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OUTLINES

OF

PHYSIOLOGY:

WITH

AN APPENDIX

ON

PHRENOLOGY.

BY P. M. ROGET, M.D.,

SECRETARY TO THE ROYAL SOCIETY, PROFESSOR OF PHYSIOLOGY IN THE ROYAL INSTITUTION OF GREAT BRITAIN,

ETC. ETC.

FIRST AMERICAN EDITION,

REVISED, WITH NUMEROUS NOTES.

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AUTHOR'S 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 Phrenology, 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 modifications and additions to the system of Gall and Spurzheim contained in Mr. Combe's System of Phrenology. 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.

PREFACE

OF

THE AMERICAN EDITOR.

The contents of the present volume—as will be seen by the Author's Preface—form the articles "Physiology" and "Phrenology" in the seventh edition of the Encyclopædia Britannica. These articles have been recently published separately in Edinburgh, in two handsome volumes, and from these the present edition has been printed.

Of the Author's qualifications as a physiological writer, it is scarcely requisite to speak. The fact, of his having been selected to compose the Bridgewater Treatise on Animal and Vegetable Physiology, is sufficient evidence of the reputation which he then enjoyed; and the mode in which he executed the task amply evinces that his reputation rested on a solid basis.

The present volume contains a concise, well-written epitome of the present state of Physiology—human and comparative—not, as a matter to be expected, the copious details and developments to be met with in the larger treatises on the subject; but enough to serve as an accompaniment and guide to the physiological student.

The attention of the American Editor has been directed to the revision and correction of the text; to the supplying, in the form of notes, of omissions; to the rectification of some of the points that appeared to him erroneous or doubtful; and to the furnishing

of references to works in which the physiological inquirer might meet with more ample information.

In Phrenology, the Author is a well-known unbeliever, and his published objections to the doctrine have been regarded as too cogent to be permitted to pass unheeded. It will be seen, that farther examination in the interval of many years, which has elapsed since the publication of the sixth edition of the Encyclopædia, has not induced him to modify his sentiments on this head. On the contrary, he appears to be as satisfied, at this time, of the fallacy of the positions of the Phrenologist, as he was at any former period.

PHILADELPHIA, *July* 1, 1839.

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PHYSIOLOGY.

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CHAPTER I.

GENERAL VIEWS.

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 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 divisable. 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 connexions 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 those 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 investi-

gation to any extent in the diversified phenomena of organization. So complicated is the mechanism, and so fine the minute 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 presents 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 the 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 subser-

vience 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 show 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 development.

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 shows 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 inju-

rious 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 situate 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 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 existence 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 impulse 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 the first effects on the brain, towards those parts which are capable of executing these determinations. Modern discoveries have shown, that for this latter purpose sets of nervous fibres are employed different from those instrumental in conveying sensitive impressions from the organ of sense to the brain. Hence a distinction is established between the *Nerves of Sensation*, and the nerves of motion, or the *Motor Nerves*.* 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.

* 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.

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 designed 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 the 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 diver-

sified 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 action 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 substance* 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*, *fasciæ*, are composed of a still 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 point required to be moved, would be attended with inconvenience. In this case, an intermediate structure is employed, analagous 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 disorganization of that fabric which so lately delighted the eye with its beauty, and in which dwelt the genial warmth of life, and the elastic vigor of youth. If we watch the progress of those dangers 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 be studied 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 *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 is 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 contained 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 contracts with enormous force, and propels 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 its place of 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 in 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 *Nutrition*. It includes the development 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 phosphate 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. The fluid is the *fat;* and it is accumulated in various

* [Absorption is not, however, effected exclusively by the lymphatics. It will be seen, hereafter (549), that when substances possess the necessary tenuity, they readily pass through the parietes of the veins under favourable circumstances, and enter the circulation.]

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, the 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 process 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. 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 process 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 development 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 have 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 development, 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 when 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 foundation 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, on the general purposes of the whole machine, and the particular uses of every part, as well as on 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 show 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 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 immortalized 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 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 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 laby-

rinth, 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 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 reindeer, 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 *camelopard*, 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 re-

semblance, are considered as composing a tribe or order, to which Linnæus has given the name *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 development 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 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 dis-

tinctive 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 starlike 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. Passeres . . . . . *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 net-work, 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* has advanced a hypothesis, 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

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

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 to 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 sacred writings, when rationally interpreted, and may even be 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.*

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

* See the Bridgewater Treatise on Animal and Vegetable Physiology, where this subject is enlarged upon, and especially the chapter on "Unity of Design." ii. 625. [American Edition, ii. 437.]

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 classifiation 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 super-

fluity 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 their organic 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 everywhere 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 connections, 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 and the circulation 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,* Richerand,† and other systematic authors on physiology, with the exception of Haller,‡ who adopted a classification of functions founded altogether on the anatomical relations of the organs by which they are performed.

83. Bichat,§ 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 distinction among the powers of life, he has perplexed 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 has been guilty of a still more palpable error in deeming it necessary to add to

* Principes de Physiologie.
† Primæ Lineæ Physiologiæ.
‡ Elémens de Physiologie.
§ Anatomie Générale.

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 as functions of the nerves. Adelon* distinguishes the following eleven actions as being the functions of life; namely, *sensibility*, *locomotion*, *language*, *digestion*, *absorption*, *respiration*, *circulation*, *nutrition*, *calorification*, *secretion*, and *generation*. Bourdon† 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 referred to definite purposes. The same confusion may be remarked in the classification of the functions by Béclard,‡ 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

* Physiologie de l'Homme. [The arrangement of Adelon is adopted from Magendie, and has been embraced by Dr. Dunglison. The functions are divided into three classes. The *first* class, the *functions of relation*, or *animal functions*, includes those that establish our connexion with the bodies surrounding us;—the *sensations*, *voluntary motions*, and *expressions*. The *second* class —the *functions of nutrition*—comprises *digestion*, *absorption*, *respiration*, *circulation*, *nutrition*, *calorification*, and *secretion*; and the *third* class, *the functions of reproduction*,—*generation*.—Dunglison's Human Physiology, 3d edit. i. 51. Philad. 1838.]

† Elémens d'Anatomie.

‡ Principes de Physiologie Médicale.

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 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 of 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 influence, from which results what are called *temperament* and *character*. These lead to the consideration of functions of a more purely and 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* 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 *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 connection 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 author in a treatise on Physiology which appeared many years ago in the last Supplement to the Encyclopædia Britannica, 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

* Outlines of Physiology and Pathology, Edinburgh, 1833.

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 as, 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, therefore, 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,* differs but little from that adopted by Dr. Alison.

88. The author has given, in his *Bridgewater Treatise*,† an arrangement of the functions founded altogether on the basis of final causes: and corresponding 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

* Outlines of Human Physiology, 3d edition, London, 1833. [4th edit. Lond. 1837.]

† Roget, Animal and Vegetable Physiology, considered with reference to Natural Theology, 2 vols. London, 1834. [Philad. 1836.]

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 aëration 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* comprehend 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 development 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 phenomena 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 show, 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,* and sanctioned by many other eminent physiologists, is in

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

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.

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 effort 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 a 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 classifi-

cation 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, 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 show 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.* 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, 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

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

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 showing 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 organised tissues, which call out and develop 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 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. Physical causes only 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.

109. 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 fits 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 agents, 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.*

* See Béclard, Elémens de Anatomie Générale, p. 77.

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 it to the first section of his great work on Physiology.* 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 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

* Elementa Physiologiæ Corporis Humani.

† [The notion of Haller must be regarded as a mere abstraction; for as different animal substances are found to be composed of different proportions of carbon, hydrogen, oxygen, and azote, it is fair to infer that the elementary fibre must differ also in the different structures. See Dunglison's Physiology, ii. 36.]

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,* appear to have established, that the globular appearance of the different organized textures, when viewed with microscopes of high magnifying power, 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 this 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 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.† 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 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.

* Philosophical Magazine, and Annals of Philosophy, vol. ii. p. 136; and also in the appendix to their translation of Dr. Edwards's work.

† See his *Anatomie Générale.*

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 the cellular texture, contained in the second volume of the *Medical Observations and Inquiries*,* and which also deserves particular notice, as presenting the best account of this branch of general anatomy.

* Page 26, et seq.

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 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 canvas 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 corrugation 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 of 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 differ-

ent 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, *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, ἐλαιον.

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 mechanical 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 re-

cipient 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 wherever 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 situate the organs of digestion and chylification, is lined by the *peritoneum*, which is also a serous membrane. The same, also, applies to the cavites 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

* [The only exception to this is in the case of the peritoneum, on which the ventral extremities of the fallopian tubes terminate.]

† [Rudolphi (*Grundriss der Physiologie*, 113) asserts, that some membranes are incapable of inflammation, are not vascular, and do not secrete, but that the secretions of shut sacs take place from the subjacent parts and transude the serous membranes proper, which, in his view, are, consequently, a kind of epidermis.]

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 *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 show that there is no essential difference between them.*

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,† who first discovered them. Their existence, however, was for a long time considered dubious; but it has been lately verified by Mr. Howship,‡ who, with the help of the solar microscope, obtained distinct views of them, and was

* Elementary System of Physiology, third edition, p. 61.
† Osteologia nova, § 35, 37.
‡ Medico-Chirurgical Transactions, vii. 393.

enabled to trace their course. He ascertained the diameter of these canals to be about the 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* 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† 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.‡ A portion of this solid animal substance affords gelatin 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 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 analyses of different bones taken from the same individual, in a state of perfect dryness, and quite free from fat, periosteum, or cartilages, deduces from his researches the following conclusions:§ 1. The long bones of the extremities contain more earthy matter than those of the trunk. 2. The bones of the upper extremity contain

* Memoires de l'Académie des Sciences, pour 1739, 1741, 1742, and 1743.
† Ibid. 1758.
‡ This was first satisfactorily shown by Mr. Hatchett. Phil. Trans. for 1800.
§ Medico-Chirurgical Transactions, xxi. 409.

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 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 adults; 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

* [Professor Miescher, of Basel, in Switzerland, who has published an excellent account of the general anatomy of bones, with which he has favoured the Editor, gives the following as the proportions of the animal and earthy parts.

	Infants.	Adults.	Aged.
Animal matter, . . .	47.20	20.18	12.20
Earthy matter, . . .	48.48	74.84	84.10
	95.68	95.02	96.30

The proportions, however, differ in the different bones: According to Thilenius, in a dissertation on the chemical composition of bones, published at Göttingen, in 1823, the bones of the extremities of the new-born infant, freed from animal matter by burning, left 57.59 per cent.; the vertebra of the neck and back, 47.41; the clavicle of a boy, 63.26; the os frontis and os parietale, 65.21; the petrous bone of the adult, 68.72; the bones of the extremities, 66.66; the ribs, 63.37; the frontal, femoral, occipital, and inferior maxillary bone of an old person, 66.79.—*Miescher, De Inflammatione Ossium eorumque Anatome Generali*, p. 48: Berol. 1836. See, also, *Pancoast's Edition of Wistar's Anatomy*, i. 29. Philad. 1838.]

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,* 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,† 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‡ that all writers, before the time of Scarpa, considered the structure of bone as laminated, or fibrous 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 hesition in agreeing with Scarpa that it is really cellular. At the same time, it must be confessed, that the sides

* Anatomia Ossium. † De Penit. Structura Ossium.
‡ Cyclopædia of Anatomy and Physiology, vol. i. p. 433.

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 show that we have torn the cells, and destroyed the true texture. The laminated disposition supposed to be shown 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, which 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 which 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 a 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 shown 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 the substance as an essential ingredient in their composition.

The mechanical property which particularly dintinguishes 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 de-

scribed. 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 sarfaces 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 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 combine 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 super-incumbent 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 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

* [Buffon asserts, that the son of one of his most zealous *collaborateurs*, M. Guéneau de Montbeillard, a young man of tall stature, lost an inch and a half, after having danced all night.]

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 gives 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 of 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 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 compose 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* 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 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

* See his Anatomie Générale, tom. iii. p. 142.

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 the 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,* 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 distingush 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 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

* Dictionnaire des Sciences Médicales. Organization.

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,* 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."†

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 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 distinctions 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

* Natural Theology. † De Natura Deorum, l. ii. c. 35.

with a formidable array of technical terms. 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 adapted 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 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 are 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.** 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.

* For 1743, vol. 42, p. 544.

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 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 joints where the motion is frequent and considerable, and where the ends of the bones are subjected to great pressure; 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 liga-

mentous 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,—requiring 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 order 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 retain their displacement, by tightly binding them in

* [This is true in the main; yet the abdominal viscera—wounds of which, of the liver and intestines, for example, are almost always fatal—are contained in a cavity, the anterior parietes of which afford very slender protection to the important contents.]

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 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 adjacent 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. The 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 ex-

* [Breschet (*Nouvelles Recherches sur la structure de la Peau, Paris*, 1835) calls the corpus papillare the '*Neurothelic Apparatus*.]

istence 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 net-work on its surface. In this opinion he is supported by other anatomists of high authority, as Chaussier and Rudolphi. Mr. Cruickshank,* on the contrary, who 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 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 situate 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 vessels which exhale the perspiration, and nearly the same views have been entertained with regard to their nature

* On Insensible Perspiration.

† [Breschet (*Op. citat.*) affirms, that there is a special "*chromatogenous apparatus*" for producing the colouring matter, composed of a glandular or secreting parenchyma, situate a little below the papillæ, and presenting particular excretory canals, which pour out the colouring matter on the surface of the derma.]

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. Leewenhoeck 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.‡ 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

* [The researches of the investigators, referred to in the third note, have exhibited that the tissue of the epidermis is complex, and that its organization is connected with the functions of exhalation and absorption. Its vitality, if any it possess, has been compared to that of the vegetable.]

† Lectures on the General Structure of the Human Body, p. 133.

‡ [Still later investigations have been made by MM. Breschet and Roussel de Vauzème, (*Op. citat.*) by Wendt (*Muller's Archiv.* 1834,) and Von Gurlt, (*Ibid.* 1835,) which have thrown considerable light on its structure. See, also, *British and Foreign Med. Review*, ii. 429.

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 analagous to the horns of animals. They adhere to the subjacent corion, (which is in those parts furnished 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

* [Breschet affirms, that there is a special *blennogenous apparatus* for the secretion of the mucous matter constituting the epidermis, which is composed of a glandular parenchyma or organ of secretion, situate in the substance of the derma, and of excretory ducts, which issue from the organ, and deposite the mucous matter between the papillæ.]

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 a 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 connects 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 micro-

scope 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* 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 appearance 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

* De Carne Musculari.

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,* whose observations appear to have been influenced by preconceived theories, imagined that they were cellular. Borelli,† who was also biassed by his favourite hypothesis, believed them to be composed of a series of rhomboidal vesicles. The Abbé Fontana‡ 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§ states that a muscular fibre duly prepared, by washing away all adhering extraneous 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,‖ 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 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 coesion 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,¶ and subsequently those of Mr. Skey,** have clearly shown 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

* Dissertatio de Structura et Motu Musculari.

† De Motu Animalium.

‡ Sur les Poisons.

§ Philosophical Transactions for 1805.

‖ *Ibid.* for 1818, p. 164.

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

**Philosophical Transactions for 1837, p. 371.

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 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 of 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 characterised, 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 parts 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,* 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.†

* Phil. Trans. for 1805, p. 22, 23.

† Anatomical and Physioligical Commentaries, p. 12. [See, on the whole of this subject, *Dunglison's Physiology*, 3d edit., i. 341.]

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 control 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 sense 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, 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 into 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 perfect 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 on 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 observe 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* 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

* De Motu Animalium.

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 explained 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 affected. 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, Gir-

* [Dr. Roget, himself, was at one time disposed to think, that light might be thrown upon the subject of muscular contraction by investigations of this nature. A slender harpsichord wire, bent into a helix, being placed in a voltaic circuit, instantly shortened itself whenever the electric stream was sent through it, but recovered its former dimensions the moment the current was intermitted. (*Electro-Magnetism*, p. 59, in Vol. II. of Natural Philosophy, Library of Useful Knowledge, Lond. 1832.) From this experiment, the author presumed, that possibly some analogy might hereafter be found to exist between this phenomenon and the contraction of muscular fibres. From his silence, however, in the text, it would appear, that farther reflection had not confirmed the suggestion.

A striking objection to all these hypotheses is,—that the irritability of the muscle is lost sight of, and the nerve alone regarded to be active; whereas, the nervous power appears to act merely as an excitant—like galvanism—to the irritability, and—as experiments show—exhausts it like any other excitant.]

tanner 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 effects of muscular power indicated a peculiarity in 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 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 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,* 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 corrugation, 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† 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 Fabric 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

* Philosophical Transactions for 1810, p. 2.
† Anatomie Générale.

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 powerful 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 their 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 the 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 powerful 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 occurrence 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 tend 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.

* [This is questionable. Observation has shown, that the sutures do not possess much, if any, effect in putting a limit to fractures. In all cases of severe blows, the skull appears to resist, as if it were constituted of but one piece.]

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 incompatible 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 spread 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 vertebra 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.

8. *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,* 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 is 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.†

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 membranous 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

* Anatomy of the Bones and Muscles, p. 21.
† Edinburgh Medical Essays, vol. i. p. 95.

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* 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 that can be produced out of a cabinet maker's shop. Their durability

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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."*

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 instinctively 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

* Natural Theology.

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 instantly 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 of 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 mechan-

ical 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 situate 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 their 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 places 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 astragalus, 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 lessoning 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.*

261. 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 has 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 ther 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 difficulties 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; three, 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.

266. 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. 2. Nitrogen. 3. Carbon. 4. Hydrogen. 5. Lime. 6. Phosphorus. 7. Sulphur. 8. Soda. 9. Potass. 10. Chlorine. 11. Magnesia. 12. Iron. 13. Silica. 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. 2. Albumen. 3. Fibrin. 4. Mucus.

278. To these have been added some others, such as *urea*, *picromel*, *stearin*, *elain*, *osmazone*, 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 some-

what 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 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 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 160° 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 occa-

sions 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.* 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 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

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

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, owning 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 de-

composition, 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 shown 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 action of the nitric acid, fibrin is converted into a kind of gelatin, and a similar change has been effected on albumen by the same reagent. 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 this affords an easy character of distinc-

tion 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 the same ultimate principles, — 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 Thénard, 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 last 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 pro-

portions 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 shown 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 Thénard.

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, 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 portion of nitrogen. Their descriptive account of its properties, however, is deficient in the precision which the subject seems to require, and which has 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 phos-

phates 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 or two hundred grains of water, was not affected either by the bichloride of mercury, or 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, 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 effect 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 process 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 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 by 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 is 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 portion 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 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 principles contained in vegetables, and blended with 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.* Cullen thought that this property appertains to two substances, the nutritous matter being either of an oily or saccharine nature, or consisting of these two qualities combined.† Richerand considers alimentary matter as either gummy, mucilaginous, or saccharine.‡ Dr. Fordyce referred all nutriment to the presence of mucilage.§ 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*,‖ 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 alimentary 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

* Elementa Physiologiæ, xix. 3, 2.
† Physiology, § 211.
‡ Elémens de Physiologie, § 3, p. 82.
§ Treatise on Digestion, p. 84.
‖ For the year 1827, p. 355.

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.* Dr. Stark made 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 peservation 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

* Physiologie, tom. ii. p. 390.

in many cases check the tendency of 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 shows 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

* [So much is this the case, that if, after an individual has been accustomed to live on both animal and vegetable food, he be restricted to one only, his nutrition, in course of time, becomes impaired, and scurvy is induced. There is at this time, (June, 1839,) in the wards of the Philadelphia Hospital, Blockley, a female, who has refused all animal food for many months, and who is effected with purpura on the extremities, spongy gums, and every sign of anæmia. It is this restriction to a single article of diet, with the confinement to a small space, and the privation of wonted air and exercise, that explains the phenomena observed in the dog fed exclusively on sugar, (§ 319) better than the want of azote in the aliment to which it was at one time ascribed by Magendie.]

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

* [These reasons are not satisfactory. The circumstances referred to, tend merely to show, what we observe constantly as the effect of mental emotions—that the sensation of hunger can be postponed for a time. An unanswerable objection to them, however, is the fact, repeatedly proved by Dr. Beaumont, and verified, in the same case, by Dr. Dunglison, that in the fasting state there is little if any gastric juice in the stomach. Hunger is an internal sensation connected with the wants of the economy; instinctive, therefore, and as inexplicable—in the existing state of knowledge—as any other internal sensation. —*Beaumont's Experiments and Observations on the Gastric Juice*, &c. p. 57, Plattsburg, 1833, and *Dunglison's Human Physiology*, 3d edit. i. 493.]

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, 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, are the great agents in mastication. The respective purposes served by each class are sufficiently evident from their shape and position in the jaw. The *incisors* 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.* 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.† 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 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.‡ Leuret and Lassaigne, whose investigations were nearly contemporaneous with those of Tiedemann and Gmelin, represent the chemical properties of the saliva as being essentially the same in all animals, and consider the animal matter it contains as a species of mucus.§

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

* Edin. Med. Journal, ii. 44.

† Medico-Chirurgical Transactions, iii. 242.

‡ Recherches sur la Digestion, par Jourdan, p. 23.

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

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 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 it 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 contraction 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, having 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 dilation 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.*

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

* Physiologie, tom. i. p. 341.

situate. The office of the stomach is to convert the food which it receives into the soft pultaceous mass of a gray colour, which has been denominated *chyme.** 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 disposed as to enable 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 agents 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 secre-

* The older authors made no distinction between *chyme* and *chyle*: the latter substance is the product of the formation of the small intestines.

