *Medico-Chirurgical Transactions*, iii. 242.

sheep, it consists of soda, with very little potass. The presence of sulpho-cyanic acid, on the other hand, is almost peculiar to the human saliva, being scarcely perceptible in that of the dog. Some insoluble salts, namely, phosphate of lime, carbonate of lime, and carbonate of magnesia, are also detected in the saliva, but in very minute quantity.[1] Leurat and Lassaigne, whose investigations were nearly contemporaneous with those of Tiedemann and Gmelin, represent the chemical properties of the chyle as being essentially the same in all animals, and consider the animal matter it contains as a species of mucus.[2]

(333.) When viewed by a good microscope, the saliva is generally found to contain globules of very minute size.

(334.) The saliva is secreted by the parotid and other glands in the vicinity of the mouth, and is poured out in considerable quantities during mastication. It has been estimated that about six or eight ounces of saliva are at each principal daily meal mixed up and incorporated with the food. It flows much more abundantly during a meal, and particularly if the food that is eaten possesses stimulating qualities, and has a sapid flavour. The quantity is augmented by the appearance, or even the idea of food, when the appetite is keen. The influence of the nerves which supply the salivary glands is very marked in regulating their secretions, as we shall have occasion to observe more at length, when we come to consider the function of secretion. The pressure of the muscles of the cheek on the parotid gland assists no doubt in the quick discharge of the secretion of that gland by its excretory ducts; and the same remark

[1] *Recherches sur la Digestion, par Jourdan*, p. 23.

[2] *Recherches Physiologiques et Chimiques sur la Digestion*, p. 33. See *Bostock's Elementary System of Physiology*, p. 487, note.

applies also to the submaxillary and sublingual glands, which also prepare saliva, and whose ducts open into the mouth; for we find, that during mastication all the muscles about the mouth are in continual action. The tongue presses the food on all sides, and thrusts it between the grinding teeth, while the muscles of the cheek, but more particularly the buccinator, against which the food is pressed by the tongue, forces it back again under the teeth, until the whole has been sufficiently subjected to their action; and during the whole of this time it is gradually receiving additions of saliva, which thus become intimately and uniformly mixed up with every portion of the divided food. When completely chewed, it is collected together on the surface of the tongue, which sweeps round the different parts of the mouth for this purpose, and moulds it into the form of a bolus; and the point of the tongue being then raised, and its basis depressed, an inclined plane is formed, along which the bolus is propelled backwards, and delivered to the pharynx, which is expanded to receive it.

3. *Deglutition.*

(335.) The action of swallowing, simple as it may appear to be, is in reality extremely complex, consisting of a succession of muscular contractions, nicely adjusted and balanced, so as to co-operate harmoniously in the production of one general effect, the descent of the food along the œsophagus. The whole exhibits one of the most beautiful examples of mechanical contrivance that is to be met with in the body.

(336.) The pharynx, as we have seen, is a large muscular bag, shaped like a funnel, capable of being contracted in diameter, and of compressing its soft contents by means of the muscles which are expanded round it, and are called the constrictors of the pharynx. Other muscles are provided for elevating it, that is, for bringing it nearer to the base of the tongue. While the food is passing downwards, the velum pendulum is expanded, thrown backwards, and raised by the muscles adapted to perform these motions, so that it closes the posterior nostrils, and acting as a valve, prevents any portion of what is swallowed from passing either into those cavities or into the eustachian tubes. The bolus is thus directed towards the œsophagus, being carried thither by the peristaltic motion of the pharynx, while the root of the tongue being at the same time depressed, the epiglottis is turned backwards, and being applied to the glottis, accurately closes its aperture, so that no part of the alimentary matter can pass into the larynx. The mass of food being now arrived at the upper part of the œsophagus, is propelled towards the stomach by the successive contractions of its circular fibres. The mucus, which is secreted in abundance by all the surfaces along which it passes, and continually lubricates them, very much facilitates its descent. The longitudinal fibres of the muscular coat of the œsophagus contribute their share in this action, by shortening and dilating those portions of the canal into which the food is about to enter. Dumas distinguishes four stages in this process; first, that by which the aliment is propelled towards the pharynx; the second, consisting in the dilatation of that cavity, by which it receives the bolus transmitted to it; the third, by which the pharynx closes upon its contents, and propels it downwards to the œsophagus; and the fourth, in which, by the action of the œsophagus, the food is propelled into the stomach.[1]

[1] *Physiologie*, tome i. p. 3[illegible].

(337.) When any impediment exists to the due performance of these actions, fluids are swallowed with greater difficulty than solids, because the particles of the former having a continual tendency to spread themselves, it requires a closer and more exact application of the organs to prevent their escape, while they are compressed in giving to the fluid its proper direction. The action of suction performed by the tongue, with the assistance of the muscles of the cheeks and lips, which remove the pressure of the atmosphere from the surface of the fluid to which the mouth is applied, is also very complex. The tongue acts here as a piston; and sometimes the action is effected by the muscles of inspiration.

SECT. VI.—DIGESTION OR CHYMIFICATION.

(338.) The food has now passed from the œsophagus into the stomach, through its cardiac orifice, which has so been named from its supposed sympathy with the heart, near which it is situated. The office of the stomach is to convert the food which it receives into the soft pultaceous mass of a grey colour, which has been denominated *chyme*.[1] These secretions do not proceed from any glands that admit of being readily distinguished, their existence being rather inferred from the presence of the secretion. The membranes composing the coats of the stomach are capable of great distension, so as to contain a large quantity of food, while at other times that organ is contracted to a very small size, partly by the elasticity of its texture, but principally by the action of the circular and longitudinal fibres which encompass its cavity, and which constitute its muscular coat. These fibres are so dis-

[1] The older authors made no distinction between *chyme* and *chyle*, the latter substance being the product of the formation of the small intestines.

posed as to enable the different portions of the stomach to act separately and successively on its contents, producing what has been termed the *peristaltic*, or *vermicular motion*. Two purposes are answered by these actions; in the first place, the food contained in the stomach is agitated and thoroughly mixed together, while it is at the same time exposed to the chemical action of the gastric juice; and secondly, the ultimate effect of this motion is to carry the mass very gradually towards the pylorus, through which it is transmitted into the beginning of the intestinal canal.

(339.) While the food is thus rolled and agitated by the peristaltic action of the muscles, it is at the same time subjected to a degree of pressure, the purpose of which seems to be, to bring into closer approximation the solvent fluids with the materials on which they are to act, and thereby increase the chemical power of the former, and also to repress the evolution of gas, which has a tendency to be generated during the species of fermentation which the aliment undergoes in the process of digestion.

(340.) The principal agent in effecting those changes which constitute digestion, that is, which convert the aliment into chyme, is the gastric juice. The important office which this secretion performs has induced chemists to bestow great pains in obtaining its correct analysis, and in examining all its physical properties. When carefully collected, it appears to be a transparent and colourless fluid, having a saline and somewhat bitter taste, occasionally possessing acid properties, but probably in its natural and healthy condition being neither acid nor alkaline. It contains a small proportion of albumen, together with a matter which is either gelatin or mucus. But while it thus differs to all appearance in so trifling a degree from many of the other secretions, it yet possesses very extraordinary solvent powers over the substances usually employed as food. Even when made to act upon these substances in vessels out of the body, provided they are kept in a temperature equal to that of the human body, it will reduce them in a few hours to the state of a soft pulp, producing apparently the very same change which is induced upon the same species of aliment by the digestive process within the stomach. It is evident that the chemical analysis of the gastric juice affords as yet no clue to the explanation of this singular property. The power which the gastric juice possesses of coagulating milk, and other albuminous fluids, and of retarding the putrefaction of animal and vegetable substances subjected to its action, and even of counteracting this process when it has already commenced, are equally involved in mystery, and baffle all our endeavours to explain them on any of the hitherto known chemical principles.

(341.) There are three ways in which the gastric juice has been observed to act on alimentary matter; the first is that of coagulation, which is exerted on all the fluid forms of albumen, whether existing in the serum of the blood, or the white of the egg, or in different secretions, more especially milk. It is by means of this property, indeed, that cheese is obtained from the coagulation of its albuminous portion by the addition of rennet, which is an infusion of the digestive stomach of a calf.' The object of this coagulation appears to be to detain the substance for a longer time in the stomach, and subject it more completely to the solvent power of the same fluid, by previously acquiring a solid form, which prevents its escape by the pylorus.

(342.) The second kind of action exerted on the food by the gastric juice is that of counteracting the tendency to putrefaction, and even to the ascescent fermentation. This effect takes place in a remarkable degree in many carnivorous animals, who frequently take their food in a half putrid state; and in whom the first operation of the gastric juice is to remove from it all putrescence; shewing that this secretion possesses the property not only of preventing putrefaction from taking place, but also of suspending its further progress when it has actually commenced.

(343.) The third species of chemical action exhibited by the gastric juice is that of solution. That this effect takes place independently of any concurrent mechanical operation of the muscular powers of the stomach has been very decisively proved by the experiments of Reaumur, of Stevens, and of Spallanzani. Those of Stevens in particular, are highly valuable, from being made on the human subject. He was fortunate enough to meet with a man who had been in the habit of swallowing stones, which he could afterwards, by a voluntary effort, reject by vomiting from his stomach. Taking advantage of this power, Stevens induced him to swallow hollow metallic spheres perforated with holes, and filled with different kinds of alimentary substances, which, after being allowed to remain a sufficient time in the stomach, were returned, and their contents examined. It was invariably found that the food under these circumstances of exposure to the gastric fluid alone, and protection from external pressure of a mechanical nature, was more or less completely dissolved, and reduced to the state of a pulp. He afterwards pursued a similar train of experiments on dogs, causing them to swallow the perforated spheres, and after a certain time destroying the animals, and examining the changes effected in their contents.

(344.) Spallanzani has also varied and multiplied experiments of this kind in a manner that leaves no room to doubt the truth of the conclusion deduced from them as to the solvent power of the gastric secretion. Dense membranes and even bones are reduced into a pulpy mass by this fluid in many animals, while at the same time many bodies of comparatively delicate textures, such as the skins of fruits, and the fibres of flax or cotton, are not in the slightest degree affected by it. This difference of action on different substances is analogous to the operation of chemical affinity, and corroborates the theory that digestion is effected principally by chemical agency. The results of these experiments have been fully confirmed by experiments made on the stomachs of persons, who, in consequence of a wound, had a permanent opening into that organ from the skin of the abdomen.

(345.) Portions of the stomach are sometimes found dissolved after death. This takes place more especially when death has occurred suddenly during the act of digestion. This effect can never take place during life, because the living structures resist the solvent power of the gastric juice, which affects only dead animal matter. Thus it happens that worms, and the larvæ of insects live for a considerable time in the stomach, without being acted upon by its secretions.

(346.) Gas is frequently evolved in the stomach during the process of digestion; but this would appear to take place only in a disturbed or morbid condition of that process, and by no means to be a necessary attendant upon healthy digestion.

(347.) Acid is also frequently developed during imperfect digestion; but it appears from the experiments of Dr. Prout, which have been fully confirmed by other experimentalists, that this effect is also attendant upon healthy digestion, and that it is principally the muriatic acid which is thus disengaged from its combinations, and makes its appearance in a free state. The lactic acid, an acid which appears to be a modification of the acetic, also is present in considerable quantity.

Professor Tiedemann and Gmelin, in an elaborate treatise on Digestion lately published, found the acetic acid always present in the gastric juice. They observe that water alone, at the temperature of the human body, is capable of dissolving many of the substances employed as food; and of these many that are not soluble in water are so in the diluted muriatic and acetic acids at a high temperature, and they are inclined to ascribe to a chemical solution of this kind the principal change effected by digestion.

(348.) Among the agents concerned in the digestion of the aliment, the high temperature at which the contents of the stomach and intestines is retained, must be considered as one of the most important. The heat of the body unquestionably tends to promote the chemical action of the secretions which effect these changes. Whilst digestion is taking place, both orifices of the stomach are closed, and there often comes on a feeling of chilliness, especially in a weakly constitution, in consequence of the demand which the stomach makes upon it for an additional supply of heat to assist in the process that is going on. There is also a disinclination to exertion, and frequently a tendency to sleep while digestion is performing. Yet the indulgence in this disposition, as well as violent exercise immediately after a meal, tend equally to retard the formation of chyme. The circumstances most favourable to perfect digestion, are gentle exercise, with cheerfulness, and moderate mental exertion.