† [This is more than questionable. Whenever the secretions of the stomach have been obtained unmixed with alimentary matters, as in the case, referred to hereafter, of the man with the fistulous aperture into the organ, they were found of a distinctly acid taste.]

tions, 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; showing 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

*[Some interesting experiments have been made on the powers of acidified mucus in effecting artificial digestion, by Eberle of Germany, Professor Müller and D. Schwann, and by Dr. T J. Tood. By steeping the mucous membrane of an animal's stomach in an acid liquor a solution is obtained, to which Eberle gave the name *Pepsine*. This solution has the property of dissolving coagulated albumen, muscular fibre, and animal matters in general.]

experiments of Réaumur, 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 skin of fruits, and the fibres of flax or cotton, are not in the slightest degree affected by it. This difference of action on different subjects 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 through the parietes 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 prin-

cipally 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 favorable 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

* [In the case referred to in a subsequent paragraph (349) Dr. Beaumont had innumerable opportunities for obtaining the gastric secretions unmixed with alimentary matter. These were examined by Drs. Dunglison and Emmet, and found to contain free muriatic and acetic acids, phosphates and muriates, with bases of potassa, soda, magnesia, and lime, and an animal matter soluble in cold water, but insoluble in hot. The quantity of free muriatic acid, contained in them was surprising. On repeated examination, the acid character was distinct, and the odour of muriatic acid not to be doubted.—See a letter from Dr. Dunglison to Dr. Beaumont, in Beaumont's Experiments, &c., on the Gastric Juice, p. 78.]

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 Dr. 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.†

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

* [From his experiments on this individual, Dr. Beaumont inferred, that pig's feet soused, rice, and tripe soused, were soonest sent on into the duodenum; but it need scarcely be said, that all such tabular results apply, in strictness, to the individual concerned only; yet they afford useful comparative views, which, with exceptions depending upon individual peculiarities, may be regarded as approximations applicable to mankind in general.—Beaumont, *Op. cit.*

Dr. Beaumont's table has been copied,—and a column indicating the ratio of the digestibility of the various articles added—in *Dunglison's Elements of Hygiene*, p. 233, Philad., 1835, and in his *Medical Dictionary*, 2d edit. Philad. 1839. art. Digestible. See also, Combe's *Physiology of Digestion*, Amer. ed. New York, 1836.]

† See an account of the disease lately prevalent in the General Penitentiary. By P. M. Latham. M. D. London, 1825.

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.

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 fermentation; 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 earlier 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.

A portion of aliment often passes, however, 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

*[Dr. Prout (*Bridgewater Treatise*, Amer. edit. p. 268, Philad. 1834) conceives, that the source of the muriatic acid in the stomach is the common salt existing in the blood, which he conceives is decomposed by galvanic agency; and Drs. Purkinje and Pappenheim (*Müller's Archiv.* 1838, and *British and Foreign Med. Rev.* Oct. 1838, p. 527) announce a similar opinion. From their galvanic experiments, they think it results, that the juices mixed with the food in the natural way,—the saliva, the mucus, and the portions of chloride of sodium generally present therein; and still more, the gastric mucous membrane itself,—develop as much chlorine as is required.]

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 subcarbonated 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 of 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

* [The difference between the chyle from food of such opposite character as indicated by these results is trifling, and exhibits the great uniformity in the action of the agents of chylous absorption. More recent researches by MM. Macaire and Marcet (*Mem. de la Société de Physique, &c. de Genève*, v. 389,) tend, indeed, to establish the fact, that the chyle and the blood of herbivorous and carnivorous quadrupeds are identical in their composition, in as far, at least, as regards their ultimate analysis. There must, consequently, be an action of selection at the very extremities of the chyliferous vessels, to occasion this striking uniformity in the composition of the chyle.]

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 to be 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.*

2. *Functions of the 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.

* Annals of Philosophy, xiii. 22.

† [These experiments consisted in tying the choledoch duct in animals; but similar experiments by M. Voisin (*Nouvel Aperçu sur la Physiologie du Foie*, &c., Paris, 1833) show, that the ligature of the choledoch duct does not prevent the formation of chyle, provided the passage of the pancreatic fluid is not at the same time obstructed. The bile, consequently, although an important, is not an essential, agent in digestion effected in the duodenum. *Dunglison's Physiology*, i. 539.]

3. *Properties of Bile.*

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.† 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 describes it as being of a resinous nature, and precipitable by acids; the precipitate, or *picromel*, or the *gallenstoff* 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

* [The latest analysis is by Muratori (*Bulletino Mediche di Bologna*, p. 160, Agosto et Settembre, 1836.) He assigns it the following constituents:— Water 832; peculiar fatty matter 5; colouring matter 11; cholesterine combined with soda, 4; picromel of Thénard, 94·86; extract of meat (*Estratto di Carne*) 2·69; mucus, 37; soda, 5·14; phosphate of soda, 3·45; phosphate of lime, 3; and chloruret of sodium, 1.86.)

† Cyclopædia of Anat. and Phys., art. Bile.

containing no picromel. M. Raspail considers bile to be essentially a saponaceous substance, with a base 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. The 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

* [This was the view of Cadet, upwards of seventy years ago—*Experiences sur la Bile des Hommes, &c.* in Mémoir. de l'Académ. de Paris, 1767.]

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 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 *cæcum*, 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.

* [One of the latest views is that of MM. Tiedemann and Gmelin, who regard the spleen as a ganglion of the absorbent system, which prepares a fluid to be mixed with the chyle to effect its animalization; thus regarding its functions to be identical with those of the mesenteric glands.]

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 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. 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

* [The doctrine of open mouths has been contested by Mascagni, Rudolphi, Meckel, Mojon and others, and it must be admitted, that we know nothing definite regarding the extreme radicles of the lacteal or chyliferous vessels.]

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, the sulphate and the 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.*

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

* *Edin. Med. Journal*, xviii. p. 455, &c. The above analysis of these experiments is that given by Dr. Bostock in his work on Physiology, p. 617, note.

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.

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, 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 analogous to any other with which we are acquainted, and has never been satisfactorily explained. The operation of external

* [The discrepancy of observers on this subject is great. Mr. Thackrah and Schröder van der Kolk, accord with Mr. Hunter in the belief, that the increase of temperature from this cause is very slight, or null, whilst Raspail asserts, that the temperature falls!]

† [A similar discrepancy exists on this point. Neither Dr. John Davy, nor Dr. Duncan, junr., nor Dr. Christison, could procure it during the coagulation of the blood. Yet there is no doubt, that the blood contains carbonic acid. See, on all this subject, Dunglison's Physiology, ii. 54.]

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 Humphrey Davy found that no difference in this respect takes place when blood is exposed to nitrogen, nitrous, nitrous oxide, carbonic acid, carbonated hydrogen gases, or atmospheric air, although the contrary had been asserted. 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* showed that this process is retarded for several hours by the admixture of blood with twelve times its bulk of water.†

* On Animal Heat, p. 248.

† [From recent experiments, made by Magendie on agents that are capable

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 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 venomous 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 be as much in need of explanation of 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* 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, is termed the *serosity*. The following is

of rendering the blood liquid, and such as are possessed of the power of promoting its coagulation, he is led to offer the following arrangement; observing, at the same time, that he does not put it forward as final, but that, on the contrary, it will no doubt be found necessary, from improved experience, to more or less modify it.

1. *Substances which promote the coagulation of the blood.*—Water, sugared water, hydrochlorate of soda; hydrochlorate of potassa; hydrochlorate of ammonia; hydrochlorate of baryta; serum of ascites; boric acid; borax; nitrate of silver; hydrosulphate of potass and ammonia; Seltzer water; Vichy water; Seidlitz water; ioduret of potassium; tartrate of antimony and potassa; sulphate of magnesia; alcohol; cyanuret of gold; cyanuret of mercury; acetate and hydrochlorate of morphia, and mannite.

2. *Substances which oppose the coagulation of the blood.*—The sulphuric, hydrochloric, nitric, tartaric, oxalic, citric, lactic, acetic, tannic, and hydrocyanic acids; soda, potassa, lime, ammonia, and the carbonates of soda, potassa, and ammonia. *Leçons sur le Sang, &c.* and the translation in *Lancet*, Jan. 20th, 1839.]

* Physiology, p. 271.

therefore the arrangement of the principal proximate parts of the blood, in the order of analysis.

Coagulated blood consists of { Crassamentum { Fibrin, Red particles. } Serum { Albumen, Serosity. }

The crassamentum is a mass of soft consistence, which easily bears cutting with a knife. Its mean specific gravity is about 1·245. By long-continued ablution in water, it may be freed from the red particles which it contains, and which are soluble in water. This may be conveniently effected by enclosing the crassamentum in a linen bag, immersing it repeatedly in water, and at the same time pressing it gently; or by allowing a stream of water to fall upon it, till the water runs off colourless. There remains a white, solid fibrous, and elastic substance, which has all the properties of fibrin, and is almost exactly similar to the basis of muscular flesh obtained by long boiling. It may also be procured directly from recent blood, by stirring it, as it flows from the vessel, with a bunch of twigs; or receiving it into a bottle, and shaking it during its coagulation. When formed under these circumstances, it exhibits a fibrous appearance, and the whole is converted into an irregular net-work of dense fibres. Fibrin was formerly known under the name of *coagulable lymph*, or *gluten*.

392. The *red particles* or *globules*, contained in the blood, and enveloped in the fibrin during its coagulation, have long attracted the attention of physiologists, from the irregularity of their appearance, and the importance which was supposed to attach to them. The first notice which we find of them occurs in the writings of Malpighi, soon after the introduction of the use of the microscope. They were soon afterwards examined with great care and minuteness by the indefatigable Leewenhoek, 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 deserve neglect. Leewenhoek 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 Senac, 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 irregular 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 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 shown 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.* 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 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.

* Cyclopædia of Anat. art. Blood.

398. Berzelius,* 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 alleged 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.†

399. It has long been the prevailing opinion that the blood derives its red colour from the iron it contains; but the truth of this opinion has been called in question by many writers of high authority, and in particular by Dr. Wells‡ and by Mr. Brande.§ The experiments of Dr. Wells, however, as is remarked by Dr. Bostock, seem only to prove that the colour of the blood is not occasioned by any salt of iron, or by iron in such a state as to be affected by the ordinary tests. Mr. Brande procured the colouring matter from venous blood in a detached state, by removing the fibrin from it by agitation while it was coagulating, and suffering the red globules to subside in the serum, from which they could be obtained in a concentrated form. Examining this portion by means of different reagents, he arrived at the conclusion, that the colouring principle of the blood is an animal substance of a peculiar nature, susceptible, like the colouring matter from vegetables, of uniting with bases, or mordants, and therefore admitting of being applied in the art of dyeing. The most effectual mordants for the colouring matter of the blood are the salts of mercury, especially the nitrate, and the bichloride or corrosive sublimate. On examining the colouring matter distinct from the crassamentum, Mr. Brande did not discover a greater proportion of iron than exists in the other principles of blood.

* Medico-Chirurgical Transactions, vol. iii. p. 215.
† Systême de Connais. Chymiques, vol. ix. p. 207, 208.
‡ Phil. Trans. for 1797, p. 410. § Phil. Trans. for 1812, p. 90.

These results, in as far as they relate to the quantity of iron, are at variance with the later and apparently more elaborate experiments of Berzelius, who still maintains that the colouring matter of the blood contains iron, not indeed discoverable by reagents, but decisively proved to exist in its ashes. In every respect, except in containing that metal, the colouring matter agrees with fibrin and albumen; and he seems disposed to believe that its colour, though not depending on the presence merely of an oxide of iron, may be produced by a compound of which the oxide is an essential part.

Vauquelin's experiments* may in some respects be deemed to corroborate those of Brande, inasmuch as they show that iron cannot be detected by liquid tests in solutions of the colouring matter; but they at the same time show that this metal is readily detected by these tests in the fluid from which the colouring matter has subsided.

400. The changes in the colour of the blood produced by its exposure to different gases, are probably owing to their action on the red globules. Arterial blood is blackened, and venous blood rendered darker, by nitrogen, or carbonic acid gases; but its bright florid hue is restored by exposure to oxygen gas. We shall have occasion to revert to this subject in treating of respiration.

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*.†

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, 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

* Annales de Chimie et de Physique, i. 9.

† Phil. Trans. for 1819, p. 2.

‡ [This may be near the average, but the specific gravity differs greatly. Thackrah, (*Inquiry into the Nature and Properties of the Blood*, &c., Lond 1819,) found the extremes to be 1.004 and 1.080.]

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 further 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 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, - - -	1·95
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 Thénard, 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.*

* [Dr. B. Babington is of opinion, that the blood, whilst circulating in the vessels consists of two parts only—a fluid which he calls *liquor sanguinis*, and red globules; and he is induced to believe, from his experiments, that fibrin and serum do not exist as such in the circulating fluid, but that the liquor sanguinis, when removed from the vessels, and no longer subjected to the laws of life, has then, and not before, the property of separating into fibrin and serum. *Med. Chirurg. Transact.* vol. xvi. pt. 2. Lond. 1831, and art. Blood (morbid conditions of the), in Cyclop. of Anat. and Physiol. Lond. 1836.]

CHAPTER VIII.

CIRCULATION.

SECT. I.—*Apparatus for Circulation.*

408. The object of the function of circulation is twofold. 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 belongs to Anatomy. The following brief capitulation, 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 situate 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. 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 semilunares*, 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 Arantii*, 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 valve. In the septum auriculum 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 Vieussenii,* 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 arties 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 divi-

sion 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 divide and subdivide 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 re-union 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 has been 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 showing 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.*

* [It would not be easy to account for the phenomena of nutrition, unless

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 organs which rank 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

we were to presume that some part of the capillary or intermediate system consists of coatless or membraneless tubes; and that, in the passage of the blood through them, the different tissues may act on the blood and conversely. The mode, indeed, in which the blood is distributed through the tissues may not be inaptly compared to that by which the water of a river is distributed through a marsh, conveying to the vegetable bodies that flourish on its surface, the materials for their nutrition. Wedemeyer, Gruithuisen, Döllinger, Carus, and others, consider that the blood is contained in the different tissues, or channels, which it forms in them: even under the microscope, the stream is seen to work out for itself, easily and rapidly, a new passage in the tissues, which it penetrates; and it seems certain, that in the figura venosa of the egg, the blood is not surrounded by vascular parietes. See, on all this subject, Dunglison's Physiology, 3d edit. ii. 154, and 206.]

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 Moulins 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 Keil 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 proportions 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

* [The general approximation is one third in the arteries, and two thirds in the veins. Haller estimated that the arterial blood is to the venous as four to nine.]

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

* [The use of the sinuses or dilatations immediately above these valves, is to prevent them from being so closely applied to the sides of the vessel, that the refluent blood, during the diastole of the ventricles, cannot readily strike them so as to depress them.]

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.*

6. *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

* [There is great reason for the belief, both from anatomy, and the evidences afforded by ocular inspection of the living heart whilst in action, that too much importance has been assigned to the energetic contraction of the auricles. It appears indeed probable, that the great use of the auricles is to act as true sinuses or gulfs, for the reception of the blood proceeding from every part of the body, and that little effect is produced on the circulation by their varying condition. Dunglison, *Op. cit.* ii. 159.]

† [The action of the tricuspid, in this respect, is not as perfect as that of the mitral valve. It seems, indeed, to be destined to permit a certain degree of reflux; and in this way, perhaps, to be a provision against the mischief that might, under certain circumstances, result from an excessive afflux of blood to the lungs: the tricuspid thus acting as a safety valve. Mr. King, Guy's Hospital Reports, No. IV. April, 1837.]

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 situate 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 struc-

ture 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.

* [Transfusion has been practised by Dr. Blundell, and others, in cases of extensive uterine hemorrhage, where life has been almost despaired of, and occasionally with good effect.]

Sect. III.—*Powers concerned in the Circulation.*

448. We have next to inquire 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.

* [See § 457.]

† [The organ will contract and relax after it has been removed from the body. In the case of a monstrous fœtus, its motion continued for some time after the auricles and ventricles were laid open; the organ roughly handled and thrown into a basin of cold water. In the rattlesnake, Dr. Harlan observed the heart, torn from the body, continue its contractions for ten or twelve hours; and Dr. J. K. Mitchell saw the heart of a sturgeon beat until the sides rustled from dryness, after it had been inflated and hung up to dry. Dunglison's Physiology, ii. 169.]

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

* [This is one view; but, perhaps, the great agency is the expansive force of the heart, which tends to project it forward. It must be admitted, however, with J. Müller, (Physiology, Baly's Translation, p. 175,) that great uncertainty still rests, as to whether the impulse is produced during the contraction or the dilatation of the ventricles.]

† [The existence of the suction power of the heart or derivation, although doubted by many, appears to us to be fully established. It has been observed in the living body; and the observer has been forcibly struck with the activity with which the diastole was effected. Dunglison, *Op. cit.* ii. 182.]

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. *Action 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 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 of the branches is always greater than that of the trunk out of which they arose, they constitute, when taken as a whole, a sys-

* [See section 450, note *]

tem 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 orders 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 shows 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 hemorrhage being, after some time, stopped by the 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.*

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 inferior 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

* See Milligan's Translation of Magendie, and Bostock's Physiology, p. 244. [Also, Dunglison, *Op. cit.* ii. 170.]

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 retrogade 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, how-

* [The capillaries have been supposed, by some, to possess a vital power of expansibility or turgescence; but this is probably owing to the afflux of blood to an irritated part. The erectile tissues become turgid, but not until excitation is induced, directly or indirectly, in the nerves of the parts, and this is probably the case with the capillary or intermediate vessels.]

ever, 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 bronchial arteries which have their origin from the aorta and the pulmonary artery. The phenomena which occur in asphyxia, or death from suffocation, prove that the pulmonary capillaries have a distinct action of their own in carrying on the circulation. The beautiful net-work formed by the inosculating branches of the pulmonary capillaries was first observed by Malpighi, and has received the name of *Rete mirabile Malpighi*. The pulmonary veins are wholly destitute of valves, not being exposed to variations of pressure from the actions of the surrounding muscles. They are furnished, like the venæ cavæ, with a reinforcement of muscular fibres, in the neighbourhood of the left auricle in which they terminate.

467. In one respect, the vessels of the pulmonary circulation differ from those of the systemic, namely, that the arteries are carrying dark-coloured blood, and the veins florid blood; the former being termed *venous*, from having the qualities of that which is returned by the veins of the system; the latter being termed *arterial*, because it has the qualities of that which circulates in the systemic arteries.

* [The same alternate contraction and dilatation has been observed in the venæ cavæ after the heart was removed from the body as in the heart itself. Dunglison's Physiology, 3d edit. ii. 181, and Dr. J. J. Allison, in Amer. Journ. of the Med. Sciences, Feb. 1839.

In addition to the powers already mentioned as concerned in the circulation, it has been maintained by many, that the blood possesses a power of automatic or self motion, either in consequence of its own vital properties, or of some electroid agency derived from the vessels in which it circulates; but granting that such may be the fact,—as in the embryo, in which blood in motion can be detected before vessels are *in esse*,—it can exert but little influence on the circulation.]

CHAPTER IX.

RESPIRATION.

468. The object of the function of respiration is the conversion of venous into arterial blood, by its exposure to the chemical influence of atmospheric air received into the lungs. This arterialization of the blood is a process more essential to the continuance of life than even the assimilation of aliment. The necessity for air is more imperious than the demand for food; and the interruption to its supply cannot be continued for a few minutes without being fatal to life. In comparing the extent to which this function is carried on in the different classes of animals, we shall find that in general the intensity of all the vital actions is nearly in proportion to the perfection in which the objects of this function are accomplished.

469. The consideration of the function of respiration, then, comprises an inquiry into the three following objects; first, the mechanical means by which the air is alternately admitted and discharged from the lungs; secondly, the provision made for bringing the blood to the lungs, and exposing it to the action of the air; and, lastly, the chemical changes which are produced on the blood by the action of the air in that organ. The means of fulfilling the second of these objects has already been sufficiently explained in the account we have just given of the circulation. It remains, therefore, that we consider the first and third branches of the inquiry.

Sect. I.—*Mechanism of Respiration.*

470. The anatomical structure of the organs of respiration, namely, the lungs with the air passages, including the trachea, bronchia, and air cells, together with the general conical cavity of the thorax, bounded by the sternum in front, the spine behind, and the ribs on every other side, while its lower side, or basis of the cone, is closed by the diaphragm, are subjects of anatomical inquiry.

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

472. Inspiration is accomplished by enlarging the capacity of

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

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

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

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

476. Having thus shown how the cavity of the thorax is dilated, let us next trace the effect of this expansion upon the lungs. It is obvious, that if when, by the descent of the diaphragm and elevation of the ribs, the cavity of the chest is enlarged, the

lungs were to remain in their original situation, an empty space would be left between them and the sides of the chest. But no vacuum can ever take place in the living body; the air already present in the air-cells of the lungs must, by its elasticity, expand these organs; and the external air, having access to them by means of the trachea, will rush in through that tube in order to restore the equilibrium. This, then, is *inspiration*.