(349.) It appears from Dr. W. Philip's experiments, which were conducted chiefly on rabbits, that food recently taken is always kept distinct and unmixed with that which has remained for some time in the stomach, the former being introduced into the centre of the mass previously present. The food is more digested the nearer it is to the surface of the stomach, and is least digested in the small curvature, more so at the larger end, and still more perfectly at the middle of the great curvature. The state of the food found in the cardiac portion is different from that found in the pyloric portion of the stomach; for in the latter it is more uniform in its consistence, more dry and compact, and apparently more thoroughly digested. Thus it would appear that it is at the large end of the stomach where the gastric juice is secreted in greatest abundance, that the first and principal operations of digestion take place, and that from this part the food is gradually propelled towards the small end, becoming more completely changed during its progress.

It appears from the experiments of De Beaumont on an individual who lived many years with a fistulous opening into the stomach, which allowed the contents of that organ to be at all times examined, that the different kinds of aliment all require to undergo the chemical action of the gastric juice in order to be reduced to the state of chyle; but that the rapidity of this process differs considerably, according to the delicacy of the natural texture of the food, and the extent of its previous mechanical division. Animal substances are found to be more rapidly converted into chyme than vegetable; and oily substances, although containing a large proportion of nutritious elements, are comparatively difficult of digestion. Some curious evidence was afforded by Dr. Roget and Dr. P. M. Latham, on the occasion of an epidemic scurvy which prevailed in the years 1823 and 1824, among the prisoners in the Milbank Penitentiary, that too liquid a diet, consisting of too large a proportion of soups, although abundantly supplied, did not furnish sufficient nourishment for the preservation of health; probably from their not being retained in contact with the coats of the stomach during the time requisite for their undergoing the process of digestion[1].

(350.) A great number of hypotheses were devised by the older physiologists in order to explain the process of digestion. These we shall only briefly enumerate, without engaging in any laboured refutation of what, in the present advanced state of science, does not require much examination to prove the fallacy. The ancients had generally adopted the opinion of Hippocrates, which was enforced by Galen, that the food was digested by what was called a process of *concoction*. This, however, seems to be only another term for digestion, instead of affording any explanation of its nature. Some physiologists considered digestion as resulting from a degree of putrefaction; a process which is in reality of a totally opposite nature, although agreeing in some minor points, such as the breaking down of the cohesion of the particles, and the occasional disengagement of gas. Others, reasoning from the analogy of the stomachs of granivorous birds, which are provided with a strong muscular apparatus for the purpose of grinding, conceived that a similar process took place in the human stomach, and that digestion was the effect of mechanical trituration. But the experiments of Stevens and Spallanzani, the results of which have been already stated, are alone sufficient to overturn this hypothesis.

[1] See *An Account of the disease lately prevalent in the General Penitentiary*. By P. M. Latham, M.D. London, 1825.

(351.) The earlier chemical physiologists ascribed digestion to a species of fermentation. This term, however, appears to have been misapplied, in as far as digestion is conceived to be identical with either the acetous or vinous fermentations; and if it were meant to convey the idea of a peculiar species of chemical change taking place in the stomach, and in no other situation, then nothing is gained by the substitution of the term employed for that of digestion, which must express precisely the same idea. More modern writers have imagined they were giving an explanation of the phenomena of digestion, by referring them simply to the action of the vital principle, or the vital powers, or the principle of life, or by whatever name they chose to designate an imaginary agent which gave rise to all those phenomena, not referable either to mechanical or chemical principles. But after the remarks we have elsewhere made on this radical error of substituting final for physical causes, and of prematurely generalizing the principles which actuate the living system, it is needless farther to insist upon the fallacy of this mode of reasoning.

(352.) A doctrine has lately been advanced, with greater semblance of truth, that digestion is essentially a nervous function; that is, one which is directly dependent on nervous power. A variety of facts unquestionably prove that the functions of the stomach are very much influenced by the states of the nervous system. The section of the par vagum, or eighth pair of nerves, in the neck of an animal, is followed by the almost total interruption of digestion; whence we may infer that the influence conveyed by these nerves is necessary both for the secretion of the gastric juice, and perhaps also for the muscular actions of the stomach. It is exceedingly remarkable, however, that where the galvanic influence is sent through the mutilated nerves, by means of a voltaic battery, digestion may be renewed, and goes on for a considerable time; whence it has been inferred by Dr. W. Philip, that the nervous power, or the agency which is conveyed through the nerves, and which influences secretion, is itself identical with the electric or galvanic fluid.

(353.) The pyloric orifice of the stomach is furnished with a circular band of fibres, covered by a fold of the nervous coat; and acting as a sphincter muscle, which closes the passage during the early stages of digestion, so as not to suffer the escape of the food until it has undergone the requisite changes which constitute its digestion. The aliment is conveyed to the pylorus in proportion as it has undergone these changes. There appears to exist in this part of the stomach a peculiar and extremely delicate sensibility, and a power of selecting those portions of the food that are properly digested, and of allowing them to pass, while those which are undigested are retained in the stomach.

It would appear, however, from some recent experiments, that a portion of aliment passes unchanged through the pylorus along with the chyme. We observe, for instance, that many hard substances, such as the stones of cherries and plums, find their way through the pylorus without much difficulty. The seeds of many plants are only softened by their detention in the stomach, and passing with no other change through the intestinal canal, are prepared for germination in the soil to which they may be transferred. Thus many species of plants and trees have been known to grow at places very remote from each other in consequence of their seeds having been conveyed by birds that had swallowed them.

CHAPTER VII.

CHYLIFICATION.

(354.) The aliment, now converted by the process of digestion into chyme, after passing the pylorus, enters into the duodenum, which is the first of the small intestines. In the duodenum the chyme undergoes further changes, which are quite as great and as essential to its proper assimilation, as those which the food experienced in the stomach, and they are at the same time involved in equal obscurity. Almost all that is known respecting the nature of these changes, is, that soon after the chyme has been received into the intestines, it begins to separate into two parts; the one a white milky fluid, which is termed the *chyle;* and the other, residual matter, which afterwards becomes *fæces*, and is eventually ejected from the body.

(355.) Previously to our examining the processes by which this separation is effected, it will be proper to consider the chemical properties of the chyle.

1. *Properties of Chyle.*

(356.) Chyle is the fluid which is prepared from the food taken into the stomach, and which, being the last process of digestion, is formed in the intestinal canal. It is only of late years that we have acquired any accurate knowledge of its chemical properties. It is evident that experiments on this fluid can only be instituted on quadrupeds, and that it is only by reasoning from analogy that we can extend the knowledge so obtained to the human economy. If chyle be taken from the thoracic duct of an animal a few hours after it has taken food, it has very much the appearance of cream, being a thick fluid of an opaque white colour, without smell, and having a slightly acid taste, accompanied by a perceptible sweetness. It restores the blue colour of litmus, previously reddened by acetic acid; and appears, therefore, to contain a predominance of alkali. When subjected to microscopic examination, chyle is found to contain a multitude of globules, of smaller diameter than those of the blood, and corresponding in size and appearance to those of milk. In about ten minutes after it is removed from the thoracic duct, it coagulates into a stiff jelly, which in the course of twenty-four hours separates into two parts, producing a firm and contracted coagulum, surrounded by a transparent colourless fluid.

(357.) The coagulated portion, according to Vauquelin, is a substance of a nature intermediate between albumen and perfect fibrin, marking the transition from the one to the other. It has perhaps, indeed, a closer resemblance to the caseous part of milk than to fibrin. It is rapidly dissolved both by pure and sub-carbonated alkalies, forming pale brown compounds. Its solution in ammonia has a reddish hue. The acids throw down a substance intermediate between fat and albumen, which an excess of nitric acid re-dissolves in the cold; and sulphuric, muriatic, oxalic, and acetic acids, by boiling for a short time, also dissolve it. Diluted sulphuric acid also very readily effects its solution. Very dilute nitric acid gradually converts it into adipocire; when the acid is more concentrated, the coagulum assumes the appearance of gelatin; and when heat is applied, oxalic and carbonic acids are evolved. It is insoluble either in alcohol or ether.

(358.) That portion of chyle which retains the liquid form contains a portion of albumen, which may be coagulated by heat, alcohol, or acids. The clear liquid, reduced by evaporation to half its bulk, deposits crystals, which were found by Mr. Brande to bear a strong resemblance to those of sugar or milk.

(359.) A few saline bodies, similar to those existing in most animal fluids, were found by Dr. Marcet, to be present in chyle.

(360.) The principal ingredients in chyle are, therefore, according to Vauquelin, 1st, a large proportion of albumen; 2d, a smaller one of fibrin; 3d, a fatty substance which gives to the chyle the appearance of milk; 4th, several salts, such as carbonate of potass, muriate of potass, and prophosphate of iron.

(361.) Berzelius is strongly inclined to distrust the supposed analogy between chyle and milk, as having but little foundation in their real chemical nature.

(362.) It would be exceedingly interesting to ascertain the differences which exist in the properties of chyle taken from different orders of animals, that we might be able to trace the influence of different kinds of food upon this fluid. Dr. Marcet and Dr. Prout have made comparative experiments with this view upon the chyle taken from different dogs, some of which were fed exclusively on animal, and others on vegetable food. The chyle in the former case was found to be much whiter, contained more solid matter, and yielded more albumen than in the latter. The general results of these experiments are contained in the following table. Some faint traces of oily matter and of sugar of milk were obtained, but in quantities too minute to be estimated.

	Chyle from vegetable food.	Chyle from animal food.
Water	93·6	89·2
Fibrin	·6	·8
Incipient albumen	4·6	4·7
Saline matters	·8	·7

(363.) When both kinds of chyle were submitted to destructive distillation, the vegetable chyle produced three times as much carbon as the animal chyle ; the latter, therefore, probably contained a greater proportion of hydrogen and nitrogen. The chyle of a horse, derived of course from vegetable food alone, was found by Vauquelin to be in a more animalized state than that which Dr. Marcet procured from dogs. Dr. Prout, also, comparing the chyle as prepared from vegetable and from animal food, found the former to contain more water and less albuminous matter, while the fibrin and the salts were nearly the same in both, and both exhibited traces of oily matter. On the whole, he states the difference between the two kinds of chyle as being less considerable than had been observed by Dr. Marcet. On tracing the successive changes which the chyle undergoes in its passage along the vessels, he found that its resemblance to blood increases in each of these successive stages of its progress.[1]

[1] *Annals of Philosophy*, xiii. 22.

2. *Functions of Intestines.*

(364.) At the part of the duodenum where the separation of the chyme into chyle and residual matter takes place, the ducts from the pancreas and the liver terminate, so that the chyme is subjected to the action of the secretions from these two important glands, namely, the *pancreatic juice*, and the *bile*, which slowly distil into the duodenum. Sir Benjamin Brodie concluded, from experiments which he made upon living animals, that the formation of chyle is the immediate result of the admixture of bile with the chyme. In studying the changes which occur in this process, it will be necessary first to examine the chemical properties of these secretions.

(365.) The secretion from the pancreas, which flows into the intestine, and is mixed with the digested food almost immediately on its exit from the stomach, has, no doubt, some share in the process of chylification; but as it appears to be exceedingly analogous, both in its sensible properties and chemical composition, to the saliva, it is difficult to understand the mode of its operation, independently of mere dilution. As it is found, however, to contain a large quantity of albumen, a great portion of this substance may perhaps go to the formation of chyle.

3. *Properties of*

(366.) The bile, a secretion prepared by the liver, is poured into the same part of the intestine as the pancreatic juice. Its great importance in the animal economy induced physiologists from the earliest times to pay much attention to its chemical properties. Its analysis has been attempted by Boyle, Boerhaave, and Baglivi, and more recently by

Fourcroy, Cadet, Thénard, and Berzelius. But it unfortunately happens, that in several important particulars the accounts given by these different chemists do not accord with one another. These discrepancies, as Mr. Brande observes, seem partly to arise from the extreme facility with which chemical reagents react on this secretion, so that many of the supposed *educts*, or component parts which have been enumerated by different chemists, are probably *products* of the different operations to which it has been submitted, or, at all events, modifications of its true proximate elements.[1] The bile of the ox, from the facility of preserving it, has been that chiefly selected as the subject of experiment, and made the standard of comparison with that of man and other animals.

(367.) The substances to which this fluid owes its specific properties are, according to Thénard, first, a peculiar inflammable resin, soluble in alcohol; secondly, *picromel*, a substance insoluble in water and in alcohol, incapable of being crystallized, but forming, with resin and a small portion of soda, a triple compound which is soluble in water; and it is in this state that it exists in bile; and, thirdly, a yellow matter, distinct from either of the former. In addition to the soda, which is combined with the resin and picromel, bile contains a small quantity of phosphate, muriate and sulphate of soda, as also phosphate of lime, and a minute trace of iron.