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

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

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

480. The quantity of air taken into the lungs at each inspiration has been very variously estimated by different experimentalists. It differs, indeed, considerably in different persons, and in different states of the system; but from the concurrent testimony of the most accurate experimentalists, the average quantity appears to be about forty cubic inches. By a forcible expiration there may be expelled, in addition to this quantity, about a hundred and seventy inches more. But even after this

* [The number of expirations or inspirations, in a given time, varies. The average may be estimated at about 18 per minute.]

effort has been made, there still remain about a hundred and twenty cubic inches in the lungs; so that, adding all these quantities together, it will appear that the lungs are capable of containing, while in their most expanded state, after ordinary inspiration, about three hundred and thirty cubic inches of air. One-eighth of the whole contents of the lungs, therefore, is changed at each respiration. If we suppose that we respire twenty times each minute, the quantity of air respired during twenty-four hours will amount to six hundred and sixty-six cubic feet.*

Sect. II.—*Chemical Effects of Respiration.*

481. Before we inquire into the changes produced on the blood by its exposure to the air in the lungs, it will be proper to notice the changes which the air undergoes by this process. The air of the atmosphere is found by chemical analysis to consist of seventy-nine per cent. of nitrogen, twenty of oxygen, and one of carbonic acid.† When expired, the principal change which has taken place in it is the substitution of a certain quantity, which, on an average, is about seven and a half per cent. of carbonic acid gas for a nearly equal quantity of oxygen gas, and the addition of a quantity of aqueous vapour. Air which has passed through the lungs only once is incapable of supporting the combustion of a taper, which is accordingly extinguished the moment it is immersed in the air. The weight of the oxygen consumed in the air respired in the course of a day, will be found to amount to about two pounds and a quarter avoirdupois, or nearly 15,500 grains, occupying in its gaseous state a volume of 45,000 cubic inches, or a little more than twenty-six cubic feet. The quantity of carbonic acid expelled from the lungs is somewhat less than this; its total bulk in the twenty-four hours amounting on an average only to 40,000 cubic inches, or 23·2 cubic feet. Its total weight is 18,600 grains, or 2·86 pounds avoirdupois. The weight of the quantity of carbon contained in this amount of carbonic acid is 5,208 grains, or very nearly three quarters of a pound; and that of the quantity of oxygen is 13,392 grains. Hence the quantity of oxygen which disappears from the air respired, over and above that which enters into the composition of the carbonic acid gas, is 2,108 grains, and had occupied, while in a gaseous state, 5000 cubic inches. The only way in which we account for the disappearance of this oxygen is, by supposing it to have been absorbed by the blood.

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

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

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

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

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

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

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

487. It has been much disputed whether the combination

*We refer particularly to the 3d section of chap. vii. p. 336–362. [See, lso, on the whole of this subject, Dunglison's Physiology, 3d edit. ii. 99.]

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

488. It appears from a multitude of experiments, as well as from observations of the phenomena which take place in asphyxia, (that is, in the suspension of the vital actions from an interruption to respiration, as in hanging or drowning, or immersion in any gas not fitted for respiration,) that if the blood be not arterialized, and if, retaining its venous character, it be circulated in that state through the arteries of the system, it will act as a poison to the organs to which it is sent, destroying both the nervous and sensorial powers, and impairing the irritability of the muscles; and that this is the cause of the rapidity with which

* [The knowledge we have attained, of late years, on the transmission of gases through animal membranes, aids us materially in the solution of this interesting question. The rate of transmission of carbonic acid is greater than that of nitrogen. We can hence understand, that more oxygen than azote may pass through the coats of the pulmonary blood-vessels, and can comprehend the facility with which the carbonic acid, formed, as we conceive, in the course of the circulation, permeates the same vessels, and mixes, by diffusion, with the air in the lungs. Müller considers, that the air passes into the blood-vessels of the lungs, where he thinks it is decomposed, owing to the affinity of oxygen for the red particles of the blood; carbonic acid being formed, which is exhaled in the gaseous form, along with the greater part of the nitrogen.]

death ensues under these circumstances.* It thus appears that respiration requires to be constantly kept up in order to free the blood from the continual additions of carbon which are made to it by the various processes of assimilation and absorption. It is also a principal agent in perfecting the animalization of the chyle, which is added to the blood, and in converting it into fibrin.

Sect. III.—*Animal Temperature.*

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

490. It would appear, however, from some recent experiments of Dulong and Despretz,† that only three-fourths of the whole

* [This was the view of Bichat, but there are numerous difficulties in the way of its adoption. The experiments of Williams (Edinburg Med. and Surgical Journal, lxxvii. 1823,) and of Kay (Ibid. xxix. and the Physiology and Pathology, &c. of Asphyxia, Lond. 1834.) have shown, that the interruption is owing to the nonconversion of venous into arterial blood, and to the non-adaptation of the radicles of the pulmonary veins for anything but arterial blood; owing to which causes, stagnation of blood supervenes in the pulmonary radicles, and the passage of the blood from the right to the left side of the heart is prevented. Art. Asphyxia, in Amer. Cyclopedia of Practical Medicine and Surgery, Part X. Philadelphia, 1836; and Dr. W. P. Allison, in Edin. Med. and Surgical Journal, Jan. 1836.]

† See Müller's Physiology, by Baly, p. 83.

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

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CHAPTER X.

SECRETION.

491. Secretion is that function by which various substances are either separated from the blood or formed from it, in order to be applied to some useful purpose in the economy. We have noticed, in the course of the preceding inquiries, several instances of fluids prepared from the blood, and rendered subservient to different uses in the economy. The saliva, the gastric and pancreatic juices, the bile, and the mucus lubricating the surface of the alimentary canal, are all examples of secretions subservient to digestion and assimilation.

492. Such being the general purpose answered by this function, we have first to examine the apparatus provided for its perform-

* [The view of those who regard the evolution of caloric to take place in the system of nutrition over every part of the body appears to be most consistent with observed phenomena. It would seem, that caloric is disengaged in every part by a special action under the nervous influence, and the presence of arterial blood. In this way we can account for the increased heat met with in certain local affections, and for the different temperatures of different portions of the body,—the activity of the function varying according to the organs. It would not be easy to explain this difference without supposing that each part has the power of disengaging its own heat, and that the conduction of caloric from one part to another is not sufficiently ready to prevent the difference from being perceptible.]

† [See an elaborate chapter on this subject, in Dunglison's Physiology, 3d edit. ii. 238.]

ance; secondly, the nature of the effects obtained; and, thirdly, the peculiar powers which are concerned in their production.

Sect. I.—*Apparatus for Secretion.*

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

Sect. II.—*Glandular Apparatus.*

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

495. The above description of a gland does not include those organs, which, although resembling the proper glands in their general appearance, perform no distinct office of secretion, and are therefore unprovided with any excretory duct. This is the case with those bodies belonging to the absorbent system, which bear improperly the title of *lymphatic* or *conglobate glands*. The spleen, the renal capsules, the pineal gland, the thyroid gland, and the thymus, are, in like manner, improperly included in the

class of glands; for we have no evidence of their secreting any fluid, and indeed know nothing of their real functions.

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

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

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

499. There are three different ways in which the glandular tissue, or *parenchyma* of glands, as it has been generally termed, is disposed. In those glands which have been called *conglomerate*, a term which, as we have seen, has been used in contradistinction to the *conglobate*, or lymphatic glands, the organ is made up of distinct portions, connected together by a large quantity of loose cellular tissue, in the intervals of which the vessels and nerves are situated. These larger lobes are again made up of smaller lobes united in the same way. By successive divisions we obtain smaller and smaller component portions, till we arrive at last at very small bodies still visible to the naked eye, and

* [A more common division at the present day of the organs of secretion is into, 1. The simple *exhalant*, as met with in the serous membrane. 2. The *follicle*, in which there is a crypt without any distinct duct, as in the tonsils, mucous crypts of the mucous membranes, sebaceous crypts of the skin, &c.; and, 3. The *gland*, an organ of a solid and more complex organization, furnished with a distinct excretory duct, as in the kidney, liver, &c.]

which are called by anatomists *glandular acini*. These successive lobules are firmer in proportion as they are smaller, being surrounded and connected with the adjoining portions, by shorter and denser cellular substance. The second, third, and even the fourth subdivisions of these lobes may easily be followed with the scalpel. The acini themselves are of a roundish figure and pale colour, and readily distinguishable from other parts by the absence of fibres. The microscope shows them, however, to be still farther divisible into smaller portions, between which are seen plates of cellular substance, and if we attempt to pursue these subdivisions with successively greater magnifying powers, we do not find that we can reach their limit. The above description is particularly applicable to the salivary, lacrymal, and pancreatic glands.

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

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

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

503. The theory of Ruysch, who also bestowed extraordinary care in the examination of glandular structures, is founded on the supposed continuity of the extremities of the arteries with the commencements of the excretory duct. This theory is so far opposed to that of Malpighi, that it pre-supposes all the glands to consist merely of an assemblage of vessels and of cellular sub-

stance, without any membranous cavities interposed between the arteries and excretory ducts. The opportunities of dissection which Ruysch enjoyed, and his unrivalled skill in the arts of injecting the vessels, and tracing their modes of distribution, gave great weight to his opinions, which seemed to be immediate deductions from what he saw, and had established as matters of fact. Fluids could be made by injection to pass very readily from the blood-vessels into the excretory ducts, both in the kidneys and liver. After these organs have been accurately injected, they may be resolved, by subsequent maceration, into small clusters of blood-vessels; what Malpighi had represented as hollow acini, seemed to be in reality composed of a congeries of these minute vessels. This appeal to the evidence of the senses, and the admirable preparations which supported it, brought over almost all the anatomists of that time to the opinion of Ruysch; and Boerhaave himself, who had been a zealous defender of the doctrine of Malpighi, and written in support of it, was at length induced to adopt the views of Ruysch.

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

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

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

the excretory ducts of the testicle, which pursue a singularly tortuous course before they unite into the vas deferens on each side.

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

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

509. Amongst the latest theories relating to the structure of the organs of secretion, is that adopted by Müller,* who conceives that the glandular organization consists essentially of a modification of the excretory duct, the remote extremity of which, or that most distant from the discharging orifice, is

* De Glandularum Secernentium Structura, &c. Lipsiæ, 1830.

closed;* and the particles of which exhibit a fine net-work, or plexus of minute blood-vessels, whence the secretion is in the first place derived, and afterwards conveyed away by the duct, into the cavity of which it is poured. The duct itself may be variously divided and subdivided; and its trunk and ramifications may be variously contorted and convoluted in different cases, without, however, constituting any material difference in its essential structure.

Sect. III.—*Arrangement and Properties of the Secretions.*

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

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

* [This arrangement, so far as regards the biliary system, was well shown in a pathological case, which fell under the observation of Dr. Dunglison.[a] In consequence of cancerous matter obstructing the common choledoch duct, the whole excretory apparatus of the liver was enormously distended; the common duct was dilated to the size of the middle finger; at the point where the two branches that form the hepatic duct emerge from the gland, they were large enough to receive the tip of the middle finger, and as they were proportionately dilated to their radicles, in the intimate tissue of the liver, their termination in a blind extremity was clearly exhibited. These blind extremities were closely clustered together, and the ducts proceeding from them were seen to converge, and to terminate in the main trunk for the corresponding lobe.]

† Elementa Physiologiæ, v. b. 2.

‡ Système des Connaiss. Chym. ix. 159.

§ Physiologie, § 88. p. 235.

‖ Med. Lit. p. 109.

¶ Physiology, p. 480.

** [Other classifications have been founded on the nature of the secreting organ, or the functions of the secreted fluid. Bichat, Magendie, Lepelletier, and others, adopt the division into *exhaled*, *follicular*, and *glandular* secretions (See note to § 496). Boyer, Sabatier, and Adelon, divide them into

[a] Physiology, ii. 281.

1. *The Aqueous Secretions.*

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

513. With regard to the fluid of perspiration, it seems doubtful whether it contains any ingredients that are constantly present in it, or that are essential to its nature. It appears to differ, indeed, considerably in different individuals; and varies even in the same individual, according to the state of the system. Its analysis was attempted by Berthollet, and afterwards by Fourcroy; but the most complete examination into its properties is that of Thénard, who considers it to be essentially acid, and that acid to be the acetic. He found in it, also, an appreciable quantity of the muriates of soda and potass, with traces of the earthy phosphates and of oxide of iron, together with a very minute quantity of animal matter. Berzelius, on the other hand, who has examined this fluid still more recently, finds the free acid to be the lactic, accompanied with the lactate of soda. An elaborate analysis of the fluid of perspiration in a person labouring under disease, has also been made by Dr. Bostock.* The aqueous exhalations from the lungs appears to be so perfectly similar to that from the skin, as not to require further notice.

2. *The Albuminous Secretions.*

514. The albuminous class of secretions are numerous, and comprehend both solid and fluid substances. We have already seen that all membranous and fibrous textures, but especially the latter, are composed principally of a material corresponding in its chemical properties to coagulated albumen (see § 165). But there are many fluid secretions which contain large proportions of this ingredient in an uncoagulated, or liquid state; such as the secretion which exudes from serous membranes, and also occupies the interstices of the cellular texture, and which has been termed the *liquid of surfaces* (see § 135). This fluid also con-

recrementitial secretions, or such as are taken up by internal absorption, and re-enter the circulation; and into *excrementitial*, or such as are evacuated from the body, and constitute the excretions. Some have added a third division; the *recremento-excrementitial*, in which a part of the humour is absorbed, and the remainder ejected.]

* Medico-Chirurgical Transactions, xiv. 424.

tains, besides coagulable albumen, an animal matter similar to that which is found in the serosity of the blood, and a small quantity of the usual saline matters which enter into the composition of almost all animal products.

3. *Mucous Secretions.*

515. The mucous secretions are characterised by the presence of a substance which does not pre-exist in the blood, but which is prepared by a proper secretory or glandular action. The properties of this substance, or *mucus*, have been already noticed (§ 301). To the head of the mucous secretions, Dr. Bostock is inclined to refer also the saliva, the gastric and pancreatic juices, the tears, and the semen.

4. *The Gelatinous Secretions.*

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

5. *The Fibrinous Secretions.*

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

6. *The Oleaginous Secretions.*

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

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

blood, and from most of the animal fluids, by the base of its salts being potass instead of soda. A peculiar acid, called the *lactic*, is formed by the fermentation of milk, and even alcohol may be obtained during this process. By the action of nitric acid on the lactic acid, a new acid is produced, termed the *saccholactic* or *mucic acid*, which unites readily with alkaline or earthy bases, and forms a peculiar class of salts.

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

7. *The Resinous Secretions.*

521. The resinous secretions, which compose the seventh class, derive their specific characters from an ingredient which is soluble in alcohol, and is analogous to resin. Of these the most remarkable is the substance which constitutes the basis, or specific ingredient of bile. (See § 366.)

522. In connexion with the process of secretion which takes place in the liver, we have here to notice the remarkable peculiarity which occurs in the mode in which the blood is circulated through that organ. The liver is supplied, like the other organs, with arterial blood, by the hepatic arteries, which are branches from the aorta. But it likewise receives a still larger quantity of venous blood, which is distributed through its substance by a separate set of vessels derived from the venous system. The veins which collect the blood that has circulated in the usual manner through the abdominal viscera, unite together into a large trunk, termed the *vena portæ;* and this vein, on entering the liver, ramifies like an artery, and ultimately terminates in the branches of the hepatic veins, which transmit the blood in the ordinary course of circulation to the venæ cavæ.

523. This complex arrangement of the vessels which compose the hepatic system has lately been unravelled with singular felicity by Mr. Kiernan, who, in a paper contained in the *Philosophical Transactions*, gives an account of his valuable discoveries, of which we shall present the following abstract. The hepatic veins, together with the lobules which surround them, resemble in their arrangement the branches and leaves of a tree, the substance of the lobules being disposed around the minute branches of the veins like the parenchyma of a leaf around its fibres. The

* Annales de Chimie, lxxxi. p. 37.

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

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

525. Urea is another substance of a resinous nature, which may be ranked among the secretions, and which constitues the peculiar or specific ingredient in urine. It is remarkable for containing a very large proportion of nitrogen, which is by this channel discharged from the system. This substance has been

* [This is one view. Analogy, however, would suggest, that the bile, like every other secretion, is secreted from arterial blood; and sufficient function, it appears to us, remains for the vena porta, in being the agent for the admixture of the various heterogeneous fluids, which are received into the stomach, and pass by imbibition into the venous blood. Were there no capillary system through which the veins of the stomach and duodenum had to pass in their way towards the heart, these fluids would be but imperfectly mixed with the blood, and would reach the central organ of the circulation in such a state of concentration, as to interfere materially, perhaps fatally, with its functions. The capillary distribution of the vena porta in the liver must obviate this; and the same circumstances will aid us in accounting for induration of the liver in the spirit-drinker. Light is thrown on the subject of the secretion of the bile, by the pathological case referred to in the note to § 509.]

found in the blood of animals from whom the kidneys had been removed.

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

8. *The Saline Secretions.*

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

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

Sect. IV.—*Theory of Secretion.*

529. The nature of the powers and processes by which the products of secretion are prepared, is a subject involved in the greatest obscurity. There is scarcely any question in physiology, indeed, the investigation of which presents greater difficulties. At the very outset of the inquiry we are embarrassed by the very imperfect state in which the science of organized chemistry still

remains; and it follows as a necessary consequence, that the precise nature of the chemical changes effected during secretion cannot be properly understood. That the operations themselves are of a chemical nature, must be inferred from their results, consisting of substances which differ in most instances very considerably from the constituents of the blood, whence their elements are obtained. The blood is evidently the great reservoir of nutriment, and the fountain whence all the materials of the secretions are derived. In a few instances, as we have seen, the process of secretion appears to consist simply of the separation of some of the proximate principles of the blood. The operation is, in that case, more of a mechanical than of a chemical nature, and is analogous to mere transudation or filtration, subject, however, to a certain power of selection exercised by the secreting organ. In the greater number of instances, however, the product of secretion appears to be a new formation, differing entirely from any of the proximate principles contained in the blood, and resulting therefore from a new combination of its elements.

530. Scarcely any light has been thrown on this mysterious subject by the anatomical investigation of the organs of secretion. Their intimate structure is generally so minute and complicated, as to elude the severest scrutiny of the anatomist, even when assisted by the best optical instruments. What increases the difficulty of finding any clue to the labyrinth, is, that we often see parts having apparently very different structures giving rise to secretions which are nearly identical in their qualities; and conversely, we see substances having very different properties produced by organs very closely resembling each other in their structure.

531. Sometimes we find no distinct secretory apparatus, the whole process appearing to be conducted in the capillary vessels, out of the sides of which the product seems to transude. In other instances, the secreted fluid exudes from the smooth surface of a membrane, as is the case with the serous secretions in all the closed cavities of the body, such as those of the peritoneum, pleura, pericardium, and pia mater. The matter of perspiration finds its way through the skin and cuticle without any visible ducts or even pores, appearing simply to transude through the bibulous substance of the latter.

532. In other cases we find the secreting membrane furnished with minute processes, or *villi*, from the extended surface of which the secretion is produced. At other times, there are *follicles*, or *crypts*, as they are called, into which the secreted fluid is poured, and where it is collected previously to its discharge by its appropriate channels. These minute cavities are occasionally grouped together, and covered with a denser investing membrane common to the whole assemblage, constituting the

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

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

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

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

536. On the whole, as it appears impossible to refer the phenomena of secretion to any of the other known laws of matter, whether chemical or mechanical, it becomes us to acknowledge our ignorance of the real causes that produce them, and to ascribe them to the agency of those powers to which we have given the name of the *organic affinities;* by which term, however, we are far from wishing to imply that these affinities essentially differ in their kind from the ordinary chemical affinities which regulate the combinations of the same elements in unorganized bodies; but only that their operation is modified by the peculiarity of the circumstances in which they are placed. One of the principal causes of this peculiarity appears to be the influence of the *nervous power;* a power carefully to be distinguished from the sensorial powers hereafter to be considered, and wholly of a physical character

exercised by the nervous system, and controlling the actions of the blood-vessel, and more especially of the capillaries, and also those chemical changes which produce the evolution of animal heat, regulating in a particular manner the processes of secretion, and in some instances producing the contractions of the muscles in a way directed to some beneficial purpose, and in cases where the interference of the mind does not take place. But of this latter exercise of the nervous power we shall have to speak more at large when we come to treat of the involuntary motions.

CHAPTER XI.

ABSORPTION.

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

Sect. I.—*Structure of the Absorbent System.*

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

539. Absorbent vessels are met with in almost every part of the body. They may be regarded as analogous, or even supplementary in their office, to the veins; and, accordingly, their structure and mode of distribution are very similar to that por-

tion of the sanguiferous system. The absorbents arise from the various surfaces of the body, external as well as internal, by very minute branches; but whether these branches commence by open orifices, or imbibe the fluids they receive through the medium of their coats, we have hitherto no certain knowledge. The lesser branches of the lymphatics, like those of the veins, join together to form larger branches; while these again successively unite into larger and larger trunks, till they conduct their contents into the veins, into which they open. They communicate with one another freely in their course; and these connexions are frequently so numerous and intricate, as to form an extensive net-work, or plexus of lymphatic vessels. They are furnished with numerous valves, which, like those of the veins, are of a semilunar or parabolic form, disposed in pairs, and placed so as to prevent any retrograde motion of the contents of the vessels.

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

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

542. The continuity of the course of the absorbents is interrupted in a variety of places, by small rounded bodies, which have been called *lymphatic* or *conglobate* glands, and which are situate on the track both of the lacteals and lymphatics. They seem to have a similar relation to the absorbents which the ganglia have to the nerves; and they have, on that account, been sometimes called the *lymphatic ganglia.* They are of various sizes; the smaller being placed near the origin, and the larger on the more considerable trunks of these vessels. Those of greatest magnitude are situate at the root of the mesentery, in the course of the lacteals, and are denominated the *mesenteric glands.* These glands

are sometimes detached, and sometimes in groups or clusters, and commonly of an oblong rounded shape, and somewhat flattened, bearing some general resemblance to an almond. Their colour is a whitish red, of more or less intensity, according as they are situate more externally. Those of the mesentery are nearly white; those of the spleen brown: and those belonging to the lungs are of a very dark, or almost black hue. Each gland is enveloped in a thin, fibrous, and very vascular membrane, surrounded with dense cellular tissue, which sends down processes into the substance of the gland, dividing it into numerous compartments.

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

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

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

546. The nature of the lymph, or fluid contained in the lym-

phatic vessels, is but imperfectly known, in consequence of the difficulty of collecting it in sufficient quantity for examination. When viewed under the microscope it is seen to contain a number of colourless globules, much smaller and less numerous than the red particles of the blood.* Mr. Brande separated a small quantity of albumen from it by the application of voltaic electricity: he found that it also contained some muriate of soda. Berzelius states that the lactates are likewise present in it, derived, as he supposes, from the decomposed substance of different parts of the body, which is taken up by the absorbents. Reuss, Emmert, and Lassaigne obtained fibrin from the lymph of the horse, and Nasse and Müller† obtained some also from human lymph. When removed from the body, this fluid fibrin coagulates in less than ten minutes. Besides the above ingredients, Tiedemann and Gmelin state that the lymph contains salivary matter, osmazome, carbonates, sulphates, muriates, and acetates of soda and potass, with phosphate of potass.

Sect. II.—*Function of the Absorbents.*

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

* Müller's Elements of Physiology, by Baly, p. 258. † Ibid. p. 259.

earthy particles of the bone are themselves changed, or successively absorbed and deposited along with the madder.*

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

Sect. III.—*Venous Absorption.*

549. Soon after the discovery of the lymphatic absorbents, a keen controversy arose as to whether absorption was performed exclusively by these vessels: for it was contended by many that the veins assisted in this process, and occasionally acted as absorbing vessels. The arguments and reasonings of Hunter and Monro, founded on numerous experiments, appeared to have completely decided the question, and established the exclusive agency of the lymphatics in the performance of this function.

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

Of late years, however, the ancient opinion has been revived by Magendie and others, who seem to have satisfactorily proved that absorption is occasionally carried on by the veins themselves; and that many of the lesser lymphatic vessels terminate in the small veins, instead of proceeding to the thoracic duct. It has been ascertained, for instance, that where the great lymphatic trunks are tied in animals, substances injected into the stomach quickly find their way into the general mass of circulating blood, and may be detected in the urine. Poison, introduced into a portion of intestine, completely isolated from the rest of the body, with the exception only of the artery and the vein, produces its effect upon the system nearly in the same time as if the natural connexions had been preserved. The same result takes place when a limb is separated from the body, by dividing every part excepting the artery and the vein, and the poison is introduced under the skin. It proves fatal in the usual time, although the only medium through which its influence can be supposed to be transmitted is the circulating blood, which must therefore, it is concluded, have received the poison by venous absorption.

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

Sect. IV.—*Effects of Absorption.*

551. The absorbents have a powerful influence in modifying the fluid secretions, as well as the solid materials of the body. Their agency in assisting the arteries and capillaries which

* [A careful investigation of the whole of this interesting subject leads us to infer, that the chyliferous and lymphatic vessels form only chyle and lymph, refusing all other substances with the exception of saline matters, which enter probably by imbibition; that the veins admit every liquid which possesses the necessary degree of tenuity; and that whilst all the absorptions, which require the substances acted upon to be decomposed and transformed, are effected by the chyliferous and lymphatic vessels, those that are sufficiently thin, and demand no alteration, are accomplished directly through the coats of the veins by imbibition. See Dunglison's Physiology, 3d edit. ii. 81.]

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

Sect. V.—*Function of the Lymphatic Glands.*

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

CHAPTER XII.

EXCRETION.

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

SECT. I.—*Excretory Function of the Lungs.*

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

SECT. II.—*Excretory Function of the Skin.**

555. We have already given the results of the chemical analysis of the matter of perspiration, in our account of the aqueous secretions (§ 514). The chief ingredient is unquestionably water; and the average amount of water which escapes from the body through the channel of the skin, has been very variously estimated by different physiologists; for, indeed, it is hardly possible to arrive at any definite conclusion on this subject, from the great variations that occur even in the same individual at different times, especially according to the variable states of atmospheric temperature and humidity, and also according to differences in the activity of the circulation. The only satisfactory information we can hope to attain is, as to the aggregate loss by exhalation from the skin and

* [MM. Breschet and Roussel de Vauzème have described an apparatus in the skin for the secretion of the sweat, consisting of a glandular parenchyma, which secretes, and of ducts, which pour the secreted humour on the surface of the body. These ducts are said to be arranged spirally, and to open very obliquely under the scales of the epidermis. To this apparatus they apply the epithet "diapnogenous," and to the ducts the epithet "sudoriferous" or "hidrophorous."]

the lungs. The daily loss of weight from these two sources taken together is stated by Haller* to vary from thirty ounces in the colder climates of Europe, to sixty in the warmer, and is estimated by Lavoisier and Seguin† at forty-five ounces in the climate of Paris. But this quantity is, of course, from the causes already mentioned, liable to extreme variation. It has been estimated that, of the whole quantity thus exhaled from the skin and from the lungs, about two-thirds are derived from the former source, and one-third from the latter.

Sect. III.—*Excretory Function of the Kidneys.*

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

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

558. The daily quantity voided, as well as the sensible qualities of this secretion, is greatly modified by circumstances. The former has been estimated at an average as being about two pounds

* Elementa Physiologiæ, xii. 2, 11.
† Mémoires de l' Académie des Sciences, pour 1790, p. 601.
‡ Annals of Physiology, ii. 428.

avoirdupois.* Its mean specific gravity has been fixed at 1·03.† In a healthy state it generally exhibits acid properties, arising from the presence of uncombined phosphoric, lactic, uric, benzoic, and carbonic acids. These acids, together with the muriatic and fluoric acids, also exist in combination with several earthy and alkaline bases, comprising ammonia, lime, magnesia, potass, and soda; the principal compounds thus formed being the phosphates of lime and magnesia, ammonia and soda, the sulphates of potass and of soda, the lactate of ammonia, the muriate of soda, and the fluate of lime. There exist, besides, a large proportion of urea (composing nearly one-thirteenth of the whole quantity of urine, and about one-half of its solid ingredients), mucus, gelatin, albumen, and a small portion of the unacidified sulphur. The presence of a minute quantity of silica has also been detected by Berzelius, amounting to about the 220th part of the solid matter contained in the urine. The weight of the solid ingredients obtained by evaporation is one-fifteenth of the whole fluid, the rest being water. The several ingredients above mentioned may each be rendered evident by the application of appropriate tests.

559. Urea is a peculiar animal product, which is procured from urine evaporated to the consistence of a syrup and allowed to crystallize; after which alcohol is added, which dissolves the urea, whence that substance is obtained by evaporation. It then appears in the form of crystalline plates, and has a light yellow colour, a smell resembling garlic, and a strong acrid taste. It is chiefly characterised by the bulky flaky compound which it forms with nitric acid. By distillation it yields about two-thirds of its weight of carbonate of ammonia: and by spontaneous decomposition it is resolved into ammonia and acetic acid. It possesses the very remarkable property of changing the form of the crystals of common salt of muriate of soda, which, as is well known, usually crystallize in cubical crystals; but which, when mixed with a small quantity of urea, assume the form of octohedrons. What adds to the singularity of this effect is, that its operation is precisely the reverse on muriate of ammonia, or sal ammoniac; the ordinary form of the crystals of this salt are octohedrons, but when urea is present, they take the form of cubes. Urea contains a much larger proportion of nitrogen than

* [The estimates of observers vary; Boissier states the average daily quantity to be twenty-two ounces; Dr. Thomas Thomson fifty-three; and Lining from fifty-six to fifty-nine ounces. Perhaps the average in the text is rather too small.]

† [This is probably too high. Its specific gravity of course varies according to circumstances. Chossat estimated it from 1.001 to 1.038; Cruickshank from 1.005 to 1.033; Prout from 1.010 to 1.015, Gregory ,from 1.005 to 1.033; Elliotson, from 1.015 to 1.025; and Dr. Thomas Thomson found the average, during ten days, to be 1.013. Dunglison's Physiology, ii. 299.]

any other animal principle. This substance has been found in the blood, after its separation by the kidneys has been prevented, by the extirpation of those glands. Berzelius has advanced an opinion, that urea is furnished by the animal matter of the serosity of the blood, from the similarity of some of its properties, and also from the circumstance, that after the kidneys have been removed, the animal matter of the serosity is first increased in quantity, and afterwards assumes the character of urea. It appears probable that the principal function of the kidney is the separation from the blood of the excess of nitrogen which it may contain, and its excretion in the form of urea; thus performing an operation with respect to this element analogous to that of the lungs with regard to the superfluous carbon of the blood.*

Sect. IV.—*Excretory Function of the Liver.*

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

561. It is doubtful how far these two peculiar substances, urea and cholesterine, may be considered as pre-existing in the blood, or as formed by the organs which respectively secrete them. It has been ascertained by the experiments of Prévost and Dumas, that in animals in whom the secretion of urine is suppressed by the removal of the kidneys, urea may, after some time, be detected in the blood; and Dr. Bostock ascertained that a similar substance makes its appearance in the human blood, in cases where the secretion of urine had been much obstructed by disease of the kidneys. The secretion from the liver is not liable to so much variation in its amount, as that from the other excernent organs; it is, however, diminished during febrile excitement and inflammatory conditions of the circulation, and increased by moderate exercise, and by external warmth. Both the liver and the kidneys, accordingly, may be ranked among the compensating organs, or those which have their actions occasionally increased in order to supply deficiencies in the functions of others. The excretion of watery fluid from the skin and lungs

* See Bérard, Annales de Chémie et de Physique, v. 296.

is evidently made to alternate with that from the kidneys, each of these organs being capable of occasionally supplying the office of the others. The chemical properties of the urine are very much influenced by the condition of the digestive functions. But the necessity of the excretion of urea is apparent from the rapidly fatal consequences which ensue from its accumulation in the system, when the secretion from the kidneys is suppressed, and which would lead to the conclusion, that this substance, when present in sufficient quantity, speedily acts on the nervous system as a virulent poison.

CHAPTER XIII.

NUTRITION.

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

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

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

Sect. I.—*Ossification.*

565. The process of ossification is particularly interesting, from its exhibiting the operations of nature in the completion of an elaborate structure of such great importance in its mechanical relations to the system, as the osseous fabric. In the early periods of the fœtal state, we can but just trace the figures of some of the larger bones, which appear to be modelled in a soft gelatinous matter contained in a delicate membrane. This substance, as well as its membrane, acquires greater density, and the form assumes more the appearance of cartilage. In process of time, opaque white spots are perceived on different parts of its surface, which, when examined by the microscope, exhibit a fibrous appearance. These lines increase in number and extent; and, after a time, red points are seen dispersed throughout the future bone, in consequence of the enlargement of the vessels which now admit the red globules of the blood. Soon after this, we find the earthy matter deposited in great abundance, imparting hardness and rigidity to the structure. In the long bones of the extremities, the osseous substance forms at first a short hollow cylinder, as if it were deposited from the vessels of the investing membrane, or periosteum. In the flat bones of the cranium, ossification commences from a few central points, and spreads on all sides, the fibres taking a radiating direction. In proportion as the bony material extends, the cartilage is removed by the absorbent vessels, in order

* Elements of Physiology, translated by Baly, p. 359.

to make room for the extension of the bone. After a certain time, in the cylindrical bones, a cavity is formed in the middle, in consequence of the absorption of central portions of cartilages and of bone which had occupied that situation. These two opposite processes of absorption and deposition continue during the whole of the future growth of the bone, the interior parts being removed in proportion as fresh bony layers are added at the exterior surface. Thus, when the outer part of the bone is compact and hard, the interior is either formed into a complete cavity, or into the cancellated structure formerly described.

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

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

Sect. II.—*Dentition.*

568. No less curious and interesting is the process employed in the formation of the teeth. The rudiments of every tooth, when examined in the fœtus, consists of a gelatinous pulp, which

is extremely vascular, enclosed in a double investment of membrane. The outer membrane is soft and spongy, and is apparently destitute of vessels; while the inner one is firmer, and extremely vascular. The first depositions are those of bony matter, which take place on the exterior surface of the vascular pulp, and chiefly on the upper part, but within the membranous coverings already noticed. The shell of bone thus formed has the shape of the future tooth, and acquires thickness from successive deposits of bone in its inner surface, which are still made by the outer surface of the vascular pulp. When the ossification is sufficiently advanced, the pulp which has thus served as a mould for the tooth, divides itself into two or more parts, corresponding to the intended number of fangs, so that the ossific matter is now deposited in the form of as many tubes round these portions of the pulp, and growing in a direction towards the jaw, forces the tooth in the contrary direction; thus in the lower jaw the tooth rises, and in the upper jaw it descends. The enamel is deposited after the body of the tooth is considerably advanced in its formation. It is the product of a secretion from the inner surface of the outermost of the two membranes, which form the capsule of the tooth, and the materials deposited from it adhere strongly to the bony crown of the tooth which they surround. This secreting capsule has been called the *chorion* by Hérissant, who has given an accurate description of the process of dentition. Layer after layer of enamel is thus deposited, till the growth of that part of the tooth has been completed; then the chorion shrivels and is absorbed, and the tooth still continuing to grow at the root, pierces the gum, the resistance of which has been gradually diminishing by the absorption of its substance.

Sect. III.—*Nutrition of the Softer Textures.*

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

A question here presents itself, of great importance with relation to our knowledge of the nature of the vital powers, but of which the solution is attended with the greatest difficulties. It is this: how far, it may be asked, are the powers of secretion exerted in merely separating from the blood those organic products which are already contained as ingredients of that fluid, and how far do they also extend to the actual formation of new

proximate elements; and next, what reason is there to believe that the vital powers are capable of producing, from the materials presented to them, originally derived from the food, or the atmosphere, any quantity of those chemical substances, which, never having hitherto been decomposed, must, in the present state of the science, be regarded as elementary?

The consideration of the chemical analysis of the blood, and of the substances prepared from it will suffice to show that most, if not all the secretions, may very possibly be produced solely by the operation of ordinary chemical affinities. It has been found, indeed, that we are able, by certain chemical processes, to form from the blood, out of the body, substances similar to many of the secretions; and we are therefore warranted in the supposition that operations of the same kind are carried on by the secreting organs within the body. It is interestng, however, to trace the origin of many of the products of the secretion, from the ingredients contained in the blood itself. On this subject Müller* remarks, that some of the proximate elements of the tissues exist in part ready formed in the blood. The albumen which enters into the composition of the brain and glands, and of many other structures, in a more or less modified state, is contained in the blood; the fibrin of the muscles and muscular structures is the coagulable matter dissolved in the lymph and blood; the fatty matter, which contains no nitrogen, exists in a free state in the chyle; the azotised and phosphoretted fatty matter of the brain and nerves exists in the blood combined with the fibrin, albumen, and cruorin. The iron of the hair, pigmentum nigrum, and crystalline lens, is also contained in the blood; the silica and manganese of the hair, and the fluor and calcium of the bones and of the teeth, have not hitherto been detected in the blood, probably from their existing in it in but very small proportion. The matters here enumerated are attracted from the blood by particles of the organs analogous to themselves, partly in the state in which they afterwards exist in the organs; in other instances, their ultimate elements are newly combined in them, so as to form new proximate principles; for the opinion that all the component elements of the organs exist previously in the blood in their perfect state, cannot possibly be adopted; the components of most tissues in fact present, besides many modifications of fibrin, albumen, fat, and osmazome, other perfectly peculiar matters, such as the gelatin of the bones, tendons, and cartilages, nothing analogous to which is contained in the blood. The substance of the vascular tissue, and also the different glandular substances, cannot be referred to any of the simple components of the blood. Even the fibrin of muscle cannot be consi-

* Physiology, &c. p. 361.

dered as exactly identical with the fibrin of the liquor sanguinis. Between coagulated fibrin and coagulated albumen, there is scarcely any chemical difference, except in their action on peroxide of hydrogen; the only very important distinction between the fibrin dissolved in the blood and the albumen is, that the former coagulates as soon as it is withdrawn from the animal body, while the latter does not coagulate spontaneously, but requires a heat of from 158° to 167° Fahr., or some chemical agents, such as acids, concentrated solutions of fixed alkali, or metallic salts; and the fibrin of muscle in its chemical characters has scarcely a greater analogy with coagulated fibrin, than with coagulated albumen. In its vital properties the fibrin of muscle differs from both. The comparison of nervous substance, again, with the fatty matter containing nitrogen and phosphorus, is only justified by the present imperfect state of organic chemistry.

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

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

Sect. IV.—*General Phenomena of Nutrition.*

570. The instances we have above given of the processes

* Elementary System of Physiology, p. 518. † Ibid. p. 532.

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

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

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

* See the Article Age, in the Cyclopædia of Practical Medicine, vol. i. p. 34.

decrepitude. The fabric then betrays unequivocal symptoms of decay, the functions are imperfectly performed, the vigour of the circulation flags, the flame flickers in the socket, and is finally extinguished in death. Thus is the whole duration of life, from the first development of the germ to the period of its dissolution, occupied by a series of actions and reactions, perpetually varying, yet constantly tending to definite and salutary ends.

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

CHAPTER XIV.

THE SENSORIAL FUNCTIONS.

Sect. I.—*General Views.*

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

575. The functions of sensation, of voluntary motion, and of thought, are those which establish our mental connexions with the external world; which enable us to acquire a knowledge of the existence and properties of the material objects that surround us; which awaken in us the operations of our own minds; which

bring us in communication with other intellectual and sentient beings, and which enable us to react on matter, to exercise over it the dominion of the will, and to influence the condition of those other beings which like us have received the gift of life, of sensation, and of intellect.

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

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

578. The *nervous system* is the name given to that assemblage of organs which perform the important functions of which we are now speaking. The primary office of the fibres composing that system appears to be to transmit certain affections, which we may call *impressions*, from one part of that system to another;

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

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

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

First, the impressions made by external objects on the sentient extremities of the nerves distributed to the organs of sense, through the medium of those organs. *Secondly*, the transmission of the impressions so made to the sensorium, through the medium of the nerves of sensation. *Thirdly*, the physical changes made on the sensorium. *Fourthly*, the mental change consequent on this physical change in the sensorium; which mental change is termed *sensation;* and in experiencing which the mind is wholly passive. *Fifthly*, the recurrence, associations, and combinations of the physical changes originally induced in the sensorium, but probably

extended through various parts of the substance of the brain, and simultaneous with various mental operations, in exercising which the mind is partly passive and partly active. *Sixthly*, the mental act denominated *volition*, which is accompanied with consciousness, and in which the mind is wholly active. *Seventhly*, the corresponding change induced by volition on the sensorium, or origin of the nerves of voluntary motion. *Eighthly*, the transmission of the impression so received by the nerves of voluntary motion, to the muscles on which they are distributed. *Ninthly*, the contractions of these muscles, constituting voluntary motion. *Tenthly*, the influence of the nerves on the muscles of involuntary motion, and on various functions apparently depending on involuntary actions.*

Sect. II.—*Organization of the Nervous System.*

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

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

582. *The brain*, or general mass which fills the cavity of the skull, is composed of a number of parts of various shapes, the particular forms and dispositions of which belong properly to descrip-

* See Bridgewater Treatise on Animal and Vegetable Physiology, vol. ii. p. 535, note. [Amer. edit. ii. 376.]

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

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

584. The medullary substance has generally been considered as constituting the most perfect state of nervous matter, or that

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

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

* In his Anatomical and Physical Commentaries.
† On the Nervous System. ‡ De Structura Cerebri.
§ Philosophical Transactions for 1818, and 1821.

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

2. *The Nerves.*

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

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

* Sur la Structure Elémentaire. † See his Anatomie Générale.

588. Many anatomists have attempted the investigation of the minute structure of nervous fibrils by means of the microscope. De la Torre* perceived in them globules similar to those of which the matter of the brain is composed. Monro† and Fontana describe the nervous filaments as being connected by cellular substance, much in the same way as the muscular fibres, and arranged like them in fasciculi of various sizes. They represent the ultimate fibril as being twelve times greater than the muscular fibre, having a serpentine or tortuous form, and being composed of a cylindrical canal, containing a viscid pulpy matter, evidently different from the substance of the canal itself. Reil has pursued this investigation with still greater care and minuteness, and states that the ultimate filaments differ in thickness from that of a hair to the finest fibre of silk. Their arrangement into larger and larger fasciculi is analogous to what we observe in the structure of muscles, but with this difference, that the nervous fibres in their course along the nerve, frequently divide and subdivide, and are again variously united and conjoined, so as to produce an extensive connexion among all the parts of the same nerve. The membranous neurilema, besides giving support to each individual filament of nerve, and uniting them into fasciculi, furnishes also a general covering to the whole nerve ‡

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

3. *Ganglia.*

590. *Ganglia* are small rounded nodules, which are placed in different situations in the course of nerves, sometimes in the trunk of a single nerve, and sometimes where two nerves unite. They are most numerous on those nerves which are distributed to the viscera, and to the muscles of involuntary motion. Their appearance is very different from that of a mere dilatation of a nerve, being of a reddish-brown colour, having a minute fibrous texture, a firmer consistence, and a greater number of blood-vessels than ordinary nerves. The nerves which pass out from

* Philosophical Transactions for 1769. † On the Nervous System.