(368.) Berzelius denies the correctness of the distinctions which Thénard has endeavoured to draw between the three animal ingredients of bile above mentioned. He gives to its characteristic principle, the name of *biliary matter;* and

[1] *Cyclopædia of Anat. and Phys.* art. Bile.

describes it as being of a resinous nature, and precipitable by acids; the precipitate, or *picromel*, or the *gallensteff* of Berzelius, being a compound of the acid employed and this biliary matter. According to Thénard, human bile differs from that of the ox chiefly in containing no picromel. M. Raspail considers bile to be essentially a saponaceous substance, with a trace of soda.

(369.) The peculiar matter of *bile* is found in the residual matter, and does not enter into the composition of chyle. The chief uses of the bile appear to be those of a chemical agent, promoting the decomposition of the chyme, and also stimulating the secretion of mucus, and the peristaltic motion of the intestines. Digestion may, however, go on to a certain degree, and imperfectly, although the flow of bile into the intestines be entirely prevented.

4. *Functions of the Small Intestines.*

(370.) Professors Tiedemann and Gmelin found, from their experiments, that the upper part of the small intestines contains a considerable quantity of uncombined acid, which is principally the acetic, mixed with a little butyric, and rarely with the muriatic. On proceeding to the lower parts of the small intestines, they found the fluids had alkaline instead of acid properties. This gradual disappearance of acid is probably in part the effect of its neutralization by the free alkali contained in the bile. The following, according to these physiologists, are the changes which take place in the contents of the small intestines. The chyme, which is acid, mixes with the bile, the pancreatic juice, and the mucous secretion from the coats of the intestine. The muriatic acid combines with the soda of the bile, and at the same time disengages from it the acetic or carbonic acids with which it had been previously united. It also separates the mucus and cholesterine of the bile in the form of white flakes, which have often been mistaken for chyle. The pancreatic juice and the intestinal mucus contribute, in some unknown manner, to this effect. Their chemical changes are promoted, and the contents of the intestines successively propelled forwards along the whole tract of the canal, by the peristaltic actions of the muscular coat, the effects of which are analogous to those we have already described as taking place from a similar action in the stomach.

5. *Function of the Spleen.*

(371.) It is probable that the spleen is an organ subservient to some purpose connected with digestion; but what that precise purpose can be is a question involved in great obscurity. A vast number of hypotheses and conjectures have been hazarded on this subject; but they are, for the most part, devoid of even the slightest probability. Any theory that assigns a very important office to the spleen will be overturned by the fact, that in many animals the removal of this organ, far from being fatal, or interrupting in any sensible manner the continuance of the functions, seems to be borne with perfect impunity. Sir E. Home has of late years advanced an opinion, for which there appears to be some probability, namely, that the spleen serves as a receptacle for any superfluous quantity of fluid taken into the stomach, and which, if not removed, might interfere with the regular process of digestion. This excess he supposes is transmitted directly to the spleen by communicating vessels, and lodged there until it is gradually removed, partly by the veins, and partly by the absorbents.

(372.) It appears, indeed, from the observations of Bichat, Leuret, Lassaigne, and others, that during digestion, and even after copious draughts of liquids, the vessels of the spleen become exceedingly turgid with blood. Hence the opinion has arisen, that the chief use of the spleen is to relieve the stomach and intestines from that congestion which would otherwise take place in their blood-vessels during digestion. The very vascular, approaching to a cellular structure, of the spleen, which very readily admits of dilatation, would seem to countenance this hypothesis.

6. *Functions of the Large Intestines.*

(373.) The functions of the large intestines are not confined to the mere conveyance and expulsion of feculent matter, although the exact nature of the changes which take place in their contents, and the subserviency of those changes to the object of nutrition, have never been clearly determined. It would appear that some important changes are effected in that enlarged portion of the canal which is termed the *cœcum*, and which has by some been regarded as a kind of supplementary stomach, in which fresh chyme is formed, and fresh nutriment extracted from the materials that have passed through the small intestines. This chymous product is supposed to be converted, as in the former case, into a species of chyle, which, from containing a greater proportion of oil, bears a resemblance to fat, and is in this state absorbed from the inner surface of the great intestines. The capability of the great intestines to extract nourishment from their contents is proved by the fact, that nutritious matter injected into them has been known to support life for a certain time, and also from their being able to effect the coagulation of milk.

(374.) A certain quantity of gas is almost constantly present in the intestinal canal, and often also in the stomach. Magendie and Chevreul, who have analysed these gases, found that what the stomach contained consisted of a mixture of oxygen and nitrogen; but that in the lower intestines the oxygen had wholly disappeared, as also a great part of the nitrogen, and that, instead of these, the component parts of the gas were carbonic acid, hydrogen, carburetted hydrogen, and a little sulphuretted hydrogen.

(375.) The time required for the completion of the processes we have described as taking place in the stomach, the small, and the large intestines, varies much, not only according to the nature of the food, but according to the conditions of the organs and of the general health, and to constitutional peculiarities. The digestion of food in the stomach is usually considered as requiring three or four hours. Animal food is longest retained, and undergoes the greatest alteration in the stomach. Vegetable food, on the other hand, passes more quickly and with less alteration, out of the stomach, and undergoes more change in the intestines than animal food.

SECT. VIII.—LACTEAL ABSORPTION.

(376.) The chyle, which has been prepared in the duodenum, and along the whole course of the small intestines, in the manner we have described, is received by absorption into the lacteals, and by them conveyed to the thoracic duct, which transmits it to the great veins in the vicinity of the heart. The lacteal vessels may be considered as forming part of the great system of absorbents which, as we shall afterwards find, are extensively distributed throughout the body. We shall therefore reserve their description until a general account is given of this system, in treating of the function of absorption generally.

(377.) The discovery of the lacteals was made in the year 1622 by Aselli, in the mesentery of a dog, which he had killed a few hours after the animal had made a plentiful meal. Their termination in the thoracic duct was discovered by Pecquet in 1651. They originate by open mouths from the villi of the inner coat of the small intestines, in the form of very minute tubes, which soon unite into one common vessel proceeding from each of the villi; and these vessels afterwards joining successively form larger and larger branches, which ascend along the mesentery, generally following the course of the veins, till they are collected at the root of the mesentery, and, after passing through numerous glands, terminate at the lower end of the thoracic duct, where there is an enlargement which has been called the *receptaculum chyli.*

(378.) Since uncertainty, however, still exists respecting the minute anatomy of the lacteals, at their origin from the intestine, many anatomists having in vain sought for the appearances above described. Their open orifices can only be seen when the lacteals are distended with chyle, and they are more readily detected in fishes where they have no valves, and where therefore the branches admit of being injected from their trunks. Their coats, although thin and perfectly transparent, yet possess considerable strength, so as to allow of being distended by injections without being ruptured; and even afford decisive indications of having the power of contracting and propelling forwards their contents. The utility of the numerous valves with which they are provided in every part of their course, in preventing any retrograde motion of the fluid they transmit, is sufficiently obvious.

(379.) The power by which the chyle is made to enter the open orifices of the lacteals, is by no means easily determined. It has been referred generally to capillary attraction. But the application of the laws which govern the ascent of fluids in rigid inorganic tubes, to the elastic vessels of the living system, is liable to much fallacy. The phenomena appear to indicate that the lacteals exercise, in the exclusive absorption of chyle, a power of selection somewhat analogous to that of chemical or electric attraction. It has been supposed, accordingly, that there is a specific attraction between chyle and the lacteal vessels, which causes that fluid to enter into them; while other fluids which are presented to the same vessels are rejected. This obscure subject has given rise to various speculations, which are more curious and ingenious than leading to any satisfactory conclusion. It is now generally agreed among physiologists, that the power which the lacteals possess of admitting the absorption of extraneous substances, if it exist at all, is exceedingly limited, and is exerted only on rare occasions.

Various experiments made on animals fully warrant the conclusion, that by far the greater portion of the nutritive matter imparted to the system is conveyed into the blood-vessels through the channels we have been describing, namely, the lacteals and the thoracic duct. On the other hand, there appears to be evidence that a large portion of the thinner fluids received into the stomach passes at once into the veins by the immediate absorption of these veins; for they always disappear rapidly from the stomach, in whatever quantity they are introduced. It is probable also, that some admixture of the contents of the lacteals with those of the blood-vessels takes place in the mesenteric glands, and that part of the chyle finds its way into the mesenteric veins by more direct channels than that of the general circulation.

(380.) An elaborate series of experiments was undertaken by Tiedemann and Gmelin, with a view to ascertain whether there exists any direct communication between the digestive cavities and the blood-vessels, exclusive of the known channel through the lacteals and thoracic duct. The experiments consisted in mixing with the food of certain animals various odorous, colouring, and saline materials, the presence of which might be easily detected by their appearance, odour, and other sensible or chemical properties; and in comparing, after a proper interval of time, the state of the chyle with that of the blood in the mesenteric veins. The odorous substances employed were camphor, musk, alcohol, oil of turpentine, and assafœtida. These were generally discovered to have found their way into the system, by their being detected in venous blood, in the urine, but not in the chyle. The colouring matters were sap-green, gamboge, madder, rhubarb, alkanet, and litmus; these appeared, for the most part, to be carried off without being absorbed; while the salts, namely potass, sulphuro-prussiate of potass, muriate of barytes, muriate and sulphate of soda, acetate of lead and of mercury, and prussiate of mercury, were less uniform in their course. A considerable portion of them seemed to be rejected, while many of them were found in the urine, several in the venous blood, and a very few only in the chyle. Hence the authors conclude, that the odorous and colouring substances never pass into the lacteals, and that saline bodies do so occasionally only, or perhaps incidentally; the whole of them are, however, found in the secretions, and they must, therefore, have entered into the circulation by some other channel than the lacteals.[1]

[1] *Edin. Med. Journal*, xviii. p. 455, &c. The above analysis of

(381.) There appears not, as far as we know, to be any thing specific in the action of the thoracic duct, which, as it appears, transmits its contents into the subclavian vein, as it receives it from the absorbents.

SECT. IX.—SANGUIFICATION.

(382.) The chyle consists, as we have seen, of alimentary matter, reduced to a certain state, which may be regarded as the first stage of animalization, having already made a near approach to the nature of that blood into which it is afterwards to be converted. This conversion of chyle into blood takes place after its introduction into the sanguiferous system of vessels, and while it passes round in the course of circulation. During this course, it necessarily traverses the minute vessels of the lungs, where it is subjected to the chemical action of atmospheric air, and its constituents gradually acquire the characteristic properties which they possess as the ingredients of the blood. The chief changes experienced are, first, that the fibrin of the chyle obtains a greater cohesive tendency, and a power of spontaneous coagulation; and, secondly, that the white globules of the chyle receive an addition of red colouring matter, and are invested with an external vesicle, by which their size is increased. But in order correctly to estimate their changes, it will be necessary to take a general review of the chemical and other physical properties of the blood.

(383.) The nature and properties of the blood have attracted a very large share of the attention of physiologists in all ages; and immense labour has been devoted to the investigation of its chemical constitution.

these experiments is that given by Dr. Bostock in his work on Physiology, p. 617, note.

(384.) When examined immediately on its being drawn from the vessels, the blood appears as a smooth and homogeneous fluid, of an unctuous adhesive consistence, of a slightly saline taste, and of a specific gravity somewhat exceeding that of water. It exhales a vapour which has a peculiar smell; but which, when condensed and collected, affords a liquor not differing sensibly from water. Much importance was formerly ascribed to this vapour, which was dignified with the name of *Halitus.* As the blood does not preserve the same consistence at different times, its density is liable to variation. Haller states the specific gravity of human blood to be at a medium, 1.0527. Dr. Milne Edwards says that it varies from 1.052 to 1.057. Dr. Davy states that the specific gravity of arterial blood is 1.049, and of venous blood, 1.051. Although it appears homogeneous, it is found by microscopical examination to contain a large proportion of minute globular particles, diffused through a liquid.