‡ [Ehrenberg and some other recent writers are of the old opinion, from their microscopic researches, that the nerves are tubular. See Dunglison's Physiology, 3d edit. i. 86; and Müller's Physiology, translated by Baly, part 3, Lond. 1838.

For an excellent epitome of the recent researches of Ehrenberg, Berres, Remak, Valentin, Emmert, Burdach and others—into the intimate structure and distribution of the nerves—see the British and Foreign Medical Review, No. XII. for Oct. 1838, p. 394, and No. XIV. for April, 1839, p. 394.]

a ganglion are generally of a larger size than those which entered into it, as if they had received, in their passage through it, an additional quantity of matter. It would appear, from numerous observations, that the filaments of the different nerves which join the ganglion proceed through it individually without interruption, but are, at the same time, involved and twisted together in a very complicated manner; the result being, that filaments from many different nerves are united in the formation of a new nerve; so that the parts to which the nerve is distributed receive a supply of filaments from many different sources, and are in very extensive communication with various parts of the brain, spinal cord, and indeed the whole nervous system.

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

CHAPTER XV.

THE EXTERNAL SENSES.

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

Sect. I.—*Touch.*

1. *Sensation of Pressure.*

593. Every part of the surface of the body is exposed to the contact of foreign bodies; and in most parts of the skin very

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

594. Professor Weber of Leipsig* has made a series of very interesting experiments on the relative sensibilities of the skin in different parts of the body, with reference more particularly to its power of conveying to the mind accurate perceptions of mechanical impressions made upon it. He found this power possessed in the highest degree by the tip of the tongue and ends of the fingers, the sensibility of which he estimated at eighty times greater than that of the skin of other parts of the body. He observed, also, that even the skin in different parts of the face, when touched with the points of a pair of compasses opened to a small distance, showed the greatest diversity in the power of conveying distinct perceptions of touch as to the object in contact being single or double, and as to the distance between the points, when they were perceived to be double.

2. *Sensations of Temperature.*

595. The same organs which, when pressed by an external body, convey the impression of resistance, communicate also

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

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

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

3. *Anomalous Sensations.*

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

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

4. *Sensation of Pain.*

598. Every sensation thus referred to the sense of touch, when it rises beyond a certain degree, is accompanied with the additional feeling of pain, which, if considerable, engrosses the whole attention, and effaces all marks of discrimination as to its origin.

Pain is generally readily referred to a particular part of the body, as being the origin, or as it is commonly called, the *seat* of pain, especially when the part is external. But in internal parts, this specific reference is often extremely vague and imperfect; and there frequently exists a general feeling of uneasiness, often more intolerable than any other, and to which it is impossible to assign any particular locality. It may also be observed, that in general the actual sensibility bears no relation to the capacity for feeling pain.

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

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

601. Pain often arises from internal causes; from pressure, or distension, or other mechanical or chemical irritation applied to nerves; or from some changes taking place in the texture of the nerve itself. It will appear evident, on a general review of the sensibility allotted to the different organs of the body, that each has received from nature that particular kind and degree which is most needed, and which best accords with the relative import-

ance of its functions, and the dangers to which, in the ordinary course of events, it is exposed.

5. *The Muscular Sense.*

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

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

Sect. II.—*Taste.*

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

605. If any of the senses could be considered as a finer sense of touch, it would be that of taste, by which we receive impressions of a peculiar kind from the sapid qualities of bodies in

contact with the upper surface of the tongue. This sense is manifestly intended to guide us in the choice of our food, and it is accordingly placed at the entrance of the alimentary canal.

1. *Organs of Taste.*

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

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

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

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

610. The *tongue* is a complex organ, principally consisting of a mass of muscular fibres, irregularly disposed, and crossing each other in a great variety of directions, and being also intermixed with a soft kind of fat. It is invested by a mucous membrane, being a continuation of that which lines the mouth generally, and which here presents large and numerous *papillæ.* These papillæ are distinguished by anatomists into three kinds, according to

their size, form, and situation. The first class of these, called *papillæ, maximæ, lenticulares*, or *capitatæ*, are by much the largest, have a lenticular form, with round heads and short stems. They are placed at the base of the tongue, in superficial fossulæ. They have been regarded as auxiliary salivary glands, and have each a perforation in the middle of their convex surface, for the excretion of mucus. The second class, or *papillæ mediæ*, or *semi-lenticulares*, are much smaller than the former, and are scattered over the upper surface of the tongue, at some distance from each other; their form is cylindric, while some are terminated by a round, but not dilated extremity. Others are more or less tuberculated at the summit. The third class, or *papillæ minimæ*, which have also been termed *conicæ*, or *villosæ*, are exceedingly numerous, but of very minute size. They cover almost the whole of the upper surface of the tongue, but are most abundant towards the tip, where the sense of taste is most acute.

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

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

its ducts open by several orifices arranged in a line near the gums, a little to the outside of the frænum.

2. *Functions of Taste.*

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

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

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

Some substances, such as peppermint, produce a pungent impression on the back of the fauces; and others, again, such as mezereon, excite in the same part a peculiar sense of irritation, which appears to proceed more from a generally acrimonious property, affecting particularly the nervous surfaces, than from any real sapidity; indeed, if the impressions made on the organs of smell be excluded from consideration, it will be found that the extent of the part of the tongue which really receives impressions of taste, is very limited. Mr. Mayo* states that salt, aloes, sugar, or acids, which excite the most acute sensation when applied to the tip or edge of the tongue, produce none at the fore or upper

* Outlines of Human Physiology.

part of the organ, or on the hard palate. But at the back of the tongue they again excite sensation enough to be distinguishable, and they are still more perfectly tasted on the middle of the soft palate and uvula. The participation of the soft palate in the sense of taste has been recently pointed out by MM. Guyot and Admyrauld, and has been carefully verified by Mr. Wheatstone and Mr. Mayo. These latter gentlemen did not find that one taste was perceived more distinctly than another, at any point of the tongue or soft palate.

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

Sect. III.—*Smell.*

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

1. *Organs of Smell.*

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

The external part, or *nose*, properly so called, consists principally of an upper bony portion commonly called the *bridge of the nose*, composed of the ossa nasi, supported by a vertical process from the ethmoid bone, together with the vomer, and an inferior cartilaginous portion, of which the middle prominence is called

* [Much dissidence has existed as to the precise nerve of taste. The view generally embraced is that of Sir Charles Bell; who considers the *ninth pair*, which arises from the anterior or motor tract of the spinal marrow, as the nerve of motion for the tongue; the *lingual branch of the fifth*, a nerve having a posterior root, as the nerve of taste, and the *glosso-pharyngeal*, as the nerve by which the tongue is associated with the pharynx in the function of deglutition. Recent researches, by Messrs. Panizza and Broughton, encourage the idea that the *hypoglossal*, or *ninth pair*, is the nerve of motion for the tongue; the *lingual branch*, or *the fifth pair*, the nerve of general sensibility, and the *glosso-pharyngeal*, the nerve of gustation. The matter is undecided, but the weight of evidence appears to be in favour of the first opinion. Dunglison's Physiology, 3d edit. i. 112.]

the *dorsum;* the rounded portions below are the *alæ nasi*, or wings; and the cartilage forming the partition between the nostrils is termed the *columna nasi.* These cartilages have a degree of elasticity which preserves the form of the organ.

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

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

2. *Function of Smell.*

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

620. It is essential to the exercise of this sense, that the membrane of the nostrils should be in a moist state; for when it hap-

pens to be dry from a deficiency of secretion, the extremities of the olfactory nerves are unfitted for the reception of the impression of odours. It is also necessary for smelling that the air charged with the odorous effluvia should impinge with some degree of force against the Schneiderian membrane.

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

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

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

Sect. IV.—*Hearing.*

1. *Acoustic Principles.*

623. The object of the sense of hearing is to convey to us certain impressions made on the nerves of the ear by the vibrations of the air; which vibrations are the result of some mechanical impulse communicated to it by the motion of a body at a distance. Other media besides air are also capable of transmitting sonorous vibrations to the organ of hearing; thus water is known to convey sounds to great distances; and solid bodies possess the same power in a degree proportioned to their molecular elasticity. If the body which is the source of sound be insulated from any such medium, its vibrations cannot be communicated, and no sound is heard. Thus if a bell be placed in the receiver of an air-pump, in proportion

* [The olfactory or first pair of nerves is distributed to this part of the nasal fossæ; and the fifth pair to the lower portion of the nasal fossæ. The integrity of both seems to be necessary for olfaction; although the first pair appears to be the proper nerve of smell;—the fifth pair being the nerve of general sensibility.]

as the air is exhausted the sound it produces when struck becomes more and more faint, till at length, when the rarefaction has been carried a certain length, it is quite inaudible. If the same bell be placed in a vessel of condensed air, the sound it gives out will be louder than in air of the ordinary density.

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

2. *Organ of Hearing.*

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

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

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

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

629. The membrane lining the meatus is continued along the osseous portion of the canal, which is closed by the *drum* of the ear, or *membrana tympani.* This is a firm, oval, and almost transparent membrane, fixed in an osseous groove at the bottom

of the meatus, across which it lies in an oblique position. It is slightly concave on the external side; and is capable of being stretched or relaxed by the action of particular muscles.

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

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

632. The principal cavity of the organ of hearing is situate still more internally, and from the intricacy of its winding sinuosities it has received the general name of *the labyrinth*. All its cavities and passages are lined with a very delicate periosteum, and filled with a watery fluid, and within them is suspended a pulpy membrane of a similar shape, on which are distributed various nervous filaments presently to be described. This saccular-shaped membrane is termed by Breschet the *membranous labyrinth*, in order to distinguish it from the osseous labyrinth, in which it is contained. It forms one continuous closed sac extend-

ing within the vestibule and canals, excepting those of the cochlea; and contains a fluid, perfectly similar to the perilymph, and termed by Blainville, *vitrine auditive*, which intervening between it and the osseous parietes of the labyrinth, surrounds it on all sides, and prevents its coming in contact with those bones.

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

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

634. It has been supposed that when the fluid in these cavities is in too great a quantity, the superfluous portion is carried off by two minute canals or *aqueducts*, discovered by *Cotunnius*. One of these opens into the bottom of the vestibule, and the other

into the cochlea, near the fenestra rotunda. They bear the names respectively of the *aquæductus vestibuli* and *aquæductus cochleæ*. They both pass through the os petrosum, and communicate with the cavity of the cranium.

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

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

3. *Function of Hearing.*

636. We thus see that the ear is an organ extremely complicated in its structure, evidently intended to convey the sonorous undulations of the air, after they are collected by the more external parts of the organ, to the branches of the auditory nerve, which are spread over the membranes lining the different cavities of the labyrinth, and the cretaceous bodies suspended within those membranes. We may therefore distinguish the several parts of the apparatus employed for this purpose, according as they are merely designed to collect the aerial undulations, and increase their intensity by concentrating them into a smaller space; or according as they contain the expanded nerves on which the impression is ultimately made. It appears that the medium by which this last effect is produced, is the

* The most accurate and complete description of the anatomy of the ear, is that given by Breschet, Sur les Organes de l'Ouie, which first appeared in the Annales des Sciences Naturelles, xxix. 129. [See, also, Breschet, Mémoir. de l'Académie de Médecin. tom. v.; and Recherches Anatomiques et Physiologiques sur l'Organe de l'Ouie, &c., Paris, 1836.] A compendious account is contained in Dr. Roget's Bridgewater Treatise, ii. 420. [Amer. edit. ii. 305. See, also, Dunglison's Physiology, 3d cit. i. 141.]

perilymph, or fluid filling the cavities of the labyrinth, and containing the exquisitely delicate membrane and cretaceous bodies which the extreme fibrils of the auditory nerve are expanded. This fluid is put in motion by the air in the cavity of the tympanum, and thrown into corresponding undulations.

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

638. The cavity of the tympanum is of a very singular form, extending into the mastoid process of the temporal bone, which has a cellular structure. A chain of minute bones, the ossicula auditus, extends, as we have seen, across the cavity, terminating at the fenestra ovalis, or aperture leading to the vestibule; while another aperture, the fenestra rotunda, also closed by membrane, leads to one of the spiral turns of the cochlea. Thus, the fluid in the labyrinth receives from the impulse made on these two membranes, which are situate in two different planes, a double undulation; and these two undulations, the one circulating along the semicircular canals, the other through the spiral turns of the cochlea, probably unite at some focal spot, like the meeting of two tidal waves, and increase the effect produced. These undulations must of course be variously modified, according to their frequency, and the order of their succession, and the impressions made on the nerve must undergo corresponding modifications. But we are so completely in the dark as to the real office of the several parts of this elaborately constructed organ, that it is exceedingly difficult to prosecute the physiology of this sense with such imperfect data. We are unable even to form a rational conjecture as to the offices of the delicate muscles provided for directing the movements of those ossicula, which are articulated

with such great nicety, and which seem calculated to alter the tension of the membrana tympani, and bring it into a state capable of vibrating in unison with the sonorous undulations that impinge upon it. What adds in no small degree to our embarrassment, is the knowledge we have acquired of the power of hearing being retained, without apparent diminution, when the greater part of this apparatus of bones, with their joints and muscles, and even the ear-drum itself, has been destroyed by accident or disease.* It should be observed, however, as Mr. Mayo† remarks, that the stapes is so strictly applied to the membrane of the fenestra ovalis, that the loss of this bone necessarily produces incurable deafness, by the attendant injury of the labyrinth.

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

Sect. V.—*Vision.*

640. The physiology of the eye is more interesting than that of any of the other organs of the senses; because, from the knowledge we possess of the laws of optics, to which it is so admi-

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

† Outlines of Human Physiology, 3d edition, p. 221, note.

‡ Medical Literature, p. 98; and Lectures, vol. i. p. 387.

rably adapted, we can understand the offices of its several parts, and the mode in which they concur in the production of the resulting effect. The study of the eye has been said to be the best cure for atheism; and it furnishes, indeed, the most striking and unequivocal proofs of the existence of design and intelligence in the construction of the animal fabric. These proofs have accordingly been always amongst those most prominently adduced by philosophers in support of the arguments of natural theology.

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

1. *Internal Parts of the Eye.*

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

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

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

645. The *choroid coat*, or *tunica choroides*, lies immediately within the sclerotica, and is composed of a congeries of blood-vessels connected together by membrane. It has been distinguished into two layers, the innermost of which has been termed

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

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

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

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

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

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

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

2. *External Parts of the Eye.*

652. The orbit is a conical cavity, in the fore part of which the globe of the eye is situate, the remaining space behind the

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

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

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

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

3. *Optical Principles.*

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

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

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

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

and also, that it is in the same plane with the incident ray, and the perpendicular line.*

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

4. *Formation of Images in the Eye.*

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

660. The same process taking place with regard to all the other pencils of rays proceeding respectively from the several points of the objects viewed, and each being collected into separate points in different parts of the retina which receives them, images of those objects will be delineated on that membrane; for it is evident that all the focal points will have, with respect to one another, the same relative positions as the points of the external objects from which each pencil of rays proceeds, when referred to the sphere of vision. The impression thus made on

* [Some interesting points of diagnosis are connected with the reflection which takes place from the humors of the eye. If a lighted candle be held before an eye, the pupil of which has been dilated, and in which there is no obscurity in the humors or their capsules, three distinct images of the flame are perceptible—two *upright* and one *inverted*; one of the former being reflected from the cornea, and the other from the anterior part of the crystalline lens; the last inverted image being caused by the reflection from the posterior concave surface of the crystalline. Mr. Sanson has proposed this "catoptric method" of examining the eye as a means of diagnosis between cataract and amaurosis; and Dr. Hays, who has employed it to some extent, regards it as a most valuable mode of investigating various conditions of the eye, which might not be readily understood without its agency. See Mr. Sanson, cited in Amer. Journal of the Med. Sciences, August, 1838, p. 494; and Dr. Hays, Ibid. May, 1839, p. 255.]

each respective point of the retina, is transmited to the sensorium, where it makes a distinct impression, and gives rise to the sensation of light and colour; and in conjunction with the experience gradually gathered from the sense of touch, imparts to us a knowledge of the existence, relative situation, form, magnitude, distance, and colour of the objects before as. This, then, is vision.

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

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

663. The humors of the eye, through which the light passes before arriving at the retina, have different degrees of density, and consequently have different degrees of refractive power. The first and greatest refraction of the rays takes place at the outer surface of the cornea; the next is at the inner surface, where the rays meet with the aqueous humor. Now this humor is rather less dense than the cornea, and consequently the rays already refracted, and rendered convergent by the cornea, have their convergence slightly diminished, when they traverse the aqueous humor. These, in fact, are converging towards points at some distance beyond the retina. The iris is interposed in the course of the rays while they are passing through the aqueous humor; the circular aperture of this membrane, the pupil, admitting only the more central portion of each pencil of rays. By intercepting the extreme rays, which, in consequence of a peculiarity in the law of spherical refraction, hereafter to be explained, would, if allowed to reach the retina, somewhat confuse the

image, greater clearness of that image is obtained, at the sacrifice, indeed, of a portion of brightness. It serves, accordingly, the same purpose with regard to the eye, which the circular ring, placed in the interior of a telescope, effects in contracting the aperture of the instrument; rendering the image more distinct, though less illuminated than it would otherwise be. But the iris has this great superiority over the circle in the telescope, inasmuch as it is capable by its contractile power of enlarging or diminishing the aperture of the pupil, as occasion requires. Thus, when the object viewed is but faintly illuminated, the pupil is enlarged, and admits more light, thus giving greater brightness to the picture; an advantage which more than compensates for the slight indistinctness of the fainter images composing that picture. When, on the contrary, an object is too bright, so that its image would produce too vivid an impression on the retina, the pupil immediately contracts, so as to reduce the quantity of light admitted into the interior of the eye, and to prevent any injurious effect upon the retina.

5. *Adjustments for the Correction of Aberration.*

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

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

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

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

668. The effort by which the eye changes its internal state, so as to accommodate its powers to the vision of near objects, after having viewed those more distant, is always attended with a contraction of the pupil; and the exclusion of the remoter rays, consequent upon this diminution of aperture, must partly contribute to the greater distinctness of the images, by excluding the rays near the circumference of each pencil. But it is certain that the refractive powers of the eye are also increased; and it is a question of considerable difficulty to determine the manner in which this increase is effected. Sir Everard Home* supposed that it was accomplished by the joint actions of the straight mus-

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

cles which surround the ball of the eye, and which, by compressing it all round its sides, might elongate its axis and increase the distance of the retina from the cornea, while they at the same time would make the cornea more convex, by drawing back its circumference, and thus rendering its central part more protuberant. This plausible theory is overturned by the fact discovered by Dr. Young,* that when the effect of any change in the curvature of the cornea is removed by placing the eye under water, the eye still retains its power of accommodation to the vision of objects at different distances, by changes which take place in its refractive powers.

669. The most probable supposition relative to this operation is, that the ciliary ligament has the power of contracting at the same time with the sphincter of the iris; a change which will be attended with the effect of bringing the lens somewhat forwards, and of increasing the convexity of its surfaces, while the convexity of the cornea will also be increased. Any cause which produces the contraction of the pupil, such as a bright light, enables the eye to adjust itself more rapidly to vision at a shorter distance; and, on the contrary, the suspension of this power of contraction of the circular fibres of the iris, occasioned by belladonna, is accompanied by the total but temporary loss of this power of adjustment. Those who, by frequent practice in experimenting on their own eyes, have acquired a considerable voluntary power of changing the refracting condition of the eye, even although there be no object before the field of vision requiring such change, when they exert this power, also contract the pupil, which by this means indirectly acquire the character of a voluntary muscle; although in other respects, and with other persons, it is strictly to be ranked in the class of the involuntary muscles. The writer of this treatise possesses this power, and has given an account of the circumstances attending its exertion in a letter to Mr. Travers.†

670. The same gradation of density in the successive laminæ of the crystalline lens, and the consequent successive refractions of the rays effected by the several humors of the eye, have also the effect of correcting the dispersion of light, arising from the

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

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

[It is very doubtful whether such power of adaptation really exists. Magendie's opinion (Précis Elémentaire, i. 72, 2de édit.) is decidedly in the negative; and the late Dr. Fletcher (Rudiments of Physiology, Part 3, p. 48, Edinb. 1837), after alluding to the various hypotheses on the subject, adds: "It appears absurd to attempt to explain a fact which has no real existence, since it has never been proved that the eye-ball has any capability of adapting itself to different distances, or that any such adaptation is required." See, on all this subject, Dunglison's Physiology, 3d edit. i. 219.]

difference in refrangibility of the differently coloured rays.* The eye, in addition to its other perfections, has the properties of an achromatic optical instrument, correcting the confusion of colour in the images it forms on the retina.

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

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

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

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

* [The iris has also a great agency in correcting this *aberration of refrangibility*, by preventing the rays of light from falling near the margins of the crystalline, and causing them to impinge upon the centre, where the opposite surfaces are nearly parallel, and consequently the dispersion of the rays is least.]

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

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

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

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

CHAPTER XVI.

PHYSIOLOGICAL LAWS OF SENSATION.

SECT. I.—*Phenomena of Sensation.*

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

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

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

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

2. *Modifications of Impressions.*

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

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

682. One of the consequences of the law of the permanence of sensations is, that impressions, which rapidly succeed one another in the same nerve, are not distinguishable as separate impressions, but produce a blending together, or coalescence into one sensation. Thus, if a circle painted in different parts of the circumference with different colours, be rapidly whirled round its centre, the colours are blended together into one tint; and if the different prismatic colours of the spectrum be properly adjusted as to their relative proportions, the effect of this coalescence of the sensations excited by the whole is that of a white colour. The thaumatrope may also be made to illustrate this principle; for the pictures on the two sides of the card appear, by the rapid revolution of the card, to coalesce into one.

683. The most remarkable and complete illustration of the same principle is afforded by musical sounds, which though they appear continuous, are, in fact, composed of separate impulses, repeated at very short, but regular intervals of time.

684. Another law of sensation, is, that when a nerve has received a strong impression, that nerve is proportionally weakened

* Philosophical Transactions for 1815.

† Journal of the Royal Institution, vol. i. p. 205. See also Dr. Roget's Bridgewater Treatise, vol. ii. p. 524. [Amer. edit. ii. 368.]

for a certain time after, and is less susceptible of a similar impression from the application of the same cause. The eye, after being dazzled by a strong light, has its sensibility diminished to the impressions of a weaker light. Different parts of the retina thus acquire different degrees of susceptibility of being affected by the same quantities of light. Thus, if the eyes be directed steadily to a bright object for a certain length of time, and be then transferred to a white sheet of paper, a dark spot, having the figure of that object, will be seen on the paper, in consequence of that portion of the retina, on which the luminous image had been impressed, being fatigued, and rendered less excitable than those parts of the retina which did not receive that image. The light from the paper which arrives at that part of the retina, which had received the impressions of the bright object, will produce less effect on that part, than the light of equal intensity from other parts of the paper does on the other parts of the retina. Those parts of the paper, which are situate so as to have their image on the exhausted part of the retina, appear darker, therefore, than the rest; and hence arises the appearance of a dark image. The experiment may be reversed by fixing the eyes attentively for some time on a dark object on a white ground, and then transferring it to some other part of the white ground; when immediately a brighter spot, corresponding in size and figure to the dark object, will be seen.

685. These appearances, which imitate those of real objects, have been called *ocular spectra*. The susceptibility of the retina to receive impressions of particular colours is also found to be affected in the same manner, when any one of them has been strongly impressed. Thus the spectrum of a coloured object, while it has the same dimensions and figures as the object, will at the same time have an opposite colour, when the eye is transferred to a white ground. It will have what is called the *complementary colour* to that of the object itself; that is, it will have that tint which results from the admixture of all the colours composing white light, when the latter colour is left out. Thus red and green, yellow and purple, blue and orange, being complementary colours respectively to each other, the ocular spectrum of a red object will be green, that of a green object red, and so with all the others.*

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

687. Illustrations of this law readily present themselves when we search for its application with regard to all the other senses.

* For more ample details on this subject, the reader may be referred to an Essay on Ocular Spectra, By Dr. Charles Darwin, published in the 76th volume of the Philosophical Transactions, and reprinted in Dr. Darwin's Zoonomia.

Sounds which are too loud produce temporary deafness, or at least impair for a time the sensibility of the ear to weaker sounds. Similar phenomena are observed as to odours and tastes, with reference to their appropriate senses. The sensibility of the skin to different temperatures varies considerably according to the previous impressions which have been made upon it. Thus the same body may appear either hot or cold, according to the previous temperature of the hand which is applied to it.

Sect. II.—*Conditions necessary for Sensation.*

688. The sensibility of the sentient extremities of nerves or their capability of receiving such impressions as lead to their appropriate sensations, is dependent on certain conditions of the organ. These conditions are principally the folllowing. *First*, it is necessary that the organ receive a proper supply of arterial blood by the vessels circulating through it, and particularly through that part on which the nerves are distributed. *Secondly*, it is required that the expansion of the nerve belonging to the organ should be exempt from excessive pressure. Compression of a nerve in any part of its course immediately puts a stop to all its functions; and consequently its power of receiving and conveying impressions is suspended as long as the pressure is continued. On the removal of the pressure, provided it has not been too violent, or too long continued, the nerve after a certain time, generally recovers its powers. *Thirdly*, a certain temperature is requisite for the maintenance of sensibility in the nerves. The benumbing effect of cold is well known, and extends generally to all the functions of the nervous system. It is very probable, that this operation of cold is referable to its retarding or arresting the circulation in the capillary vessels; and it might, therefore, perhaps, be included in the causes which influence the first of the conditions here enumerated. *Lastly*, the office of every nerve being to transmit impressions from one of their extremities to the other, it is necessary for the due performance of this function, that an uninterrupted continuity of their filaments should be preserved throughout their whole course. The complete division of a nerve in any part, necessarily prevents this transmission, and destroys the function of the nerve.

689. Irritations applied to the nerve in any part of its course, produce sensation, provided the communication of that part with the brain be uninterrupted by any of the causes above specified. Thus, if a nerve be tied or divided at any point, irritations applied below the ligature or division will produce no effect as to sensation; but when applied above that point, sensation immediately follows. What is here said applies more particularly to the nerves

distrbuted to various parts of the body, and especially to the integuments; the irritation of which nerves gives rise to a sense of pain. The nerves of the senses of sight, of hearing, of smell, and of taste, are so situate as hardly to admit of being the subjects of experiments which might decide the question as to what kinds of sensation would be excited by irritations directly applied to them; and whether these sensations would be similar to those they usually convey from impressions made upon their extremities. Analogy would undoubtedly be in favour of such similarity. Persons who have lost a limb by amputation, experience sensations not only of pain, but also of touch, and of muscular motion, exactly similar to those which they formerly derived from the parts of the limb which they have lost. These sensations arise from imitations taking place, either in the lower extremities of the nerves which have been divided, and which remain in the stump, or in the brain itself.

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

Sect. III.—*Theories of Sensation.*

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

this doctrine may be found in the popular language of medicine even in the present day, when the hypothesis from which it is derived is deservedly exploded as perfectly gratuitous, and devoid of any just foundation.

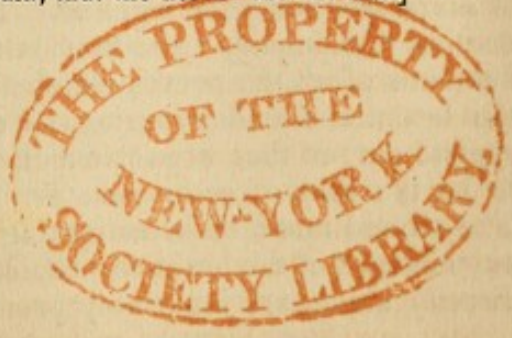
692. Another hypothesis invented to account for the propagation of impressions along the fibres of nerves, was that of their depending on vibrations or periodical oscillations of their particles, analogous to those of the strings of a harpsichord when producing musical notes. The great champion of this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

693. All these mechanical theories are overturned by the fact that no tubular structure can be discovered, on the minutest anatomical scrutiny, to exist in the filaments which compose the nerves;† nor can the slightest motion be detected in any of their parts, while they are actively transmitting the impressions of sensation.

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

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

† [We have already shown, (note to § 588,) that some distinguished observers of the present day still maintain, that the nerves are tubular.]



CHAPTER XVII.

FUNCTIONS OF THE SENSORIUM.

SECT. I.—*Locality of the Sensorium.*

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

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

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

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

Sect. II.—*Requisite Conditions of the Sensorium.*

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

* [Dunglison's Physiology, 3d edit. i. 308.]

tion slowly returns; but if any considerable injury has been inflicted on that part, the power of sensation is irrecoverably lost.

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

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

Sect. III.—*Laws of Recurrence, and of the Association of Impressions.*

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

to draw, is founded upon this essential difference in the order of sequence of the phenomena, that in the one the organic change precedes the mental change, and in the other succeeds to it.

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

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

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

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

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

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

Sect. IV.—*Volition and Voluntary Motion.*

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

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

711. Mr. Mayo* ascertained, that after any nerve which supplies a voluntary muscle is cut through, either in a living animal, or immediately after death, mechanical irritation of the part of the nerve disconnected with the brain, as for instance the pinching it with a forceps, causes a single sudden action of the muscle or muscles it supplies. On the other hand, a like effect cannot be produced by irritating mechanically the nerves distributed to those muscles over which the will has indisputably no influence. "It must be admitted, however," he remarks, "that this phenomenon is not exclusively confined to those muscles which are allowed on all hands to be voluntary; nor, indeed, is it shown in all the muscles which seem at first sight to be directly under the control of the will." But it is not easy, in various instances, to determine whether muscular actions are voluntary or not; while the point of distinction proposed by Mr. Mayo has the recommendation of being easily verifiable. Setting aside, therefore, in the first instance, the question of the influence of the will, let us be satisfied with observing what muscles act when a divided nerve that enters their substance is mechanically irritated, and what do not. We may afterwards trace the collateral differences of the two classes of muscles which are thus distinguished.

712. The parts which are susceptible of this mode of excitement, are the muscles of the trunk, head, and limbs, of the tongue, of the soft palate, of the larynx, of the pharynx, and œsophagus, and

* Outlines of Human Physiology, 3d edit. p. 39 to 42.

of the lower outlet of the pelvis. The opposite class comprehends the heart, the stomach, the small and great intestines, and the bladder.

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

Of the muscles which act when a nerve distributed through them is mechanically irritated, it may be remarked; 1. That they admit of being thrown into action by an effort of the will. 2. That with sufficient attention and resolution, their action may be refrained from. 3. That their action is attended with a conscious effort, and is guided by sensation. 4. That if divided, the separate parts retract instantaneously to a certain distance, and subsequently undergo no farther permanent shortening. 5. That when mechanically irritated, a single and momentary action of their fibres alone ensues. 6. That they remain relaxed, unless excited by special impressions, both in the living body, and before the loss of irritability after death. 7. That their action in the living body habitually results from an influence transmitted from the brain or spinal cord through the nerves.

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

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

716. Of the muscles which do not act on the mechanical irritation of any nerve distributed through them, it may be remarked, 1. That the will cannot instantaneously or directly produce action

in them. 2. That the resolution to abstain from their action is insufficient to repress it. 3. That their action is not attended with a conscious effort, and seldom has reference to sensation. 4. That if divided, the retraction which follows is in most instances slow and gradual. 5. That if they are mechanically irritated, not one, but a series of actions ensues. 6. That their natural state, in the absence of external impressions, is not continued relaxation. When the heart and bowels are removed from the body of an animal immediately after death, they continue for a time alternately to contract and to dilate. 7. That an impression transmitted through the nerves does not appear the usual stimulus to their action.

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

718. It is a remarkable circumstance that injuries or diseases occurring in the hemispheres either of the cerebrum or cerebellum produce paralysis, that is, destroy the power of voluntary motion, of the muscles situate on the opposite side of the body. This has been endeavoured to be explained by the alleged decussation or crossing of the nervous fibres of the lower part of the corpora pyramidalia on each side. But in order to account for all the

phenomena of this kind, we must suppose the decussation to take place between the fibres which compose the posterior and the anterior columns of the spinal cord.

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

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

721. It results from this discovery that the transmission of impressions in opposite directions, that is in the one case from the extremities to the brain, and in the other from the brain to the muscles, is effected by different nerves, or at least by different sets of nervous filaments, and that no filament is capable of transmitting impressions both ways indiscriminately, but always in one particular direction. These two kinds of filaments are, it is true, conjoined together into one nerve; but the object of this union is not community of function, but convenience of distribution, the two kinds of filaments still remaining distinct in their functions as they are likewise distinct in their origins. We know that all the nerves connected with the spinal cord have a double origin; that is, are composed of

two nerves, the one proceeding from the anterior, and the other from the posterior columns of the spinal cord. It is found that an injury done to the anterior roots of those nerves excites convulsions in the muscles which they supply, but does not appear to excite any sensation of pain in the animal on which the experiment is made; and the division of those nerves is followed by the immediate paralysis of those muscles, that is, by their incapability of being excited to contract by any voluntary efforts. On the contrary, the irritation of the posterior roots of the same nerve is attended with no contractions of muscles, but calls forth expressions of violent pain. The section of these nerves is followed by insensibility of the parts which those nerves supply, while the power of voluntary muscular contraction remains.

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

723. It is remarkable that the peculiar sensations conveyed by the optic, the olfactory, and the auditory nerves, have been found

by Magendie to be much impaired, or even entirely lost, by injuring the branches of the fifth pair of nerves, which also supplies the respective organs to which the above nerves appear to be particularly appropriated. The cause of this anomaly has not yet been satisfactorily explained.

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

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

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

727. Muscular contractions, then, may be distinguished, with reference to the nervous power which excites them into four classes; namely, 1. The purely voluntary motions; 2. The automatic motions; 3. The instinctive motions; 4. The involuntary motions. We have now fully considered the first of these classes, the purely voluntary motions, which may be defined to be those consequent on an effort of volition of which the mind is conscious, and which is accompanied by a distinct idea of the end intended

to be accomplished. No examples or illustrations are necessary of motions belonging to this class, as they are those with which we are most familiar. We pass on then to the other classes in the order in which we have enumerated them.

Sect. V.—*Automatic Motions.*

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

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

730. Since the actions of respiration are caused, in the first instance, by sensations, they must be dependent on the sentient nerves of the lungs, and especially on those that establish the most direct communication between them and the medulla oblongata, namely, the eighth pair of nerves. We find, accordingly, that after the sections of those nerves the actions of respiration are performed more slowly and less perfectly than when entire. They, nevertheless, continue, probably by means of the other communications which the lungs have with the brain, through

the branches of the great sympathetic proceeding from the spinal cord. When the part of the medulla oblongata from which these nerves originate is injured, all attempts at inspiration are arrested, because a final stop is put to the sensation which prompts them. The section of the phrenic nerves, or an injury to the spinal cord at any part above the origin of those nerves, paralyses all the respiratory movements of the chest, and thus occasions asphyxia and sudden death.

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

Sect. VI.—*Instinctive Motions.*

732. It is the essential character of motions which are strictly voluntary, that they are accompanied not only by a consciousness of their being performed, but also by a conviction that we may, or may not perform them, as we please; or, to speak more philosophically, according as there exists or not, a sufficient *motive* for their performance. But there are also, in the healthy state, many muscles, of the actions of which we are always conscious, and which, under ordinary circumstances, are perfectly obedient to the will, but whose actions we have, on other occasions, no direct power of controlling by any effort of the will. They occasionally seem even to be rebellious to its authority, and as if they were transferred to the agency of some other power. They are always

preceded by some sensation, as in the case of coughing, sneezing, and vomiting; or some internal affection of the mind, which has been termed *emotion*, as in the case of laughing and weeping; and they take place without any previous conception of the object they are calculated to attain, and therefore without the previous existence or operation of a motive. A very large proportion of the actions of brute animals appear to belong to this class; being characterized by the absence of that train of mental operations, which imply the agency of motives, and the previous knowledge of the consequences resulting from such actions; operations which are comprehended under the term *reason*, as contradistinguished from *instinct*, or blind and inexplicable impulse derived from other sources.

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

734. It is important, however, in the consideration of this subject, that we bear in mind, that these actions, although in themselves instinctive, are yet performed by muscles which are at other times voluntary, and whose nervous connexions with the sensorium, render it necessary for the performance of these ac-

tions, that the muscles themselves should communicate by their respective nerves with the sensorium. We may fairly presume, therefore, that such actions are immediately dependent on a change taking place in the sensorium, through the medium of which alone the impression, which is the occasion of the actions, becomes effective in their production.

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

Sect. VII.—*Involuntary Motions.*

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

737. Other cases are met with of a more complex and dubious character; namely, those in which muscles usually under the influence of the will, exhibit contractions in consequence of irritations applied, not to their own nerves, but to some more distant part, which receives other nerves. It is manifest that in these instances, the irritation of these latter nerves produces an impression which is propagated along their course towards the central parts of the nervous system, and is from thence again transmitted along the course of the nerves supplying the muscles,

in which they excite contractions of the same kind as those originating in volition. Yet these motions may take place wholly independently of the sensorium, and are found to occur, indeed, when all communication with the brain is intercepted. For if, a few seconds after an animal has been deprived of life, the spinal cord be divided in the middle of the neck, and also in the middle of the back, upon irritating either by a mechanical or chemical stimulus, or by the application of heat, any sensitive portion of the body connected by nerves with either of these isolated segments, the muscles of that portion of the limb, so connected with the spine, are thrown into action. If, for instance, the sole of the foot be pricked, the foot is suddenly retracted, with the same gesture as it would have been during life, and of course with the same apparent indication of suffering.* It is evident that here an irritation applied to a nerve, the usual office of which during life was to transmit impressions to the sensorium productive of sensations of pain, has now produced an impression which is conveyed to the spinal cord only; but which yet is followed by the contractions of those very same muscles, which, during life, obeyed the determinations of the will, and produced a motion of the limb directed to its removal from the cause of injury.

738. Phenomena of this description may be observed more readily, and are exhibited in a manner still more marked, according as the animal on which the experiment is made, occupies a lower place in the scale. Among vertebrated animals, the motions just described, and others of a similar character, indicative of sensation and volition, are most easily produced in reptiles, as in the turtle, the serpent, and the frog; in which we find that isolated portions of the spinal cord perform functions analogous to those of the brain, as far as relates to the receiving of impressions from a certain set of nervous filaments, and the transmitting of impressions to other nervous filaments, which proceed from the same part of the spinal cord, and are distributed to the muscles. These two sets of nerves correspond in their functions to the sensory and motor nerves by which sensorial phenomena are produced (see § 721). In articulated animals, whose spinal cord consists of a series of nodules of nervous matter, resembling ganglia, connected by two longitudinal cords, and severally giving origin to their respective bundles of nerves, which radiate on each side from these ganglia, as from so many centres, the capability of each ganglion to perform this double function is still more susceptible of demonstration; and each segment of a worm or an insect, for example, appears, in consequence, to enjoy a separate life, and exhibits the semblance of possessing

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

powers of sensation and voluntary motion independently of the rest.

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

are affected with involuntary movements. We are therefore fairly entitled to extend the analogy to other animals whose construction does not materially differ from that of man, however appearances may seem to countenance the hypothesis of the sensibility of the trunk, after its communication with the brain has been intercepted.

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

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

741. The power exercised in the instances we have described by the central parts of the nervous system, independently of all sensorial phenomena, is that power which we have already distinguished by the term *nervous power*, in contradistinction to the *sensorial power* exercised by the same system. (See § 96, 536, 537.) To Dr. Wilson Philip belongs the merit of having first clearly pointed out the distinction between these two orders of functions, and of having given them specific appellations. Dr. Marshall Hall has lately introduced a new term, that of *reflex function*, to designate the series of phenomena consisting of the transmission of impressions by certain nerves to the central parts of the nervous system, (which he limits to the spinal cord,) and

the consequent transmission of an action by the muscular nerves, which is followed by the contractions of muscles. To the whole system concerned in this function he gives the name of the *excito-motory system;* the nerves receiving the impressions he calls the *incident* nerves; and those conveying it to the muscles, the *reflex nerves.**

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

743. There yet exists another class of muscles, comprehending those which never, under any circumstances, become voluntary. To this class belong the heart and blood-vessels; the muscular fibres of the excretory ducts, and other parts of the organs of

* [Dr. Hall, whose views have given rise to much discussion lately, proposes to divide the nerves into 1, the cerebral, or the sentient and voluntary: 2, the true spinal or excito-motory, and 3, the ganglionic, or the nutrient and secretory. If the sentient and voluntary functions be destroyed by a blow upon the head, the sphincter muscles will still contract when irritated, because the irritation is conveyed to the spine, and the reflex action takes place in the muscle, so as to throw it into contraction. But if the spinal marrow be now destroyed, the sphincters remain entirely motionless, because the centre of the system is destroyed. Dr. Hall is of opinion, that a peculiar set of nerves constitute, with the true spinal marrow as their axis, the second subdivision of the nervous system, and as those of the first subdivision are distinguished into sentient and voluntary, these may be distinguished into the *excitor* and *motory*. To the *cerebral* system he assigns all diseases of sensation, perception, judgment, and volition; and therefore all painful, mental, and comatose, and some paralytic diseases. To the true *spinal* or *excito-motory* system belong all spasmodic and paralytic diseases. Lectures on the Nervous System by M. Hall, M.D., Amer. edit. Philad. 1836: see, also, Dunglison's Physiology, i. 73.]

† Quarterly Journal of Science, xiv. 93.

secretion; and the coats of the stomach and of the intestines. As the influence of the nervous system on those muscles is of a very peculiar kind, and as their motions are governed by different laws from those which regulate the voluntary muscles, it will be necessary to bestow on them a separate consideration.