(385.) In a few minutes after its removal from the body, a thin film appears on the surface, and after a short time, which on an average is about seven minutes, the whole mass becomes cohesive, and what is termed its *coagulation* has taken place. After it has remained for some time in this gelatinous state, a separation of the mass into two distinct parts gradually takes place. A yellowish liquid oozes out from beneath the surface of the mass, and at length the whole is resolved into a clot, or solid portion of a dark red colour, which is called the *crassamentum*, or *cruor*, and consists chiefly of fibrin, and a yellowish liquid, called the *serum*. The proportion between these two parts has been variously estimated; and does not indeed admit of accurate determination, from its being variable in itself under different circumstances. On an average, however, it may be stated that the crassamentum amounts to about one-third of the weight of the serum. Dr. Scudamore and Mr. Wood found, however, by taking the mean of twelve experiments, that the crassamentum amounted to 53.307 per cent. The period at which coagulation begins and is completed, varies not only with the condition of the blood itself, but also with the circumstances in which it is placed. It commences sooner as the vessel is more shallow; but on an average it may be said to begin in about three or four minutes, and to be completed in seven or eight. But the contraction of the coagulum continues for a long time after, and sometimes does not cease till the fourth day. It does not appear that the specific gravity of the blood is sensibly altered during its coagulation.

(386.) Great difference of opinion has existed as to the occurrence of a change of temperature during this process of coagulation. The analogy of other instances in which the conversion of a fluid into a solid is accompanied with the evolution of heat, has induced many to think that a similar effect attends the coagulation of the blood. Fourcroy stated, that a rise of temperature actually takes place; but Hunter, on the contrary, produced facts leading to an opposite conclusion. The result obtained by Fourcroy has, however, been confirmed by the experiments of Dr. Gordon, who found that the coagulating portion of a quantity of blood was warmer than the rest by about six degrees. On repeating the experiment on blood drawn from a patient labouring under inflammatory fever, the rise of the thermometer was no less than twelve degrees. Subsequent researches by Dr. John Davy, have, however, thrown considerable doubt upon the accuracy of the above conclusion, by pointing out some sources of fallacy in the investigation of Dr. Gordon. Dr.

Scudamore, on the other hand, found that heat was produced during coagulation, but to a less degree. Vogel and Brande have ascertained that carbonic acid gas is disengaged; and this appeared to happen to an unusual extent in blood drawn soon after a meal.

(387.) The coagulation of the blood is a phenomenon not strictly analagous to any other with which we are acquainted, and has never been satisfactorily explained. The operation of external agents upon it is not so well marked as to enable us to refer it to any general operation of the physical properties of matter. Moderate differences of temperature produce scarcely any perceptible difference in the tendency which the blood has to coagulate. Within the range of from 67° to 105°, blood coagulates in the same time as at the usual temperature of 98°. Sir Humphry Davy found that no difference in this respect takes place when blood is exposed to nitrogen, nitrous, nitrous oxide, carbonic acid, carborated hydrogen gases, or atmospheric air, although the contrary had been asserted by Luzuriaga. Blood, indeed, coagulates more quickly when placed in a receiver from which the air is rapidly exhausted, when slowly drawn into a shallow vessel, or when exposed to atmospheric air, at a temperature of 120°. This process is retarded by a very low temperature. Mr. Hewson placed blood in oil at a temperature of 38°; at the expiration of six hours it continued fluid; but being then allowed to attain a warmer temperature, it became coagulated in twenty-five minutes. The same physiologist froze a portion of blood confined by ligatures in the jugular vein of a rabbit; when thawed, the blood became liquified, and coagulated. Admixture with certain neutral salts prevented altogether coagulation from taking place. This happened when half an ounce of sulphate of soda was mixed with six ounces of fresh blood; but on the addition of a double quantity of water coagulation took place. Dr. Turner states that the coagulation of the blood is prevented by the admixture of saturated solutions of chloride of sodium, hydrochlorate of ammonia, nitre, and potass; while, on the contrary, alum, and the sulphates of the oxides of zinc and copper, promote coagulation. Blood coagulates slowly when drawn quickly into a deep vessel, or when detained at rest in the vein of a living animal between two ligatures. In the latter case, Mr. Hewson found the blood two-thirds fluid after the lapse of three hours and a quarter. When the experiment was varied by blowing air into the vein, the blood was found to have coagulated in a quarter of an hour. Blood extravasated through the rupture of vessels, and retained in the cavities of the body, often preserves its fluidity for a very considerable time. If the causes which are capable of postponing coagulation have continued to operate beyond a certain period, the blood is prevented from coagulating; thus recent blood remains permanently fluid if it be constantly stirred for some minutes. It has been proved by the experiments of Hewson, Hunter, Deyeux, and Parmentier, that the coagulation of blood is not entirely prevented by diluting it with water; but Dr. Crawford[1] showed that this process is retarded for several hours by the admixture of blood with twelve times its bulk of water.

(388.) There are many conditions of the living system that have a prodigious influence on the tendency of the blood to coagulate, and that operate in a manner which it

[1] On *Animal Heat*, p. 248.

is impossible to explain. Many causes of sudden death, as a blow upon the stomach, or violent injury of the brain; lightning and electricity; several animal poisons, as that of venemous serpents; narcotic vegetable principles, as cyanogen; also excessive exercise, or even violent mental emotions, when they produce the sudden extinction of life, prevent the usual coagulation of the blood from taking place.

(389.) The doctrine maintained by Hunter, that the blood possesses life, and that its coagulation is one of the acts of this living principle, is but little calculated to remove the difficulty; for the operation of this principle in producing coagulation would still be as much in need of explanation as the phenomenon itself, which it professes to account for. We must, in the present imperfect state of our knowledge, content ourselves with referring this phenomenon to an inherent disposition which the fibrin possesses to assume the solid form, when no counteracting cause is present. Dr. Bostock,[1] observes, that as it is gradually added to the blood particle by particle, whilst this fluid is in a state of agitation in the vessels, it has no opportunity of concreting; but when it is suffered to lie at rest, either within or without the vessels, it is then able to exercise its natural tendency.

(390.) We have already stated that the crassamentum consists chiefly of fibrin; but it owes its dark colour to the presence of what are called the red particles of the blood, and which are entangled in it during its coagulation. The serum, which is the part of the blood that remains fluid after the coagulation of the fibrin, is itself coagulated by heat, in consequence of the large proportion of albumen it contains; the remaining portion which still continues fluid,

[1] *Physiology*, p. 271.

after the introduction of the use of the microscope. They were soon afterwards examined with great care and minuteness by the indefatigable Leeuwenhoek, whose name stands foremost among those who made observations with this instrument. They soon became the subject of much speculation, and laid the foundation of many fanciful hypotheses which were current at the time, but are now consigned to deserved neglect. Leeuwenhoek himself was led by his imagination to the belief that these red globules were each composed of a series of globular bodies of different orders descending in regular gradations. He supposed each to be made up of six particles of serum; each particle of serum of six particles of lymph, and so on in succession. This strange hypothesis, visionary as it now appears, was so accordant with the prevailing taste for mathematical disquisitions, that it was very generally adopted, and held a powerful sway over the opinions and reasonings of the physicians of that age. It forms a leading feature in the pathological speculations of Boerhaave; and although its futility was sufficiently exposed by Lancisi and Senae, it maintained its ground even to the time of Haller.

(393.) But a better spirit began at length to prevail; the illusive dreams of fancy were superseded by the sober and attentive observation of nature; and truth was sought by the judicious cultivation of experimental inquiry, the only legitimate path by which it can be approached. About the middle of the eighteenth century, the Abbe de la Torré, employing microscopes of considerable power, obtained the appearance of flattened annular bodies, with a perforation in the centre. Hewson, who observed them with still greater attention to accuracy, states them to be hollow vesicles of a flattened shape, and containing a smaller, solid, and spherical particle, which was freely moveable within them, or, as he compares it, "like a pea in a bladder." He asserted, that by adding water, these particles swell out into a globular shape, and afterwards burst and disappear, in consequence of their being dissolved in the water; but if moistened with an aqueous solution of any neutral salt, they preserve their natural flat shape. Cavallo describes them as much more irregular in their form than Hewson represented them; and he was led from his observations to the conclusion that the appearance either of a perforation, or of a central particle, is in reality an optical deception, arising from the refraction of the light by which the objects are viewed, as it passes through the convex surfaces of the globules. He also endeavours to explain the appearance which led Hewson to believe that the central nucleus is moveable within the external vesicle, by some apparent change in the position of the luminous image, in consequence of accidental variations in the direction in which the light is viewed. Very small artificial globules of solid glass which he constructed for the purpose, presented under the microscope very nearly the same appearances as the globules of the blood; and hence he concluded, that the latter, notwithstanding these appearances, were nearly globular and composed of a uniform material.

(394.) Notwithstanding the ingenuity displayed in this reasoning, the more profound examination which the subject has received from Dr. Young, induces us to revert, to a certain extent, to the opinion of Hewson. He observes that in such examinations it is only necessary to employ a full and unlimited light, in order to obtain a very distinct outline of what appears manifestly to be a very simple substance. But we should remember that where the substances to be examined are perfectly transparent, it is only in a confined and diversified light that we can gain a correct idea of their structure. The eye is best prepared for the investigation by beginning with the blood of a skate, of which the particles are, from their greater size, so conspicuous, and of so unequivocal a form, as at once to set aside the idea of a simple homogeneous substance. They are oval and depressed, like an almond, but less pointed, and a little flatter. Each of them contains a round nucleus which is wholly independent in its appearance of the figure of the whole disc, being sometimes a little irre, ular in its form, seldom deviating from its central situation, but often remaining distinctly visible, whilst the oval part is scarcely perceptible. This nucleus is about the size of a whole particle of human blood, the whole oval being about twice as wide, and not quite three times as long. The nucleus is very transparent, and forms a distinct image of any large object which intercepts a part of the light by which it is seen, but exhibits no inequalities of light and shade that could lead to any mistake respecting its form. But if we place some particles of human blood under similar circumstances, near the confines of light and shade, although they are little, if at all less transparent, we immediately see an annular shade on the disc, which is most marked on the side of the centre on which the marginal part appears the brightest, and consequently indicates a depression in the centre, which De la Torre mistook for a perforation. It is most observable when the drop is dying away, so that the particles rest on the glass; and when a smaller particle is viewed, it has merely a dark central spot, without any lighter central space. Dr. Monro had represented the globules of the blood as being of an exceedingly flattened shape, or, as he expresses it, "as flat as a guinea." But Dr. Young never saw them of this shape, although he states their axis as being sometimes not more than one-third, or one-fourth of their greatest diameter. He also states that they do not seem, as Hewson asserted, to have their dimensions much affected by the fluid in which they are suspended, since they may easily be spread thin on glass, and dried without much change in their magnitude, at least in the direction of the surface to which they adhere; and they remain distinct as long as the access of moist air is completely excluded. When they have been kept for some time in water, and a little solution of salt is added, their form and structure, as Hewson observed, are more easily examined, and appear to resemble those of a soft substance, with a denser nucleus; but the comparison which he makes of their being like a pea in a bladder, Dr. Young thinks is quite inapplicable.

(395.) It has commonly been asserted, and especially by Hewson, that these particles are readily soluble in water; but Dr. Young has shewn that this opinion is erroneous, and depends partly on their passing readily through the filtering paper, a circumstance observed by Berzelius, and partly on the extraction of a great part of their colouring matter, together with which they lose much of their specific gravity, so that instead of subsiding, they are generally suspended in the fluid. Their presence may still, however, be detected by a careful examination; and they seem in this state to have recovered in some measure their original form, which they had lost when first immersed in the water. A curious observation on the influence of circumstances on the form of the globules, has been made by Mr. Bauer. He remarks that in the skate they are oval during the life of the animal, but become flattened after its death. This circumstance may perhaps tend to reconcile some of the discordant statements which have been made on this subject.

(396.) The size of the red globules has also been very differently estimated by different observers. These discrepancies receive some explanation by the circumstance which Dr. Milne Edwards appears to have established, of the globules differing considerably in their size in the same individual.[1] The most accurate measurements appear to be those of Dr. Young, and of Captain Kater, who both agree that the particles of human blood are between the four-thousandth and the six-thousandth of an inch in their diameter; and they may therefore be taken at a medium at the five-thousandth of an inch. Mr. Bauer has stated them to be considerably larger, even as much as the one thousand-seven-hundredth of an inch in their entire state, and that the central part is the two-thousandth of an inch in diameter. But the observations of Dr. Young are more probably correct, from their coincidence with those of Captain Kater, which were conducted in a different manner.

(397.) The difficulty of procuring the red particles in a separate state, unmixed with serum, is so great as to preclude us from obtaining any distinct knowledge of their chemical composition and properties. The colouring matter of the blood has been termed *hematine*, or *hematosine*. But according to M. Lecanu, the substance usually termed hematine is in reality a combination of albumen and the pure colouring matter of the blood, which he proposes to designate *globuline*. Although it appears from Dr. Young's observations, that the globules themselves do not dissolve in water, yet they impart to it the whole of their colouring

[1] *Cyclopædia of Anat.* art. Blood.

matter. The watery solution turns syrup of violets green; and after some time deposits a flocculent precipitate, probably from the coagulation of albumen, the presence of which is indicated also by the effect of boiling the solution. Hence it has been concluded that the colouring matter consists of albumen, dissolved by an excess of pure soda. When evaporated and calcined in a crucible, a residuum is obtained, amounting to about one-thousandth of the weight of solid matter, and composed, according to Fourcroy and Vauquelin, chiefly of subphosphate of iron.

(398.) Berzelius,[1] who has made minute inquiry into this subject, informs us that the colouring matter of the blood, separated from the other part, leaves one-eightieth of an incombustible residuum, of which rather more than one-half is an oxide of iron. The existence of iron in the blood was first discovered by Menghini; but its amount was much over-rated both by himself and many of the earlier chemists who succeeded him. It is difficult to determine in what state this iron exists in the blood. It would appear not to be in the state of any of the known salts of this metal; because before the blood has been calcined, the iron escapes detection by any of the tests which usually indicate its presence in solutions; and yet the solubility of the colouring matter in the serum would, on the other hand, appear to support the opinion of its possessing saline properties. Berzelius has been able to deduce from his numerous experiments on this point, merely the negative conclusion, that no salt of iron which he tried was capable of being combined with the serum, so as to produce a compound similar to the colouring matter of the blood; thus refuting the alleg-

[1] *Medico-Chirurgical Transactions*, vol. iii p. 215.

ed synthetic proof adduced by Fourcroy, who had stated that subphosphate of iron dissolves in albumen, and imparts to it a bright red colour, resembling that of blood.[1]

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(401.) Besides the ordinary red globules, others of a much smaller size have been detected by Mr. Bauer floating in the serum, and even apparently generated while the fluid is under examination. To these Sir Everard Home gave the name of *lymph globules*.[2]

(402.) The serum of the blood, or the fluid part which is left after the separation of the crassamentum, is a transparent and apparently homogeneous liquid, of a yellowish and sometimes greenish colour, of a saline taste, and adhesive consistence. Its specific gravity is variable, but may be taken,

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on an average, at about 1·025. When exposed to a temperature of 160°, the whole is converted into a firm white mass, perfectly analogous to the white of an egg which has been hardened by boiling. It may, in fact, be regarded as identical with coagulated albumen, the chemical properties of which we have already described.

(403.) Although the whole of the mass of serum appears to be rendered solid by the process of coagulation, yet if this coagulum be cut into slices, and subjected to gentle pressure, or if it be placed on the mouth of a funnel, a small quantity of a slightly opaque liquor drains from it, which is called the *serosity*. It has a saline taste, and a peculiar odour, and consists of several ingredients. Its existence as a substance distinct from the albumen was first pointed out by Dr. Butt in 1760, and its properties were farther examined by Dr. Cullen, who speaks of it as a solution of fibrin in water. Hewson believed it to be of a mucous nature. Parmentier and Deyeux published, in 1790, an elaborate set of experiments which they made upon it, from which they drew the conclusion, that the animal substance contained in the serosity was gelatin. This statement seemed so satisfactory, from the apparent accuracy of the investigation, that it was generally acquiesced in. Not only was jelly considered as one of the constituents of the blood, but means were pointed out for ascertaining its proportion; and its supposed agency in the economy was made the foundation of many physiological speculations. But Dr. Bostock has since proved that this opinion is not founded in fact. He was unable to detect the smallest quantity of jelly either in the serosity of the blood, or in any other of the albuminous fluids. In this conclusion he is fully supported by the testimonies of Berzelius, Marcet, and Brande.

(404.) It may be inferred from the experiments of Mr. Brande, that serosity consists of a small quantity of albumen, still retained in solution by a large proportion of alkali. According to Berzelius, the serosity contains no sulphuric acid, and only a vestige of the phosphoric, and consists chiefly of water, with some pure soda holding albumen in solution, of muriates of soda and of potass, of lactate of soda, and a peculiar animal matter which always accompanies the lactate. Dr. Bostock found the amount of solid contents to vary from the forty-sixth to the seventieth part of its weight, or, on an average, about the fiftieth. It has been a matter of dispute which of the mineral alkalies exists in serum in an uncombined form. Dr. Pearson maintained that it was potass; but Drs. Bostock, Marcet, and Berzelius, with much greater appearance of correctness, allege that it is soda.

(405.) The component parts of human serum, according to the analysis of Dr. Marcet, are—

Water,....................................	900·
Albumen,................................	86·8
Muriates of potass and soda,..........	6·6
Muco-extractive matter,...............	4·
Subcarbonate of soda,..................	1·65
Sulphate of potass,......................	·35
Earthy phosphates,.....................	·6
	1000·

(406.) This analysis coincides very nearly with that of Berzelius, who considers the substance termed by Dr. Marcet *muco-extractive matter* to be impure lactate of soda. But Dr. Bostock is led by his experiments to the conclusion, that a peculiar animal substance exists in the serosity, not coagulable by heat, or by any other means; not affected by corrosive sublimate, or by tannin, which are the appropriate tests of albumen and of jelly respectively, but copiously precipitated by muriate of tin, and still more readily by the acetate of lead; and he thinks this substance is quite independent of the lactate of soda, which may exist at the same time in the blood.

(407.) Wienholt discovered that the serosity contained a small quantity of the peculiar substance which exists in greatest abundance in the flesh of animals, and was first noticed as a distinct proximate principle by Rouelle. It was subsequently termed *ozmazome* by Thenard, who examined its properties more minutely. This substance is of a yellowish brown colour; it is soluble both in water and in alcohol, and is precipitated by infusion of nutgalls, nitrate of mercury, and by the acetate and nitrate of lead. It is still a matter of uncertainty what connexion exists between this substance and the muco-extractive matter above mentioned. There is also another proximate principle, namely, *urea*, of which we shall afterwards have occasion to speak, which is found in small quantity in the blood, when that fluid is in its natural state, but which is abundantly found in the blood of animals from which the kidneys have been removed. Besides these, Dr. B. Babington discovered the presence in the blood of an oily substance, separable from the other parts by means of ether. Lecanu, in addition to this oily matter, found a crystallizable fatty matter in the blood; and similar observations have been made by Chevreul. Manganese is said to have been detected in the blood by Wurzer. M. Boudet has also lately discovered a new substance in the serum, which he has termed *uroline*. This is a white, slightly opalescent substance, fusible at 94° Fahrenheit, not forming an emulsion with water, soluble in alcohol, not saponifiable, and apparently containing nitrogen.

CHAPTER VII.

CIRCULATION.

SECT. I.—APPARATUS FOR CIRCULATION.

(408.) The object of the function of circulation is two-fold. The first is to distribute to all the organs that due share of nutritive fluid which they require for the performance of their respective offices, for the maintenance of their temperature, and for nutrition, and to keep up a constant supply of this fluid. The second, and no less important object, is to expose every portion in succession of this fluid, which is the blood, to the influence of atmospheric air in an organ appropriated to this particular purpose; the continual renewal of the action of the oxygen contained in the air upon the blood, being necessary for the maintenance of its salutary qualities, and indispensable to the preservation of life. The organs in which this process is carried on are the *lungs;* and the function by which it is accomplished is *respiration.* The great agent for the distribution of the blood both generally to the organs of the body, and specially to the lungs, is the *heart;* the pipes through which it is conveyed to those parts are the *arteries;* those through which it is brought back to the heart, the *veins.* A set of finer vessels interposed between the minute extremities of the arteries, and the minute beginnings of the veins, are called the *capillaries.* The structure and distribution of all these parts, have already been described in the treatise on ANATOMY, to which we of course refer for the descriptive details. The following brief recapitulation, however, of the structure of the heart will assist us in understanding the physiology of its action.

1. *Cardiac Apparatus.*

(409.) The heart is a hollow muscle, of a conical shape, occupying the central and inferior part of the cavity of the thorax, having its *basis* turned towards the right side, and its point or *apex* towards the left, nearly opposite to the space between the sixth and seventh ribs. Its lower surface is somewhat flattened, where it lies upon the diaphragm. Its basis, with which the great vessels are connected, is covered with fat. The whole heart, and the roots of the large blood-vessels at its basis, are protected by a general investment of membrane, which is a reflected production of an extended serous membrane, forming a cavity for its reception, and for allowing it considerable freedom of motion. This membrane, which is remarkable for its strength, is called the *pericardium*, and is situated between the laminæ of the mediastinum, which are separated in order to contain it.

(410.) The heart is principally made up of muscular fibres, the course of which is extremely complex; some extending longitudinally from the basis to the apex, others taking an oblique or spiral course; and a third running in a more transverse direction. There are two considerable cavities, called *ventricles*, distinguished, according to their situation, into the right and left ventricle. The former has also been called, in reference to its functions, the *pulmonic*, and the latter the *systemic* ventricle. They are separated by a strong and thick partition, called the *septum ventriculorum*, which is composed of fleshy and tendinous fibres. Attached to these, at the basis of the heart, are two hollow and fleshy projecting appendages, called the *auricles*, the cavities of which are also separated from each other by a partition, distinguished by the name of *septum auriculorum*, and they open into those of the ventricles. The right auricle, which, together with the right ventricle, is placed more in front, receives the blood from the venæ cavæ, and transmits it to the right ventricle, by which it is propelled into the trunk of the pulmonary artery. The left auricle, in like manner, collects the blood from the four trunks of the pulmonary veins, and transfers it into the left ventricle, by which it is forcibly driven into the aorta, or main trunk of the arterial system of the body at large. The membrane which lines the cavities of the heart, and the great vessels just mentioned, is produced so as to form valves at the two orifices of both the ventricles; that is, where the auricles open into them, and also at the origin of the arterial trunks which arise from the ventricles. The valves placed between the right auricle and ventricle, are usually three in number, and are called *valvulæ tricuspides;* but in the left ventricle there are only two, and these are named the *valvulæ mitrales.* The membranes which form these valves are attached so as to project somewhat forward in each of these cavities, and are connected with tendinous strings, called *chordæ tendineæ*, which arise from detached and projecting portions of the muscular substance of the heart, named from their cylindrical form, *carneæ columnæ.*

(411.) The valves at the origin both of the pulmonary artery and of the aorta, are three in number, and are called the *valvulæ semilùnarês,* from their semicircular figure; their convexities are turned towards the ventricle; they are concave next to the cavity of the artery; and in the middle of their loose edge is found a small hard triangular substance called *corpus aurantianum,* and sometimes *corpusculum Morgagni,* or *sesamoideum.* When these valves are made to approach each other, by the pressure of the blood in the artery in the direction of the ventricle, they unite so as completely to close the passage, and prevent any of the blood from returning. Opposite to the semilunar valves, the artery bulges out and forms three projections, which have corresponding pits or depressions within, and are called, from their discoverer, *sinus Valsalvæ.*

(412.) Where the two venæ cavæ meet, there is a small angular projection, which has been called the *tuberculum Loweri.* The term *auricula* more properly applies to the jagged portions which project from the sides of the base of the heart, like the ears of a dog from its head; whilst the expanded cavity where the venous tubes enter is called the *sinus venosus.* On the side next to the auricula, there is a remarkable semilunar fold, projecting within the cavity, between the vein and auricle, so as to be convex next to the vein, and concave next to the auricle. This doubling has been called the *Eustachian valve.* Between the concave part of this fold, and the opening into the ventricle, is the orifice of the coronary vein, which returns the blood that has circulated through the substance of the heart itself, and which is provided, at this point, with its proper valves. In the septum auriculorum is seen a depression, the *fossa ovalis,* which is the remains of a passage of communication between the right and left auricles that had existed in the fœtal state. The sides of the fossa ovalis are strong and thick, and have received the name of *isthmus Vicussenii*, or *columnæ*, or *annulus fossæ ovalis*.

2. *Sanguiferous System in general.*

(413.) The blood-vessels, consisting of arteries, veins, and capillaries, compose by their assemblage what is termed the *sanguiferous system*; and the channels which they form for the transmission of the blood constitute a double circuit. The principal circuit consists of that through which the blood is distributed to all parts of the body indiscriminately, and which includes therefore the whole system. But there is also another circuit of lesser extent, which is performed by the blood, by its being sent from the heart to the lungs, and again returned to the heart, after circulating through those organs. This is termed *the lesser circulation*, by way of contrast with the circulation through all the rest of the body, which constitutes *the greater circulation*. For effecting this lesser circulation, a distinct set of blood-vessels, namely, the *pulmonary vessels*, is provided.