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

745. It would appear, therefore, that although there is no essential difference between the real nature of the irritability of the involuntary, and that of the voluntary muscles, yet that each is influenced by different kinds of stimuli, and by stimuli applied through a different medium. Mechanical stimuli, such as punctures or partial divisions of the fibres of the muscles of voluntary motion, act on them only through the medium of their nerves; and if applied to the parts of the brain whence these nerves originate, will throw those muscles into the most violent spasmodic contractions. The heart, on the contrary, is but slightly disturbed in its

movements by the same kind of injury done to the brain or spinal cord, provided the injury be confined to a small portion of those organs. That important organ appears to be affected only in proportion to the extent of the parts that have suffered injury, and to the suddenness with which that injury has been inflicted; as is exemplified by wounding the brain rapidly in many directions. Chemical stimuli, on the contrary, applied to any part of the brain or spinal cord, produce considerable and immediate increase of the action of the heart: while the voluntary muscles continue all the while unaffected; and the animal betrays no sense of pain. Accordingly the heart, having no direct dependence on any part of the nervous system, may continue its action when the brain and spinal cord are destroyed, and even when it is itself removed from the body.* The nerves with which it is supplied, however, render it capable of being influenced through those causes, as, for example, by the passions, and by various poisons, which effect a considerable portion of the nervous system.

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

* [See § 450, note.]

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

Sect. VIII.—*Psychological Relations of the Sensorium.*

748. In treating of the functions of the nervous system which involve operations both of the body and of the mind, it is very difficult to draw the strict line of distinction between them, and avoid treating of subjects which properly belong to metaphysics. We have endeavoured, in the preceding account of the physiology of man, to confine ourselves strictly to the consideration of the corporeal changes which accompany the different mental affections, and to avoid, as much as possible, encroaching upon the province of the metaphysician. That certain physical changes take place in some portion or other of the cerebral mass in connexion with various mental changes, we have the clearest evidence: but of the nature of these physical changes we are wholly ignorant; nor does the present state of our information afford a shadow of hope that we shall ever gain any more precise knowledge of them. The mental changes, on the other hand, constitute a distinct and separate branch of science; to the knowledge of which we arrive by channels totally different from those which instruct us relatively to the former; namely, by consciousness, and by reflexion on the series of phenomena furnished to us by consciousness. These two subjects of study, the material and the immaterial, however numerous may be the subtle and inscrutable links that connect them, constitute two worlds, which in our conception must for ever remain totally distinct; nor is it even possible for us to conceive how any knowledge which we can obtain with relation to any physical changes in our corporeal frame, or any physiological laws that may regulate the succession of those changes, can in the smallest degree assist us in understanding the phenomena of intellect, and the affections of the soul.

749. The brain has been very justly regarded as the organ of the mind; that is the corporeal instrument invariably employed in the operations of the mind. This is a necessary corollary from the proposition that no mental operation can take place without the co-existence of some physical change in the brain. But a

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

second proposition, the converse of the former, has been advanced; namely, that the mental operations are the "functions of the brain." But this latter proposition would be true only on the supposition that the physical change in the brain, and the corresponding mental change of which we are conscious, are one and the same thing. Until this fundamental doctrine of materialism, namely, the identity of matter and mind, be proved, we cannot include under the functions of the brain, both the mental changes and the corporeal changes. The physiological office, or function of the brain is the production of certain corporeal changes, connected in some inexplicable manner with certain mental changes; which two classes of changes are in their nature, as far as we are capable of forming any conceptions of them, radically and essentially different from each other.

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

751. The affections of the mind are very various and complicated; a great multitude of ideas and associations are treasured up in it, and constitute a variety of powers, of faculties, of propensities, of instincts, and of passions. The conformation of the

brain, which is the organ of the mind, is also very complex, and appears to consist of an assemblage of different parts, constructed evidently with extreme refinement, and arranged with great care, and with very elaborate design. The idea naturally suggests itself, that these different portions recognised by the anatomist, may perhaps have some correspondence with the several faculties into which the phenomena of the mind have been analyzed by the metaphysician. This question has indeed been often started, and is quite distinct from that of the materiality or immateriality of the soul; for it is perfectly conceivable that if the immaterial soul acts by means of material organs, and receives impressions from those organs, its different operations may require different organs. But this subject, together with the theories to which it has given rise, are amply discussed in the Appendix on PHRENOLOGY.

SECT. IX.—*Sleep.*

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

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

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

755. A state very similar to that of natural somnambulism, is induced in some nervous constitutions, especially those of young females, by certain manipulations which produce a long-continued reiteration of impressions made on the senses, and which probably act through the medium of the mind. These have been ascribed to a special agency, termed *Animal Magnetism*, or *Mesmerism*.*

CHAPTER XVIII.

THE VOICE.

756. The function of the voice, and its modulation into articulated sounds, by which it is rendered subservient to speech, has been already pointed out as an important part of the animal

* [The whole history of animal magnetism exhibits that impressible persons may have hysterical or *hysteroid* irregularities of nervous distribution induced through the medium of the senses, especially through those of vision and touch; but there is no adequate evidence to show, that the effects can be induced without impressions being made on some organ of sense; or that there is any special agency of the kind that has been imagined. The *clairvoyance* or lucidity of vision of the magnetized is a delusion,—perhaps in all cases a deception.]

economy of a being designed, as man evidently is, to hold extensive communion with his fellow-creatures, and effect the rapid interchange of ideas and feelings, through the medium of the sense of hearing (§ 24).

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

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

these parts, and the application, in particular, of the tongue and of the lips to the palate and to the teeth.

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

760. The *epiglottis* is a cartilaginous lid, which has a pointed shape, resembling the leaf of an artichoke. It is fixed at its base to the os hyoides, to the thyroid cartilage, and to the root of the tongue; and hangs obliquely backwards over the opening of the glottis, which extends in a line from behind forwards, and is formed by the approximation of the vocal ligaments, or *chordæ vocales*. These ligaments, which consist of fibres endowed with a high degree of elasticity, are covered with the fine membrane which invests the whole of this delicate apparatus, and extends down the trachea into the lungs, and above to the posterior fauces. These are attached together in front to the thyroid cartilage, and behind to the arytenoid cartilages, where, in the relaxed condition of the organ, they are at some distance from each other, so as to leave a triangular opening for the passage of the air. The effort to speak, or to utter a vocal sound, commences with the action of certain muscles, more particularly the *crico-thyroidæi*, which stretch the vocal ligaments, and the *crico-arytænoidei laterales*, and the *arytænoidei transversi and obliqui*, which conspire to make the arytenoid cartilages approximate. By these combined actions, the vocal ligaments are brought near to each other, in parallel directions, so that the interval between them or *rima glottidis*, as it is called, is reduced to a mere narrow linear fissure.

761. When, therefore, the air is forcibly propelled from the lungs through the glottis, whilst the vocal chords are in this approximated position, different vocal sounds will be produced, ac-

cording to the degree of tension which is given to the chordæ vocales. The greater the tension of these ligaments, the more frequent will be their vibrations, and the higher the pitch of the note they produce. The loudness of the sound emitted is proportioned, not to the frequency of the vibrations, but to their extent, or the magnitude of the excursions made by the vocal chords in vibrating. The varied degrees of tension which can be imparted at will, and instantaneously, to the vibrating ligament of the larynx, by the finely regulated actions of their different muscles, constitute the chief source of superiority in the vocal organ to any instrument of human invention.

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

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

* Mémoires de l'Académie, pour 1700, p. 244; 1707, p. 66.
† Ibid. pour 1741, pp. 409, 416, 422.
‡ Lectures, p. 400, and Philosophical Transactions for 1800, 141.
§ De Corporis Humani Fabrica, vi. 93. ‖ Physiologie, i. 196.
¶ Cambridge Philosophical Transactions, iii. 231.
** Human Physiology, 3d edit. p. 350.

to all acoustic principles, be regulated solely by the tension of the chords.

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

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

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

"Such a vibrating apparatus as we have described the ligaments of the glottis to compose, is by itself capable, from the varying tension of those ligaments, of producing all those sounds of which we find the voice to be susceptible. But the intervention of a tube between the lungs and the larynx, must necessarily exercise an important influence on the voice, though it has never yet been taken into consideration. For, if we unite such an apparatus, or a free reed, which may serve as a substitute for it, with a tube (supposing it for the moment fixed to a determinate degree of pitch), it is found, that, unless the column of air in the tube is of

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

† Ibid. p. 252.

such a length as to be separately capable of producing the same number of vibrations, the sound cannot be obtained in its greatest force and purity, and that when the tube is half this length, the discordance between the tube and the reed is so great, as to prevent the production of the sound: between these limits the sound is intermediate in intensity and quality. This influence of the tube is by experiment found to be the same, whether the tube be placed after the reed, as in several wind instruments, or before it, as in the vocal organ. We will now suppose the tube to be unalterable in its length, and the reed necessarily to undergo all its varying modifications of pitch; the sounds, instead of being of even quality, will be irregular in intensity, and require different degrees of effort to produce them, whilst in some parts of the scale, they will be totally extinguished. All this may be prevented, and the utmost regularity obtained, by shortening the tube, in proportion as the vibrations of the reed increase in frequency. The trachea is obviously incapable of changing its length within limits sufficiently considerable to serve this purpose; but Savart's experiments have shown, that a tube of constant length may be made to produce a great range of sounds, by making it of elastic sides susceptible of variable tension. The analogy between such a tube and the trachea is perfect."

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

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

769. This branch of the subject has been ably investigated by Sir Charles Bell,* who has traced the influence which the changes produced by the muscular actions of the tongue and fauces, on the shape of the cavities of the mouth and pharynx, have on the resulting articulate sounds. He has examined the succession of actions which must be performed before a word can be uttered, and which he finds to consist in the compression of the thorax,

* Philosophical Transactions for 1832, p. 299.

as well as the adjustment of the glottis, the elevation and depression of the larynx, and the contraction of the pharynx.

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

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

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

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

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

775. Continuous consonants are pronounced when the vocalized air passes through some part of the organ, previously ren-

* Outlines of Human Physiology, p. 354.

dered very narrow. Explosive consonants are those which are produced by the interruption to the current of air occasioned by the entire closing of the passage, and its being allowed to burst out with some force by the sudden opening of the same passage.

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

777. We refrain from entering into any further details with regard to the position of the fauces, tongue, and lips, in the pronunciation of the different consonants, having already treated of this subject at some length.*

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

779. Some curious observations on the mechanism of the voice during singing have lately been given by Dr. Bennati,† who states, that the compass of his own voice extends to three octaves. He concludes from his inquiries, that it is not merely the muscles of the larynx which modulate the sounds, but those also of the os hyoides, and the other neighbouring parts. He mentions that, on removing part of the tonsils, the operation was followed by the raising of the voice half an octave, without altering its compass. Mr. Mayo supposes this effect to result from the cicatrix stretching the mucous membrane of the larynx, and thus giving increased tension to its inner surface.‡

* Art. Deaf and Dumb—Encyclopædia Britannica, 7th edit. See also Haller's Elementa de Physiologiæ, ix. 4; Dr. Young's Lectures, ii. 276; and the work of Mr. Mayo, already quoted.

† Annales des Sciences Naturelles, xxiii. 32.

‡ [See an elaborate article on the voice in its various manifestations, in Dunglison's Physiology, i. 395.]

CHAPTER XIX.

GENERATION.

SECT. I.—*General Views.*

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

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

782. But although the purpose is thus manifest, and the provisions for its execution thus effective and even exuberant, the immediate agency by which one living being is rendered capable of giving rise to another similar to itself, is enveloped in the most profound and most hopeless obscurity. No means within the compass of our understanding, no combination of the powers of matter which we can possibly conceive, no process of which the utmost stretch of human imagination can give us the most remote idea, has ever made the least approach towards the solution of this most inexplicable of all enigmas,—the production, nay, the apparent creation, of a living plant or animal by powers inherent

in the organization of a similar being. We must content ourselves, in studying this inscrutable mystery, to observe and generalize the phenomena, in silent astonishment at the marvellous manifestation of design and of power exhibited in this department of the wonderful works of the Almighty.

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

* See Bridgewater Treatise, on Animal and Vegetable Physiology, vol. ii. p. 591, note. [Amer. edit. ii. 415.]

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

785. *Gemmiparous generation* occurs when a new individual grows from the parent as a bud or sprout; at first exhibiting but little resemblance in shape or structure to the parent animal, but gradually assuming that form whilst still adhering to it, and being afterwards detached to commence an independent existence. Numerous examples occur of this mode of reproduction amongst the lower orders of zoophytes, such as animals belonging to the tribe of polypi, of which the hydra viridis, rendered celebrated by the researches of Trembley, may be taken as the type. Sometimes, as happens in the sponge, the actinia, and some of the lower orders of mollusca, the young are formed from small detached masses after they are separated from the body of the parent. These bodies, which are called *spores*, or *gemmules*, are generally of a rounded form and homogeneous structure; and the whole substance of which they are composed is converted during their development into the new animal. Hence they may be regarded as buds formed in the parent body, but detached from it before the evolution of the new animal begins. In some species these gemmules are formed in all parts of the body indiscriminately; but in most others there is a particular generative organ provided for their formation.

786. In by far the greater number of organized beings no reproduction takes place except by the co-operation of two kinds of generative organs; laying the foundation of the distinctions of sex, and constituting *sexual generation*. As characterising the female, there is, in the first place, an organ, termed the *ovary*, of which the office is to form the *ova*, or eggs. These are organized bodies of a determinate shape, within which we first find the earliest rudiments, or *germ*, of the future animal contained in a fluid, which is itself enclosed in a vesicle. But the ovum, or, more properly speaking, the *ovulum*, thus formed exclusively

by the female organs, never advances in its development beyond this stage, and can never give rise to a new animal, unless it receive a certain vivifying impression given to it by the contact of a peculiar fluid, denominated the *semen*, which has been prepared by a totally distinct apparatus, constituting the male organs.

787. The nature of the impression thus made by the seminal fluid on the ovulum, or immature ovum, and which constitutes its *fecundation*, and awakening in it a power of reproduction, which had before remained dormant, is wholly unknown; nor is it accompanied with any immediate alteration in its appearance or structure. None of the parts of the new animal can yet be discerned in the fluid contents of the ovulum, the great mass of which consists of a fluid holding in suspension granules of albuminous or oily matter; and a certain time must elapse, even in the most favourable circumstances, before the formative process exhibits its effects. The form of the egg is given by the external coverings, and there is in every egg a determinate part, at which the minute rudimental germ of the embryo is first visible. It is to this germ that the power of independent life and development appears more immediately to belong, the granular fluid serving only as nutriment laid up in store for the supply of materials for growth.

788. Thus the processes essential to sexual reproduction consist, first, in the formation of an ovulum by the female organs; second, in the secretion of the seminal fluid by the male apparatus; third, in the application of the seminal fluid to the ovulum so as to confer on it fecundity.

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

in by far the largest portion of the animal kingdom, including all the tribes of insects, nearly all the mollusca, and all warm-blooded vertebrated animals.

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

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

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

793. In *mammiferous generation*, on the other hand, the ovum, which is not perfected in the same degree as in the two former cases, remains within the female, and is attached, by the medium of a substance called *the placenta*, to the inner surface of an organ termed the *uterus*, where it receives nourishment from the maternal system, and where it remains until it is capable of independent life, and it is then brought forth. This retention during growth in the uterus is termed *utero-gestation*, and its subsequent exclusion is termed *parturition*. The young of mammalia after birth, although they cease to be organically connected with the mother, continue to derive from her a certain quantity of sustenance in the form of milk, which is a secretion from certain glands termed *mammæ*, the possession of which is the characteristic feature of this class of animals. An exception occurs in the

case of marsupiate animals, in whom the young leaves the uterus at a very early period of its formation, while it is yet of a very small size, and its organs are comparatively imperfectly formed. On being born it is introduced by the mother into a pouch, termed the *marsupium*, formed by a folding of the integuments of the lower part of the belly; and a short time after it has been deposited there, it is found attached by its mouth to one of the nipples of the mammæ, which are concealed within the marsupium, and there receives its nourishment until it has acquired sufficient size and strength to quit its habitation. *Monotrematous generation*, which is peculiar to the ornithorynchus and echidna, is not yet perfectly understood. The generative organs, and the ova within the ovaries, in these animals, partake in a great degree of the oviparous type; but they are also combined with the presence of mammary glands, which perform the office of lactation, as in the strictly viviparous class of animals.

794. The following table, which is nearly that given by Dr. Allen Thomson,* exhibits a synoptical view of the various forms of the reproductive process occurring in different classes of animals:—

Modes of Reproduction.

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

795. A wide range of inquiry is here opened to us, comprehending, if we were to include in its field the whole of the animal

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

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

Sect. II.—*Unimpregnated Ovum.*

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

797. It is well established, from these combined sources of information, that the essential part of the female system concerned in generation is the *ovary*, or *ovarium*, of which there is one, situate on each side, in the cavity of the pelvis. The ovaries are small capsular bodies, of an oblong, or oval, and somewhat flattened shape, which are enveloped in the fold of the peritoneum, forming the broad ligaments of the uterus. They are composed of a white and loose cellular texture, in which we discover several minute vesicles, or cysts, filled with a transparent fluid, and termed, from the name of De Graaf, who first observed them, the *Graafian vesicles*. Their number is generally from fifteen to twenty in each ovarium, and they vary in size, the largest being about one-third of an inch in its longest diameter. The

fluid which is contained in these vesicles is slightly viscid and albuminous, inclining to a yellow colour in the most turgid vesicles, containing numerous granules of an irregular shape, and a few globules of oil, but being otherwise pellucid.

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

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

801. The ovisac, being originally an independent structure, can be better studied in this state, than at a later period, when it has become the lining membrane of the Graafian vesicle or calyx. Thus, while the perfect Graafian vesicle of the mammal, and the perfect capsule of the bird, are obviously corresponding structures, there yet exists this difference, that there is a space,

filled with a large quantity of fluid in the former, not present in the latter; a difference which does not exist in the early stages of formation, when ovisacs in general appear in this respect to be essentially the same. The structure of the ovisac may be examined, in some mammalia, when it does not exceed in length the 600th, or even 1200th part of an inch; so that in the latter case, a cubic inch would contain 1,728,000,000.

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

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

804. After the ovulum has reached the periphery, its tunica granulosa may, at least in some animals, by contact with the membrane of the ovisac, become attenuated, or may even disappear at one side; which circumstance, together with the great transparency of this tunic, may have been the cause of Baer's assigning to it a discoid form. This approximation of the ovulum to the exterior surface of the ovisac, is doubtless for the purpose

of exposing it to the action of the fecundating seminal fluid, which reaches it while it is in this situation, and still in the ovary. The next step being now the application of this fluid, we are brought to the next stage of our inquiry, namely, into the series of apparatus and of functions provided for the preparation of the semen, its introduction into the female organs, and its transmission to the surface of the ovulum.

Sect. III.—*The Male System.*

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

806. The substance of the testicle is extremely vascular, and the ultimate branches of its spermatic arteries are collected into small bundles of fine convoluted vessels, separated from one another by *septulæ*, or membranous partitions. From these the *vasa seminifera*, or beginnings of the excretory ducts, take their rise, and gradually unite to form a smaller number of canals of larger diameter, but exceedingly tortuous in their course. On arriving at the surface and back part of the testicle, they suddenly become straight, assuming the name of the *vasa recta;* they, however, again subdivide, and their branches have very numerous communications with one another, composing the net-work of tubes called the *corpus highmorianum*, or the *rete testis*. From the rete testis arise the ducts denominated the *vasa efferentia*, which, after being again contorted into numerous convolutions, form the conical

bodies called *coni vasculosi;* these again, alternately join to form the epididymis, already mentioned, which consists of one slender tube, of enormous length, coiled upon itself into a small compass.* The epididymis at length emerges, in the form of a tube of larger diameter, which is the *vas deferens*, and which ascends along the spermatic cord towards the abdomen. On tracing these ducts into the pelvis, we find them passing up by a circuitous route through the spermatic passage, and on reaching the pelvis, again descending by the lower side of the bladder, to the under part of its cervix. Each duct is here connected with an oblong membranous bag, called the *vesicula seminalis*, which is a long blind sac, folded many times upon itself; its open extremity entering the vas deferens at an acute angle. These sacs are supposed to be receptacles for the retention and accumulation of semen, until the time when it is required to be expelled. But Hunter remarked that the fluid contained in them is somewhat different from that obtained from the seminal ducts of the testicle itself; and he therefore supposed that these vesicles secrete a peculiar fluid which may perhaps dilute and add to the bulk of the semen. He even contended that the proper office of these cavities is not that of reservoirs of semen; supporting his opinion by arguments derived from comparative anatomy, which furnishes many examples where no direct communication exists between them and the vas deferens, and others where these vesicles are entirely absent. Notwithstanding these analogies, the prevailing opinion is in favour of the vesiculæ seminales in man being reservoirs of the seminal secretion.

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

808. The urethra is a canal, lined by a mucous membrane, serving the double purpose of discharging the urine and the

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

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

809. These parts, namely, the glans and corpora cavernosa penis, and the corpus spongiosum urethræ, consist principally of large convoluted veins, which in the last named part are particularly dilated and branched, and are bound together and crossed in various directions by ligamentous bands and fibres. This arrangement, by obscuring the connexions which the veins have with one another, as well as their tortuous course, has led to the mistake that has so long prevailed among anatomists, of ascribing to these bodies a cellular structure. These bands appear to have been provided for the purpose of limiting the distention of the vessels, and adding to the rigidity occasioned by the accumulation of blood in the venous convolutions during erection. The means by which the blood is made to pass from the small arteries into these convoluted veins, is not clearly understood. Professor Müller* has lately discovered a remarkable set of minute dilated and ramified branches, which he terms *arteriæ helicinæ*, and which are appended to the terminal twigs of the arteries distributed on the sides and interspaces of the venous cavities in the

* Archiv. für Physiol. &c. 1835. pp. 27 and 220.

penis of man and several animals, and which he represents as projecting into the interior of the veins, and pouring their blood into them; a mechanism which must doubtless have some direct relation with the process of erection.* Dr. Houston† has described some muscles, under the name of *compressores venæ dorsalis penis*, to the contraction of which, and the consequent impediment to the return of the blood from the penis, he attributes the erection of that organ. It is more probable, however, that this effect is produced principally by an altered action of the blood-vessels themselves, and is analogous to the turgid state of the vessels which occurs in blushing, than is owing to any mechanical cause. The purpose served by the dilatation, elongation, and rigidity of the male organ, effected by this vascular action, is obviously that of enabling it to penetrate to a sufficient distance into the female organ during coition, for the conveyance of the semen to those parts of the latter whose office it is to carry it on to the ovulum which it is intended to fecundate. With this view, the secretions from the testes, vesiculæ seminales, prostate gland, and the glands of Cowper, are poured together into the bulb of the urethra, and thence expelled with force by the action of the muscles called the *ejaculatores seminis*.