(414.) Thus, there are two separate systems of blood-vessels, which have no communication with each other, except through the medium of the heart, which is the common origin and termination of both. The *aortic system*, or, as some modern anatomists have chosen to designate it, the *systemic system*, is that which, taking its rise from the left ventricle of the heart, begins with the *aorta*, or main trunk of the arteries which transmit the blood to the body at large, and is completed by the veins which are collected into two trunks, called *venæ cavæ*; which trunks, again, terminate in the right auricle of the heart. The *pulmonary system*, on the other hand, comprises the pulmonary arteries, which arise by a single trunk from the right ventricle of the heart, and after circulating the blood through the lungs, are continued into the pulmonary veins, and terminate by four large trunks in the left auricle of the heart.

(415.) All these vessels, whether arteries or veins, may be comprehended under the following general description. They are flexible and elastic tubes, for the most part of a cylindrical shape, and composed principally of a membranous or fibrous structure formed into distinct layers, and composing what are called the *coats* of these vessels. The number of these coats has been differently estimated by different anatomists; but it is now generally agreed that those proper to the vessels themselves are principally three: the *external*, the *internal*, and the *middle*, or what has been called the *muscular* coat. Besides these tunics, each vessel is surrounded by a loose and flocculent cellular substance, which connects it with the parts through which it passes, and accompanies it in its whole course; but this substance, being merely a continuation of the cellular substance which fills up all the vacuities of the body, is common to the vessel and to other parts, ought not properly to be considered as belonging to the former, but as adventitious; although some anatomists have dignified it with the title of the *cellular coat.*

(416.) The first proper coat of the vessel is the external coat, which is thicker than the rest, and formed of a membranous structure, in which are intermixed a few filaments of fibro-cellular substance, disposed obliquely with respect to the course of the vessel, and interwoven with the membranous fibres. The innermost membrane is thinner than the former, of a whiter colour, more or less pellucid, and presenting a more uniform homogeneous structure. Its inner surface is perfectly smooth, and much resembles in appearance the serous membranes. Between these membranous coats, there exists a layer of fibres, which have been generally supposed to be muscular, constituting what has been accordingly called the *muscular coat.* Compared with the diameters of the vessels, these coats are proportionably thicker in the smaller than in the larger vessels.

(417.) After giving this general description of the structure of the blood-vessels, we proceed to notice some of the peculiarities which distinguish each class of blood-vessels.

3. *Arterial System.*

(418.) Each of the great arterial trunks, belonging respectively to the aortic, and to the pulmonic systems, are furnished, at their origin from the ventricles of the heart, with valves of a semilunar shape, adhering by one of their sides to the margin of the aperture of the ventricle, or mouth of the artery, and having their loose edges turned towards the axis of the artery. These valves are formed by a duplicature of the internal coat, which contains between their folds a thin layer of ligamentous fibres, giving them considerable strength. No valves are found in any other part of the arterial system.

(419.) The external coat of an artery is formed by a dense tissue of fibres, which are interwoven together in different directions, generally very obliquely with regard to the length of the vessel. This texture becomes more compact as we trace it towards the interior, so that the individual fibres can with difficulty be distinguished, unless by a forcible tearing asunder of the substance they compose. Hence the older anatomists have distinguished this inner layer of the external coat, as forming a separate tunic, to which they have given the name of the *nervous coat,* implying thereby a participation in the structure of tendons which were not at that time distinguished from nerves. The division of the external coat into these two layers, is well marked in the larger arteries; but in proportion as we examine the smaller branches, we find a more uniform appearance, the whole assuming the firm and compact texture of fibrous membranes. This portion of the arterial structure is exceedingly strong and elastic, both with respect to a force stretching it in the direction of its length, and also transversely, or in that of its diameter. Its toughness is such that it is not easily cut asunder by a thread employed as a ligature upon the vessel.

(420.) The intermediate, or muscular membrane, is of considerable thickness, has a yellow colour, and is composed of fibres, all of which are arranged circularly; that is, in the circumference of the cylinder. In the large arterial trunks, these fibres form a distinct layer or tunic; but the membrane acquires a still greater proportional thickness in the smaller branches, and then admits of subdivision, by dissection, into several layers. The exterior layers are less dense than the interior; and those which are innermost are the densest of all. The elasticity and firmness of this coat is chiefly in the direction of the circular fibres of which it consists; so that it opposes considerable resistance to any force which tends to dilate the vessel, but yields readily to any power applied for its elongation. It may be considered as partaking of the properties of muscular and ligamentous structures.

(421.) The internal membrane of arteries, which has also been called the *nervous*, *arachnoid*, or *common coat*, is the thinnest of the three; although still, in the larger arteries, it admits of division into two or more layers. The innermost of these is extremely thin and transparent, and its surface is smooth and highly polished, in order that no resistance may be opposed to the motion of the blood. The outer portions are white and opaque, and pass gradually into the substance of the muscular tunic with which it is connected. Its elasticity is very small, and its power of resistance is limited, so that a ligature applied on the vessel generally produces a laceration of the internal coat.

(422.) The general form of the arterial system, if it were isolated from all other parts, would resemble two trees, the trunks of which would be constituted by the aorta, and by the pulmonary artery, and which divides and subdivides successively into smaller and smaller branches, till they arrive at an extreme degree of tenuity. Each portion which intervenes between these divisions preserves the same uniform diameter, and is therefore exactly cylindrical. Each branch is of course smaller than the trunk from which it arises; but the sum of the areas of all the branches into which an artery divides itself, is in general greater than the area of that artery; and consequently the total capacity of the arterial system is progressively increasing in proportion to the number of subdivisions which take place. Hence the whole system may in reality be considered as composing a conical cavity, of which the aorta is the apex, and the ultimate subdivisions the base. The number of subdivisions in the whole course of an artery scarcely ever exceeds twenty, according to the estimate of Haller, who took pains to ascertain this point. The most usual mode of ramification is that of bifurcation, or division of a trunk into two branches, which generally form between them an acute angle. In some instances, especially among the larger arteries, we meet with a branch sent off at right angles from the main trunk, or still more rarely at an obtuse angle.

(423.) Arteries have numerous communications among their different branches. These communications, or *anastomoses*, as they are called, are effected sometimes by the reunion of two arteries of nearly equal size, which happen to be proceeding in similar directions, so as to compose one common trunk, which proceeds in an intermediate direction, sometimes by collateral branches proceeding obliquely from the one to the other; while on other occasions, arteries unite from greater distances, so as to form a wide arch, in which each appears to be continuous one with the other; and from the convex side of which, branches are again sent off, which are distributed in minuter ramifications. In some parts the anastomoses are so frequent and numerous, as to resemble a net-work, or plexus of vessels.

(424.) The principal arteries of the limbs are generally found running in situations where they are best protected from injury, and where they are most secure from pressure during the actions of the muscles. Hence they are chiefly met with in the hollow spaces formed on the inner side of the flexures of the joints.

4. *Venous System.*

(425.) The chief peculiarities in the structure of the veins, as distinguished from that of the arteries, consist in the greater thinness, and diminished density of their coats, the tenuity or absence of the muscular tunic, and the numerous valves which occur in different parts of their course. The outer coat resembles that of the arteries, but does not present so dense or so fine a texture of fibres; and it possesses less absolute strength. The middle coat is formed of fibres which are more extensile and flexible than those of arteries; and their direction, instead of being transverse, is principally longitudinal. These fibres are not constantly met with in all the parts of the venous system, but vary much in their proportion to the rest of the structure in different veins, as well as in their directions and thickness. It is only in the large veins, near the heart, that this coat presents any appearance of muscular fibres. The inner coat is thin and transparent, like that of the arteries; but differs from the latter in being more extensible, less easily torn, and in its containing a certain proportion of ligamentous fibres in its composition. Some of the veins, such as those within the cranium, which are called *sinuses*, as well as the veins which traverse the bones, being protected by the surrounding parts, appear to consist altogether of this inner coat, and are unprovided with either the muscular or the cellular coats.

(426.) The large veins follow in general the course of the arteries, but are usually twice as numerous; so that where we meet with an artery, we generally find it accompanied by two veins. Their general disposition is arborescent, like the arterial system; but with reference to the function they perform, they may be more aptly compared to the roots than to the branches of a tree; for in following the course of the blood in its circulation, they may be said to take their rise from the minutest vessels, and successively uniting into larger and larger tubes, to terminate by one or two main trunks in the heart. The total capacity of the venous system is at least twice as great as that of the arterial system. The distribution and general mode of ramification of the veins, correspond very exactly to that of the arteries, presenting the same ramified appearance, and the same frequent anastomoses. These collateral communications are exceedingly numerous in the superficial veins, and wherever they are liable to partial obstruction from external pressure. It is in these situations also, that we meet with a great number of valves in the course of the veins. The veins of the deep-seated organs are generally unprovided with valves in any part of their course. The arteries, as we have already seen, have no valves except at their commencement.

(427.) Besides the two venous systems appropriated to the greater and lesser circulations, the former uniting in the venæ cavæ, and the latter in the pulmonary veins, and therefore corresponding to the two arterial systems, there is also another, and more partial system of veins, peculiar to the circulation in the liver, and other viscera of the abdomen. This particular system, which is that of the *vena portæ*, as it is called, is complete within itself that is, it constitutes a tree, having a common stem, with its proper roots and branches, the whole of which is placed as an intermediate system between the ultimate branches of the gastric, intestinal, and splenic arteries, of which the roots of the vena portæ may be considered as the continuations, and first radicles of the proper hepatic veins, which are the continuations of the ultimate ramifications of the vena portæ. By this arrangement, the blood which has circulated through the stomach, the intestines, and the spleen, is distributed by a new set of veins, throughout the substance of the liver, and is returned to the general mass of blood in the venæ cavæ, after circulating through that organ.

To this peculiar venous system there is no corresponding arterial system.

5. *Capillary System.*

(428.) The ultimate ramifications of the arteries, as well as the beginnings of the veins, are, in almost every part of the body, vessels of such extreme tenuity, as to be imperceptible without the assistance of the microscope; and they cannot even then be discerned, unless the part be artificially prepared by the injection of some coloured substance into the vessels, or unless they have been accidentally enlarged by disease, so as to have received the colouring matter of the blood. Hence the ancients, who were ignorant both of the art of injecting, and of the power of the microscope, were precluded from a knowledge of the existence of these minute vessels. They believed that a substance, which they termed *parenchyma*, and which they conceived to be of a spongy texture, was interposed between the terminal branches of the arteries, and the beginning of the veins; and this opinion was adopted almost universally by anatomists before the epoch of the discovery of the circulation, and was entertained even after this period, by a great number of eminent anatomists, down to the present day. But the injections of Ent, and the microscopical observations of Malpighi and of Leewenhoek, have sufficiently demonstrated the continuity of the canals by which the blood is made to pass from the arteries into the veins. The researches of modern anatomists, indeed, by shewing the amazing extent to which the minute division of the vascular system is carried, and in which they pervade every part of the frame, have finally exploded the hypothesis of the existence of interposed parenchyma, and have given rise to another hypothesis of an opposite kind, namely, of all the textures of the body being ultimately resolvable into vessels.

(429.) The name of *capillary vessels* is given to those minute branches of either arteries or veins, whose diameter is finer than a hair, and which can therefore scarcely be distinguished by the unassisted eye. Authors have endeavoured to establish three gradations of size in this class of vessels; the largest being those which can be but just perceived by the eye without a magnifying glass; the next, those which require the aid of the microscope for their detection; and the third, those which are capable of admitting only a single red globule of blood, and of which the calibre must consequently be only a very little larger than these globules.

(430.) The larger capillaries undergo several subdivisions in their course, before they arrive at this extreme degree of tenuity; and indeed, their lateral branches of communication are so multiplied as they proceed, that the whole forms a general and extensive net-work of vessels. The total capacity of the capillary system far surpasses that of the arteries and veins; and they contain therefore by much the greatest portion of the blood in the natural and healthy state of the circulation.

(431.) The vascular branches which form the channels of communication between the arteries and the veins, are, with but very few exceptions, referable to the class of capillary vessels. In this continuous course it is scarcely possible to mark with precision, at what point the arterial portion may be said to terminate, and the venous portion to commence. Neither the limit of size, nor the change of direction, is sufficient to lay the foundations of such a distinction; for the alteration of diameter is gradual, and the inflexions are various, and frequently tortuous, so that no determinate criterion can be assumed as characteristic of either artery or vein. Hence arises the propriety of constituting a distinct class of capillary vessels.

(432.) The texture of the capillaries, from the minuteness of their size, scarcely admits of accurate observation. Their coats are thin, soft, pellucid, and therefore invisible to the naked eye, and hardly discernible with the microscope. It is most probable that they are formed, in every instance, by a prolongation of the internal coats of the larger arteries and veins with which they are continuous.

(433.) As the capability of admitting coloured substances is apparently an indispensable condition for their being visible, the existence of vessels of still smaller diameter, containing only colourless fluids, must more or less be matter of conjecture. A very great number of anatomists and physiologists, however, among whom may be enumerated Boerhaave, Vieussens, Farrienus, Haller, Soemmerring, Bichat, Bleuland, Chaussier, have admitted the existence of another order of capillaries, or *serous vessels*, as they have termed them, of which the diameter is too small to admit even a single red globule, and which therefore circulate only the serous part of the blood. On the other hand, the reality of these pretended vessels is contested by Prochaska, Mascagni, Richerand, and others. Béclard, in his *Anatomie Générale*, has given a review of the arguments employed on both sides in this controversy, which is by no means as yet set at rest, and which will probably have to be decided, more by considerations of a physiological than of an anatomical nature.

(434.) In speaking of the communications between the arteries and the veins, it remains only to be noticed, that in many parts of the body there appears to be interposed between the extreme branches of each, a spongy or cellular structure, into which the arteries occasionally pour out blood, so as to distend these cells, and from which the veins arise by open orifices, and absorb the blood, in order to unload the cells, and remove the accumulation which has taken place. Such a structure has been denominated the *erectile tissue*. It is exemplified on a large scale, in the spleen, and in some of the sexual organs. We shall notice this structure afterwards.

(435.) The different parts and textures of the body are supplied with vessels in very different proportions. The organ which ranks first in respect to its vascularity, is the lungs; after which come the integuments, the pia mater, and choroid coat of the eye; next the glands, the glandular follicles, the lymphatic glands, the cortical substance of the brain, the nervous ganglions. To these will succeed in the order of vascularity, the muscles, the periosteum, the adipose tissue, the medullary nervous substance, the bones, and the serous membranes. The tendons and ligaments are amongst the least vascular parts. Still less so are the cartilages, and the arachnoid membrane of the brain; and lastly, the epidermis, and its appendages, as the nails and hair, together with the enamel of the teeth, may be considered as parts entirely devoid of vessels.

(436.) The actual mass of blood which the organs of the circulation have to move through the channels we have just pointed out has been variously estimated by different physiologists. The lowest computation is that of Müller and Abeildgaard, who made it out to be only eight pounds. Borelli estimated it at twenty pounds; Planche at twenty-eight; Haller at thirty; Dr. Young at forty; Hamberger at eighty; and Keill at one hundred. Blumenbach states the proportion in an adult healthy man to be one-fifth of the entire weight of the body; but Dr. Good, who has collected these authorities, is disposed to place but little reliance on the latter mode of estimation, on account of the great diversity in point of weight and bulk of adults, whose aggregate quantity of blood would appear to be nearly the same. He thinks the mean of the above numbers, which is between thirty and forty pounds, may safely be taken as nearest to the truth. The proportion of the whole mass of blood which is contained in different parts of the vascular system, varies according to age. In early life, there is nearly an equal quantity contained in the arteries as in the veins. In the adult, one-fourth only is contained in the arterial, and three-fourths in the venous system ; and the disproportion is greater as age advances.

SECT. II.—PHENOMENA OF THE CIRCULATION.

1. *Course of the Blood in its Circulation.*

(437.) Having premised this general outline of the course which the blood takes during its circulation, we shall now follow the several steps more in detail, examining, as we proceed, the evidence afforded us that such is its real course ; and we shall lastly inquire into the several powers concerned in its propulsion.

(438.) We shall, for this purpose, begin at that part of its circuit at which the blood is brought back from the lungs, after receiving the vivifying influence of the air, and being thereby *arterialized*, as it has been called. The pulmonary veins, which convey it in this state to the heart, are collected into four great trunks, which open into the left auricle of the heart. As soon as the auricle is distended beyond a certain degree by this flow of blood into it, it contracts and pours the whole of its contents at once into the left ventricle. The constant stream of blood which is flowing towards the auricle from the lungs, prevents any portion of the blood of the auricle from flowing back into them when the auricle contracts. No sooner has the ventricle received this blood, which has passed into it by a sudden influx, than it is stimulated to a vigorous contraction of its muscular fibres, which, surrounding the cavity in a spiral direction, contract its cavity, and, exerting a powerful pressure on the contained fluid, propels it with prodigious force into the aorta. The contraction of the ventricle is attended with the raising of the mitral valve, interposed between it and the auricle, and the sides of that valve being closely applied to the aperture by which the blood had entered the ventricle, all return of the blood into the auricle is thereby prevented. The whole of it rushes, therefore, as an impetuous torrent into the aorta, or main trunk of the arterial system. The blood which has entered the artery is again prevented from flowing back into the ventricle, by a valvular apparatus of the same kind as that which occurs between the auricle and the ventricle. These valves, placed at the entrance of the aorta, are called the *sigmoid*, or *semilunar valves*. They are three in number, each being attached by its convex edge to the coats of the artery, to which it is closely applied when the stream of blood is flowing in a direction from the heart, but which is immediately raised, and the three loose edges joining together, form a complete barrier to the passage of the blood when moving in the contrary direction.

(439.) The blood, having passed into the aorta, is conveyed through its branches and ramifications to all the parts where these ramifications extend, till it reaches the capillaries, where it moves more slowly, yet still proceeds on its course, supplying every part with the materials necessary for the maintenance of their nutrition and vital powers. From the capillaries the blood is brought back by the minuter branches of the veins, which, uniting successively to form larger and larger trunks, are at length collected into the two venæ cavæ, the one descending from the head and superior parts of the body, and the other ascending from the inferior parts, and both joining at the right auricle of the heart. The same process now takes place in the right cavities of the heart, which was described as occurring in the left. The right auricle is filled with blood from the venæ cavæ; it contracts and pours its contents into the cavity of the right ventricle, which, being in its turn stimulated to contract, propels the blood it had received from the auricle into the trunk of the pulmonary artery; which artery likewise distributes it, by a similar system of ramifications, to the membrane lining the air vesicles of the lungs. All retrograde motion of the blood is prevented as effectually in this case as in the former, by the interposition of the tricuspid valves between the auricle and ventricle, and by the semilunar valves placed at the entrance of the pulmonary artery.

(440.) From the ultimate ramifications of the pulmonary artery the blood is conducted into the capillary vessels, which are spread over the membrane of the air-cells of the lungs, where it undergoes the change of quality from venous to arterial, consequent upon its exposure to the chemical action of the oxygen which is contained in the atmospheric air admitted into those cells. From these capillaries it is collected by the pulmonary veins, and returned, as before stated, to the heart, to be again distributed to every part of the body.

(441.) While one portion of the blood is circulating in the system, another portion is circulating in the lungs. Both auricles are filled at the same moment, and contract together; each sending its blood into the corresponding ventricle. In like manner, the two ventricles contract simultaneously, and propel their contents into their respective arterial trunks. The contraction of the heart is called *the systole;* its relaxation *the diastole.*

2. *Proofs of the Circulation.*

(442.) The discovery of the course which the blood takes in its circulation, a discovery of such vast magnitude, that almost the whole of the present doctrines of physiology and pathology are either directly founded on it, or are more or less immediately related to it, was made in the beginning of the seventeenth century. It was one of the earliest fruits of that active spirit of inquiry, and rational process of investigation, which, since the era of Bacon, was beginning to diffuse itself in Europe. It was an honour reserved for our illustrious countryman Harvey, whose fame must live as long as science is cherished among men. While it is the fate of other discoveries, that their authors are either soon forgotten, or only known to a small class of those who devote their attention peculiarly to the subject to which they relate, the name of HARVEY is become familiar to all who have any acquaintance with general literature, or pretensions to a liberal education. However firmly the truth of his great discovery be established in the present time, it was, in its first promulgation, keenly contested by many contemporary physiologists. To us who have no such prejudices to warp our judgment, and who are furnished with so large a body of evidence on the subject, the controversy appears exceedingly frivolous and absurd. Yet we must recollect that in every subject of human opinion, it requires a considerable time to wean mankind from errors which have been long and deeply rooted in their minds, however palpable such errors may appear to the eyes of those who have not been so blinded. As it may still, however, be satisfactory to know the grounds upon which the doctrine is founded, we shall briefly enumerate the leading facts and arguments that establish it.

(443.) The most striking proofs that the course of the blood along the arteries is from the heart towards the extremities of those vessels, and along the veins in the contrary direction, are obtained from ligatures on those vessels. If any of the larger arterial branches be tied, that portion of the vessel which is situated between the ligature and the heart, immediately swells, becomes distended with blood, and exhibits strong pulsations; and if while in this state it be punctured, the blood rushes out with violence, and in successive jets, corresponding to the pulsations of the heart. The part beyond the ligature, on the other hand, or that farthest from the heart, is flaccid and empty, and affords no blood when divided; it is also void of pulsation. Phenomena precisely the reverse of these are exhibited when similar experiments are made on the veins; in them, the part most distant from the heart becomes turgid, while the nearer part is empty. This last experiment is one that is made every time a person undergoes the operation of blood-letting. A ligature is applied round the arm, from the pressure of which on the subcutaneous veins, they are made to swell every where below the ligature, that is, farther from the heart; while all the veins above the ligature are empty, the blood having been propelled onwards in its course towards the heart. Those parts which are swelled pour out their blood profusely on being punctured; and when the bandage is removed, the flow is stopped, in consequence of the blood finding a ready passage to the heart.

(444.) In the veins, we have additional evidence, from the structure of the valves, that the blood can move only in one direction, namely, towards the heart. The valves at the entrance of the ventricles and arterial trunks, which allow of motion only in a particular course, lead to a similar conclusion with respect to the direction of the current in its passage through the heart. It is impossible by artificial means to force fluid injections through the heart, in a course contrary to that in which the blood moves; and the same insuperable resistance is experienced in the attempt to pass injections in other parts of the circulating system, when in opposition to the natural course taken by the blood, while the same fluids readily find their way from the arteries into the veins, when thrown in that direction.

(445.) Ocular demonstration of the course of the blood while circulating in the smaller arterial and venous branches, and also in the capillaries, is afforded by the microscope, when a very thin and transparent membrane in which such vessels are distributed is placed in the field of a good microscope. The web between the toes of a frog, the surface of its vesicular lungs, the mesentery, the membrane in the tail of small fishes, are all of them capable of exhibiting these phenomena, and present, indeed, a spectacle of the highest interest.

(446.) The successive action of the cavities of the heart, in the order above enumerated, may also be seen when the hearts of living creatures are exposed to view; and this spectacle may be afforded without pain to the animal, if, after its head has been completely separated from the body, respiration be kept up by artificial means.

(447.) The transfusion of the blood of one animal into the vessels of another is a curious illustration of the doctrine of the circulation. In this operation, the artery of one animal is connected by a tube with the vein of another animal; the consequence of which is that the first is gradually emptied of its blood, while the vessels of the other are in a state of repletion. If an opening be made at the same time in the veins of this second animal, the blood originally belonging to it will escape, and thus the whole mass of its circulating fluid will be changed. Experiments of this kind were at one time very common, but they have long ceased to excite curiosity, and are now rarely practised.

That the blood moves with great rapidity and force through the larger vessels, is proved by the immense quantity that is quickly lost if any great artery or vein be wounded.

SECT. III.—POWERS CONCERNED IN THE CIRCULATION.

(448.) We have next to enquire into the nature and magnitude of the forces by which the blood is impelled in its course, the resistance opposed to its progress, and the general laws by which its movements are regulated.

(449.) The subject will naturally divide itself into four parts; namely, as relating to the powers of the heart, of the arteries, of the capillaries, and of the veins.

1. *Action of the Heart.*

(450.) The intention and purpose of the auricles, which are placed as ante-chambers to the ventricles, is to receive the blood in a constant stream from the veins, which fill it gradually and equably, so that when the distension has reached a certain degree, the auricle may contract and discharge the whole of its contents, with a sudden impetus, into the ventricle. The thickness and muscular force of the auricles are very inferior to those of the ventricles, which being destined to propel the blood with considerable momentum into the arterial system, are exceedingly powerful, but seem to require the stimulus of a sudden and forcible distension, in order to excite them to a sufficiently energetic action. It appears, indeed, that this mechanical distension and separation of their sides from the influx of fluid, is the natural stimulus that excites them to contraction ; for they are not affected by any of the causes which produce contractions in the voluntary muscles, such as irritation of the nerves which supply the heart. On the other hand, the mere introduction of warm water into these cavities, when previously emptied of blood, is sufficient to renew the action of the heart.

(451.) It is exceedingly difficult to form any probable estimate of the absolute force exerted by the heart, and more particularly by the left ventricle, in propelling its contents. No inquiry in physiology was pursued with more ardour, has been the subject of more various controversy, or has given rise to so many voluminous and elaborate calculations.

(452.) It will be quite evident that a very considerable power is required, in order to enable the heart to propel the blood through the arteries, when we consider the enormous resistances opposed to its progress, and when we also take into account the great velocity given to it in its motion. The column of blood already contained in the arterial system, must have its velocity accelerated, in order to admit of the passage of fresh blood into the aorta. The arteries require also to be distended for the admission of this additional quantity of blood, every time that the ventricle contracts. The angles and flexures which the blood is obliged to follow in its course through the vessels, must be causes of retardation, and must be productive of a loss of force, which the muscular power of the heart is ultimately called upon to supply. The operation of all these retarding causes is so complicated, that we need not be surprised at the problem of the force exerted by the heart, having baffled the skill of the best mathematicians, and their calculations being so widely different from one another. Thus, while Keil estimated the power of the left ventricle at only five ounces, Borelli calculated that its force could not be less than one hundred and eighty thousand pounds. Dr. Hales computes it to be exactly fifty-one pounds and a half; while Tabor concludes its amount to be one hundred and fifty pounds. Such irreconcilable results sufficiently show the futility of most of the reasonings on which they are founded, and the impossibility of making any satisfactory approach towards the solution of the problem. We should, on the whole, be more disposed to place confidence in the estimate of Hales, who moreover states, that the velocity with which the blood passes into the aorta, is about one hundred and fifty feet per minute, or two feet and a half per second; and that the quantity of blood passing through the heart during each hour, is about twenty times the whole mass of blood contained in the body; or, in other words, that the whole mass completes twenty entire circulations in an hour. The great velocity of the blood in the vessels is exemplified by the fact, that a fluid introduced into one of the jugular veins of a horse, has been detected in the opposite vein, and even in the vena saphena of the leg, in the course of half a minute.

(453.) It has been keenly disputed whether the heart is able completely to empty its cavities at each contraction; and the question, which is not one of any real importance, is hardly yet decided.

(454.) Another subject of controversy which was much agitated among the French physiologists in the middle of the last century, is, whether the heart is shortened or elongated during its systole; that is, whether the apex approaches the base during the contraction of the ventricle, or recedes from it. From the numerous observations of Spallanzani, as well as of other experimentalists, there seems to be no doubt that during the systole all the parts are brought nearer to the tendinous ring surrounding the auriculo-ventricular orifices, which may be regarded as the fixed pivot of its movements, and consequently the length, as well as the other diameters of the heart, is shortened. During this action, however, the curvature being suddenly straightened, the apex is projected forwards, and produces that striking against the ribs which is felt by the hand applied externally to the chest.

(455.) The right ventricle having only to perform the lighter task of circulating the blood through the lungs, is much inferior in thickness and strength to the left ventricle, which has to propel the blood through the whole aortic system, forming a course of much greater magnitude than that of the pulmonary vessels. But, on the other hand, the capacities of the two ventricles are nearly equal, as might be expected, when it is considered that the same quantity of blood which is forced out from the one, must, in the course of circulation, pass through the other; and that both the ventricles contract the same number of times in a given interval. The quantity of blood expelled by the heart at each contraction, is estimated by Blumenbach at two ounces. So that, reckoning the whole mass of blood at thirty-five pounds, or four hundred and twenty ounces, and the contractions to be repeated seventy-five times in a minute, the whole of the blood will have passed through the heart in about three minutes; thus agreeing very nearly with the estimate of Hales already stated, (§ 452.)

(456.) It has been supposed that the heart exerts some force in the diastole as well as systole; and that the recoil of the muscles when they spring back, after they have performed their contraction, creates a force of suction, which promotes the flow of blood in the great veins towards the heart. But the truth of this proposition is exceedingly dubious.

(457.) The movements of the heart are completely involuntary; that is, are entirely beyond the control of the will. Nor are its natural actions accompanied by any sensations. They are, generally speaking, totally independent of the nervous system; for they may be maintained after the destruction of the brain and spinal cord, and even after all the nerves which supply the heart have been divided. Yet these movements are capable of being influenced, often very suddenly, by an impression made upon any considerable portion of the nervous system. The regular contractions of the heart appear to be excited simply by the stimulus of distension from the periodical influx of blood into its cavities. This organ is evidently endowed with a very high degree, and a very peculiar kind of irritability, not subject, like that of the voluntary muscles, to exhaustion, by the most powerful exertions, reiterated for an indefinite time.

2. *Actions of the Arteries.*

(458.) Whatever be the velocity with which the blood is projected from the heart into the aorta, that velocity is soon retarded, in the course of its progress from the larger to the smaller branches of that arterial trunk. This is amply illustrated by the observation of the effects which follow the division or wounds of arteries in different parts of their course. A wound of the carotid artery is almost instantly fatal, from the deluge of blood which rushes out from the opening. The division of the other large arterial trunks is no less certainly fatal, if means be not at hand to stop the torrent that gushes out with resistless impetuosity. In the smaller arteries, such as those in which the motion of the blood can be viewed with the microscope, the current is very languid and feeble. It is, in reality, however, much slower than it appears to be; for it should be recollected, that in viewing the magnified image of an object, its motion is magnified in the same proportion as its dimensions.

(459.) The cause of this continual retardation of the blood is to be traced in the structure of the arterial system itself. The velocity of a fluid passing through a tube of unequal diameter in different parts, must be inversely as the area of the tube at each respective point of its length; that is, inversely as the square of the diameter. Accordingly, if we suppose two cylinders of different diameters joined together, and that a fluid is passing from one end to the other, it must evidently move with less velocity in the wider than in the narrower part; for if it did not, it would leave behind it a vacant space. But a vacuum of this kind can never take place in the living body, in which, with whatever other properties they may be endowed, the fluids are still obedient to the laws of hydraulics. The arterial system consists of an assemblage of tubes, which, though they continually diminish in their diameter as they divide into branches, yet as the united area of the branches is always greater than that of the trunk out of which they arose, they constitute, when taken as a whole, a system of channels of continually increasing capacity, as we follow them from the heart to the extremities. The whole cavity through which the blood moves, may therefore be represented by a cone, having its apex at the heart, and its base at the termination of the minutest arterial ramifications. The beginning of the aorta is, in reality, the narrowest part of the whole channel, considered with reference to the united areas of the successive order of branches as they divide. The sum of all the areas of the minutest ramifications of the arteries existing in the body, comprising myriads of myriads of vessels, if they could be collected together, would form an area of immense extent. No wonder, therefore, that the motion of the blood, when it arrives at this part of the circulation, should be so prodigiously retarded as actual observation shews us that it is.

(460.) Notwithstanding this great difference in the velocity of the blood in different parts of its arterial circulation, it would appear from the experiments of Poiseuille, that the pressure exerted by the blood, as measured by the column of mercury it will support at different distances from the heart, is not very different.

(461.) The arteries being always full of blood, and their coats distended by its presence, the elasticity of these coats is always exerted, and produces a constant pressure on the blood, independently of any force that may urge it forwards. The entry of a fresh quantity of blood forced into them by the action of the heart, produces a slight additional distention of their coats, and a consequent reaction of their elasticity. This reaction of the arteries in each interval of the heart's pulsation, tends much to equalize the motion of the blood; and has the effect also of propagating the impulse originally given to it by the heart very quickly to the remoter parts of the arterial system. The velocity with which this impulse is transmitted, is much greater than the actual motion of the blood, and partakes of the nature of a wave, which, as is well known, advances with incomparably greater rapidity than the progressive motion of the fluid itself. It is the impulse given to the sides of the artery by this wave, as it may be called, which constitutes the *pulse*, and which is more particularly rendered sensible on compressing the artery with the finger.

(462.) It has been a much disputed question, both here and on the continent, whether the arteries assist the circulation by exerting any contractile power of their own. The evidence in favour of their exerting such an action is very strong, and apparently irresistible. The power of the heart, however enormous we may suppose it to be, would appear to be quite inadequate to drive the whole mass of the blood through the infinite number of narrow and contorted channels through which it actually moves, were it not assisted by some additional force, derived from the contractions of the arteries themselves. Many facts prove that variations in the impetus of the blood, and in the quantity which circulates in particular parts, occur at different times, quite independently of any general alteration of the circulation, or of any corresponding change in the action of the heart. The only assignable cause for such differences is a variation in the extent of action of the arteries. Numerous experiments show that stimuli applied to the smaller arteries occasion in them a temporary constriction at the points where irritation has been excited; which, after a certain time, goes off spontaneously. Various other facts also prove that the arteries have a power of spontaneous contraction; this power is exhibited in the most unequivocal manner when an artery has been cut across; the consequent hæmorrhage being, after some time, stopped by this action of the coats of the artery. This contractile force of arteries is probably derived from muscularity, although the muscular structure is not distinctly perceptible. It is considerably greater in the smaller than in the larger arteries; and it is probably greatest of all in the capillaries.

(463.) Notwithstanding the facts above stated, the muscularity of the arteries is denied by some of the most eminent of the continental physiologists; and among others, Magendie, Broussais, Adelon, Alard, Rolando, and Müller.[1]

3. *Action of the Capillaries.*

(464.) The particular agents by which the circulation is carried on in the capillary vessels cannot be very precisely determined; and the subject has given rise to much controversy among physiologists. The action of these vessels is evidently of the greatest importance in relation to every other function, and more especially to the production of every permanent change which may take place in the form or composition of the organs. The variable state of the circulation in different organs at different times, must be occasioned principally by diversities in the actions of the capillaries. It appears from the experiments of Hunter, that while the larger arteries possess a greater proportion of elastic power, the smaller arteries have a comparatively greater muscular contractility; and this reasoning may, with great appearance of probability, be extended to the capillaries. It would appear, indeed, from various observations on the in-

[1] See Milligan's *Translation of Magendie*, and Bostock's *Physiology*, p. 244.

ferior animals, and in particular from those made by Dr. W. Philip, that the circulation in the capillaries may be kept up for some time after the pulsation of the heart has entirely ceased, and even when that organ has been altogether removed from the body. In many cases, indeed, the capillaries, when viewed with the microscope, have been seen to contract on the application to them of stimuli, which, in other cases, excite contractions in the muscular fibre. The pulsatory motion of the blood given to it in the arteries by the periodical contractions of the heart, is scarcely sensible in the smaller arteries, and is totally lost in the capillaries, where we find the blood moving in a uniform stream. This is a necessary consequence of the tortuous course of the channels through which it passes, and of the numerous communications among these vessels, which equalize the effects of the original impulse, and extend them over the whole period of time that intervenes between one pulsation and the next.

4. *Action of the Veins.*

(465.) The blood which is returned from every part of the system by the veins, is gradually accelerated in its progress towards the heart, for a similar reason that it was retarded in its transmission through the arteries, namely, that the capacity of the channel through which this fluid is passing is continually diminishing; for the united area of the beginnings of the veins is incomparably smaller than the conjoined area of the two venæ cavæ. The office of the veins generally appears, on the whole, to partake more of a mechanical action than that of the arteries, though it is probable that the smaller veins may derive from their structure powers analogous to those of the capillaries. The power which impels the blood forwards in the veins is chiefly the impulse it has already received, and the pressure exerted on it from behind, or what has been technically termed the *vis à tergo*. This force is assisted also in many situations by the pressure made on the veins by the action of the neighbouring muscles, which, in consequence of the valves placed in the course of the veins, preventing all retrograde motion in the blood, must contribute to force it onwards towards the heart. It is probable, however, that the veins are not altogether destitute of a power of contraction, though less considerable than that possessed by the arteries; and that the exertion of this power has some share in accelerating the motion of the blood in the venous system. Whatever power may arise from the force of dilatation exerted by the auricles of the heart during their diastole, which, however, we have reason to believe is very trifling, must be added to the account of the forces that tend to promote the motion of the blood towards those cavities. Some have supposed that a similar power is derived from the expansion of the chest in the act of inspiration; but this, if it exist at all, is of very inconsiderable amount. The venæ cavæ near their termination in the auricles, are furnished with a distinct layer of muscular fibres, apparently for the purpose of enabling them to resist the retrograde impulse communicated to the blood by the contraction of the auricles.

5. *Pulmonary Circulation.*

(466.) There is nothing very different in the circulation through the pulmonary arteries, capillaries, and veins, from what takes place in the corresponding vessels of the systemic circulation, excepting that junctions are occasionally formed between the smaller branches of the branchial arte-

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