810. The seminal fluid, which acts so important a part in the process of generation, has at all times attracted much attention. It is found to be considerably heavier than water, and to have a peculiar odour, which increases on keeping; to exhibit alkaline properties, and to give off ammonia when heated. From the analysis of Vauquelin, it appears that human semen contains six per cent. of animal mucus, three of phosphate of lime, and one of uncombined soda; the rest being water. The phosphate of lime is deposited in crystals when the fluid is at rest. But the most remarkable circumstance in its composition is, the constant presence of immense number of microscopic animalcules, the form, appearances, and size of which are different in almost every different animal; but in each species of the more perfect animals, the kind of animalcules, like that of the entozoa, is constant and determinate. Leewenhoek claims the merit of having first discovered them; but the priority of this discovery is assigned by Haller to Ludwig Hamm, who, when a student at Leyden, is said to have observed them in the year 1677. Another claimant of

* [The researches of Valentin (Müller's Archiv., and Lond. Med. Gaz. June 23, 1838, p. 543,) are not in accordance with those of Müller. The result of numerous examinations has convinced him, that the helicine arteries are not peculiar vessels, but merely minute arteries that have been divided or torn, and that the real distribution of the vessels of the corpora cavernosa follows, in every respect, the most simple laws.]

† Dublin Hospital Reports, vol. v.

the discovery is Hartsoeker,* but apparently on no good grounds. An account of the controversy that arose on this subject, is given by Dr. Bostock.† Doubts were at one time entertained of the fidelity of the representations of these singular beings given by Leewenhoek; but they have been wholly removed by the later researches of Spallanzani, and the still more recent inquiries of Prevost and Dumas. These animalcules have a definite figure, consisting of a flattish rounded head, from which proceeds a long tail, exhibiting constant undulatory movements. They are accordingly classed by naturalists under the title of *spermatozoa*, as a species of the genus *cercaria*, among the infusoria.‡

811. It would appear from the elaborate researches of Prevost and Dumas, that these spermatic animalcules are found, at one time or other, in the semen of almost all the animals in which they have been sought for; but at that period of their life, and in that season of the year only, when the animals in which they exist are fit for procreation. They are almost always present in the fluid secreted by the testicles, and very often in that of the vesiculæ seminales, into which they have doubtless been introduced along with the fluid derived from the testicles. Hence it has been concluded, that their presence is intimately connected with the power of propagation; and may be essential to that process. Wagner infers from his observations, that these animalcules are subject to remarkable changes of form at different periods, and that they even go through a regular gradation of development; and phenomena leading to the same conclusion have been observed by Dr. Allen Thomson.§

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

* Essai de Dioptrique, art. 88, p. 227.
† Elementary System of Physiology, p. 642, note.
‡ [See, on this subject, Dunglison's Physiology, 3d edit. ii. 330.]
§ Cyclopædia of Anatomy and Physiology, art. Generation, p. 460.

female from that of thirteen to sixteen; but in the hottest regions of the great continents, girls are said to arrive at puberty at ten, or even at nine years of age; and in the northernmost parts of Europe, not till that of from fifteen to eighteen. The arrival of this period is retarded by habits of active bodily exertion.

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

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

SECT. IV.—*The Female System.*

815. The female generative system of organs, having to perform the offices of receiving, conducting, and applying to the ovulum

* Cyclopædia, &c. p. 444.

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

816. The ovaria, of which we have already described the structure and offices, are connected with a hollow muscular organ, termed the *uterus*, *matrix*, or *womb*, by two ducts, called, from the name of the anatomist who first described them correctly, the *Fallopian tubes*. They commence by a trumpet-shaped mouth, opening from the abdominal cavity, and of which the edges are fringed or jagged with irregular filaments, or *fimbriæ*, as they are termed.* The mouth of the Fallopian tubes are endowed with the power, on certain occasions of venereal excitement, of attaching itself to the adjacent ovarium, and of firmly grasping it. The tubes, each of which is about five inches long, in their progress towards the uterus, soon contract in their diameter, and become exceedingly narrow at their termination in the upper and lateral corner of the triangular cavity of that organ. They are enclosed in the folds of the peritoneum which form the broad ligaments of the uterus.

817. The uterus itself is a compact, dense, membranous, and fleshy organ, provided with a copious supply of blood-vessels, lymphatics, and nerves. It has the shape of a flattened pear, and is situated in the pelvis, between the rectum and the urinary bladder. The outer surface of the uterus is covered with a reflected portion of the peritoneum, which, in passing from the sides of the uterus to the sides of the pelvis, forms the broad ligaments already mentioned, or the *Alæ Vespertilionis*, as they have been called. It is also provided with round ligaments, connecting it with the external parts of the pubes. The inner surface of the uterus is lined with a mucous membrane. The existence of muscular fibres in its substance has been called in question by many anatomists, and it is certainly difficult to demonstrate their presence; yet the extraordinary mechanical force which this organ exerts during parturition can scarcely be ascribed to any power but a muscular one.† The parts of the uterus are distinguished into the *fundus*, which is the broad end turned towards the abdomen, the body and the *cervix*, or narrow end. The channel of the cervix uteri, which proceeds from the lower angle of its triangular cavity, leads into the *vagina*, which is an elastic

* This part has also been termed the morsus diaboli.

† Dr. Bostock has given in his Physiology an enumeration of the authors who have written on both sides in this controversy, p. 648, note. [See, also, Dunglison, *Op. cit.* ii. 403.]

membranous canal, opening externally, and surrounding at its upper part the cervix uteri, which forms a protuberance in its cavity, called the *os uteri*, or *os tincæ*, from its supposed resemblance to the mouth of a tench.

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

818. The external parts are the *mons veneris*, which is formed by an accumulation of adipose substance on the upper part of the *symphysis pubis*. Below this are the *labia pudendi*, forming in their progress towards the anus, from which they are divided by the *perineum*, what was called by the French anatomists *fourchette*. Between the labia is the *fossa magna*, in the upper part of which is lodged the *clitoris*, a small, round, and spongy organ, which is analogous to the penis in its erectile structure, being composed of two *corpora cavernosa*, arising from the tuberosities of the os ischii, and terminating in an impervious glans, furnished with a prepuce. The *meatus urinarius*, or orifice of the urethra, which in the female is very short, opens immediately below the clitoris. From this part, on each side of the fossa, extends the *nymphæ*, or *labia minora*, which are membranous and spongy folds. The *vulva*, or orifice of the os externum, is in part closed by a transverse membrane, of a crescentic form, called the *hymen*, the remains of which, after it has been lacerated, compose the folds called *carunculæ myrtiformes*.

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

The secretion amounts, on an average, to six or eight ounces, and usually continues for about four or five days, beginning and leaving off gradually, and being most abundant towards the middle of the period. The discharge in general takes place slowly, or drop by drop.

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

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

Sect. V.—*Theories of Generation.*

822. Having thus stated the provisions which have been made by nature for the fecundation of the ovulum, by the concurrent offices of the two sexes, we may here examine various speculations and opinions which, from time to time, have been entertained relative to the nature of this marvellous and mysterious process; speculations which, although for the most part exceedingly hypothetical, and often completely visionary, have been

dignified with the appellation of *theories of generation.* This it is our intention to do very briefly, and to notice only the more important of these theories; for the total number of hypotheses which have been advanced on this subject is so great, that their mere enumeration might occupy many pages. Drelincourt, who lived in the latter part of the seventeenth century, collected from the writings of his predecessors as many as two hundred and sixty-two "groundless hypotheses" concerning generation; and "nothing is more certain," observes Blumenbach, "that Drelincourt's own theory formed the two hundred and sixty-third."

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

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

825. The Ovists, comprising some of the older philosophers, such as Pythagoras and Aristotle, maintained that the female parent affords all the materials necessary for the formation of the offspring, the office of the male being merely to awaken the dormant formative powers residing in the female products. Malpighi and Harvey asserted that the rudiments of the fœtus are derived

principally from the female ovum; an opinion which was also elaborately defended by Vallisneri.*

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

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

* Della Generazione, part 2.

828. We have already mentioned that Harvey and Malpighi ascribed the formation of the fœtus principally to the powers of the female. This opinion gave origin to the modern theory of *Epigenesis*, first clearly promulgated by Caspar Frederick Wolff,* who not only described a successive production of organs, of the previous formation of which there existed no trace; but showed also, that after parts are first formed, they undergo many important changes in their shape and structure, before arriving at their finished state. The more recent researches, aided by delicate microscopical observation, of Meckel, Pander, Baer, Rathké, Oken, Purkinje, and Valentin; Serres, Rolando, Dutrochet, Prévost and Dumas, Coste, and others, have demonstrated that the theory of Epigenesis, or superformation of parts, is much more consistent with the observed phenomena than that of evolution. The facts which have thus been brought to light are of peculiar interest with reference to the plans of nature, into which they give us a more extended insight, by exhibiting new and unexpected affinities between remote families and classes of animals; by showing that at one period the type of their formation is nearly the same, and by explaining the seeming caprice of nature in instances of monstrous and defective formation. But to attempt adducing the proofs and illustrations of these positions, would engage us into details requiring an extensive survey of the whole animal creation, to enter into which would occupy more space than is compatible with the limits of the present treatise. We must, therefore, content ourselves with referring, for more ample elucidation of this subject, to the Bridgewater Treatise *on Animal and Vegetable Physiology*.†

Sect. VI.—*Utero-Gestation.*

829. On the arrival of the ovum in the cavity of the uterus, to which we have traced it in a preceding chapter, the first object of nature is to effect its attachment to a portion of the inner surface of that organ. A provision for this purpose has already been made, even whilst the ovum was contained in the ovarium. A vesicle, first noticed and described by Dr. Barry, is formed around the ovum; the granules of the *tunica granulosa* become less densely aggregated together, and gradually pass into the state of fluid albumen; oil globules appearing for the first time to take their place on the surface of the ovum. This fluid he supposes to correspond to the yolk of the eggs of birds; and the

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

† Part iv. chap. ii. on Organic Development; and chap. iv. on Unity of Design. Vol. ii. pp. 599, 625. [Amer. edit. ii. 437.]

membranous vesicle above mentioned, in which it is enclosed, and which thus forms after impregnation, he considers as the rudimental chorion, by which the ovum is afterwards attached to the uterus.

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

831. Dr. Barry finds that the ova of the rabbit of five or six days, when in the uterus, are in bulk about eight thousand times that of the ovulum in the ovary, and have three concentric membranes; namely, first, an outer vesicle, (the villous chorion,) originating in the ovary; secondly, the primitive membrane of the yolk, distended so as to fill the chorion; and, thirdly, an inner vesicle, or membrane, which has been called the *blastoderma*, or germinal membrane, presenting in its substance a central spot, which is the germinal spot, or *embryo*. Dr. Allen Thomson has seen this spot very evident in the ova of a rabbit, on the sixth day after impregnation. It corresponds exactly with that part called the *cicatricula* in the egg of a bird, which there lies immediately on the surface of the yolk, imbedded in a disc of granules. In the centre of the cicatricula, a dark round spot is seen, termed the *colliquamentum*, which contains a minute vesicle, discovered by Purkinje, and which bears his name. This vesicle, which is

seen in the ovulum, afterwards bursts, and leaves in its place a thin and tender transparent membrane. In the centre of this transparent spot, may be perceived, seven or eight hours after the commencement of incubation, with the aid of a magnifying glass, a small dark line. This line, or *primitive trace*, as it has been termed, is swollen at one extremity, and is placed in the direction of the transverse axis of the egg. The rounded end is towards the left, when the small end of the egg is turned from us.

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

833. A change has already taken place in the uterus, preparatory to the reception of the ovum, and before its arrival in that cavity. An increased flow of blood is directed towards that organ. A substance, consisting of lymph, or organizable fibrin, exudes from its interior surface, furnishing it with a soft flaky lining, which, when the ovum is received, is reflected over that body, so as to give it a double covering. These two folds, the one being in contact with the uterus, and the other with the ovum, constitute the two layers of the *membrana decidua;* the former portion being termed the *decidua vera*, and the latter, the *decidua reflexa.** This membrane soon becomes organized, and highly vascular.† The vessels in the progress of growth, are in some parts much dilated, so as to form sinuses, which are ultimately intermingled, though by no means continuous, with the blood-vessels of the fœtus. These latter blood-vessels, consisting of the umbilical arteries and veins, of which the trunks are collected in the umbilical cord, have passed to the chorion, which by the end of the first, and during the second month of pregnancy, has acquired a villous external surface. At the end of this period, the branches of these vessels penetrate and ramify in these villi, which become thoroughly vascular; and this thickening and vascularity is concentrated on one side of the chorion, generally on that which is adjacent to the fundus of the uterus, forming the body called the *placenta.* This body is of a flattened oval shape,

* [The very existence of a decidua reflexa has been a matter of dispute; and by those who admit it, the mode of formation and arrangement has been a topic for discussion. In the different views of obstetrical Physiologists, the reader is referred to Velpeau's Embryologie, Paris, 1833, or to Dunglison's Physiology, 3d edit. ii. 308, in which they are all detailed.]

† [It is denied by many, that the decidua is supplied with vessels. Velpeau regards it as wholly inorganic; and denominates it, in consequence, "anhistous" membrane, from αν, primitive, and ιστος, texture, that is, membrane devoid of texture or organization.]

from six to eight inches in breadth, and from an inch to an inch and a quarter in thickness at the middle part, becoming thinner towards the edges. It occupies about a fourth part of the chorion, and at birth is a pound in weight. In ruminant quadrupeds, the substance corresponding to the human placenta, is confined to a number of circular and spongy elevations, varying in number from thirty to one hundred, which are termed *cotyledons*. The human placenta is evidently formed of a structure essentially the same, composed of many lobes consolidated by contact into one organ. It has very generally been supposed that the placenta is of a cellular structure, and that the arteries and veins of the uterus communicate with its cells; but the recent researches of Dr. Robert Lee,* renders it very doubtful if these inter-placental cells really exist.

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

Sect. VII.—*Parturition.*

835. The ordinary period of utero-gestation is forty weeks; on the expiration of which the uterus takes on itself a new kind of action; its contractility, which had lain dormant for so long a time, is now suddenly and powerfully excited. A mucous discharge takes place from the vagina, the external passage is relaxed, and slight pains are felt in the back and loins, which usher in the real pains of labour. These are occasioned by powerful contraction of the uterus, accompanied by a strong action of the diaphragm and abdominal muscles; and they are repeated at short intervals. Impelled by this pressure, the membranes of the fœtus project into the vagina, and dilate the os tincæ; on their bursting, the liquor amnii escapes, and at the next pain the pressure of the uterus falls directly on the fœtus. The head of the fœtus gradually descends, urged on by succeeding spasms, the occiput foremost, the long axis of the head being disposed obliquely across the lesser basin of the pelvis. The occiput, as the external parts yield, glides off the inclined surface of the ischium, presenting at the orifice of the vulva, and bringing at the same time the long diameter of the shoulders to correspond with the greatest breadth of the pelvis, and the head being

* Philosophical Transactions for 1832.

thus disengaged, the trunk follows. After a short time, fresh pains return, and the placenta and membranes being detached from the uterus, come away. In the majority of natural births, labour is completed in from four to six hours. The uterus then very slowly and insensibly contracts, so as to diminish the ample cavity which has been rendered vacant, and at the same time its volume is reduced by absorption. During the return of the uterus to its former state, a discharge, at first tinged with blood, and afterwards of a whitish colour, termed the *lochia*, ensues, which lasts for several days.*

Sect. VIII.—*Lactation.*

836. The function by which nourishment is prepared, of a nature suited to the early periods of infant life, belongs to the reproductive class. The fluid provided for this purpose is the *Milk*, of which we have already examined the chemical properties, and noticed the qualities which peculiarly fit it for the purpose it is intended to serve. The organs which prepare it are the *mammæ*, which are glands consisting of the union of a great number of lobes, intermixed with adipose substance, and remarkable for the whiteness and fineness of their texture. The numerous excretory tubes from these lobules unite in forming ducts, which open separately in the folds of the integuments of the nipple. A remarkable sympathy is observed between this gland and the uterus; for it often enlarges and becomes tender for a few days before each monthly period. It enlarges during the latter months of pregnancy, and the brown circle surrounding the nipple, or *areola*, as it is called, assumes a dark colour. The secretion of milk would naturally continue until the middle of the second year, if the child were retained at the breast as long as it was supplied. During the period of suckling, the menstrual discharge is not renewed, but pregnanacy may, however, again take place, before its recurrence.

Sect. IX.—*Fœtal Evolution.*

837. In judging of the changes which take place in the human embryo from the period when its evolution commences, we must be guided principally by those which, occurring in the development of that of the chick, furnish the best means of following the whole succession of phenomena. Commencing the inquiry, then, from the appearance of the primitive trace in the blastoderma, or cicatricula, already described (§ 831), we find this part gradually

* The above account of parturition is for the most part extracted from Mr. Mayo's Outlines of Human Physiology, as presenting a very clear and compendious account of the phenomena.

dilating in bulk, and occupying a situation between the two layers, namely, the outer and the inner, into which, towards the twelfth or fourteenth hour of incubation, this cicatricula has divided itself. The outer of these layers is called by Pander the *serous layer;* and it subsequently gives rise to the nervous, the muscular, the osseous, cartilaginous, and tegumentary systems of the body. The innermost, which is situate in contact with the yolk, is the *mucous layer*, whence are derived the alimentary canal, and the glandular and pulmonary systems. A third layer (the *vascular layer*), is afterwards formed in the interval between the two former, and is the origin of the sanguiferous system of the fœtus, including the heart and all the blood-vessels. The respiratory system is the product of the combined changes which this, together with the last mentioned layer, undergoes.

838. The series of phenomena which present themselves in following the succession of changes occurring during the formation of the vital organs, are highly curious, and afford the most splendid instances of that refined intelligence and that provident adjustment of a long series of means for the effectual accomplishment of future and far distant ends, which strike us with profound astonishment when we penetrate into the remoter regions of physiology, removed from ordinary observation. It would far exceed the limits within which we must confine ourselves in the present treatise, to give the detailed history of these organic changes. We must content ourselves, therefore, with a brief outline of the principal phenomena, and with referring to works professedly treating on this subject, for more copious information on this highly curious department of physiology.*

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

840. When the layers of the germinal membrane have so far expanded as to cover nearly one-third of the yolk, they no longer

* The reader will meet with much instruction on these subjects, in Dr. Allen Thomson's papers on Embryology in the Edinburgh New Philosophical Journal; in the Cyclopædia of Anatomy and Physiology, by Dr. Todd; and also in Mr. Mayo's Outlines of Human Physiology, chap. xv. sect. ii. We would also beg to refer to the summary contained in the Bridgewater Treatise on Animal and Vegetable Physiology, vol. ii. p. 599. [Amer. edit. ii. 408.] The greater part of the summary given in the present article is abridged from Mr. Mayo's work. [See, also, Velpeau's Embryologie ou Ovologie Humaine, Paris, 1833, and Dunglison's Physiology, ii. 421.]

retain their flat and uniform appearance, but begin to exhibit various folds, which afterwards become the different cavities of the body. Those of the mucous layer turn downwards, and whilst its remote expansion includes within it the yolk, as in a sac, the inner folds close inwards, and by the union of their margins form two tubular cavities, one at each end of the embryo, communicating in the middle with each other, and also, by a common opening, with the cavity of the yolk. This tube is the nascent alimentary canal.

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

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

bones is at first an homogeneous jelly, enclosed in a membrane, and exhibiting no divisions into joints. This jelly gradually becomes cartilaginous, the conversion taking place from the surface inwards. It is gradually replaced by ossific matter, which grows from the interior, resembling a process of crystallization. Ossification begins in the human embryo in the seventh week.

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

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

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

845. The glandular organs which communicate with the alimentary canal are formed by the extension of its mucous membrane in the form of tubular productions, shooting into small masses of matter lodged in its neighbourhood; the blind ends of the tubes being often dilated into spherical pouches. The gall

bladder is, in like manner, formed by the extension of a tube, which not being received into a mass of elementary matter, enlarges into a simple sac.

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

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

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

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

850. Every organ begins to be formed without either blood, or blood-vessels; the circulation in them being established solely for the purpose of subsequent growth and perfection. Even the heart is formed and shaped, and its texture has acquired some degree of consistency, and it displays an undulatory motion, before the blood has reached it. We have already described the formation of vessels and of blood in the vascular area; but the blood is at first motionless. It afterwards finds its way from thence by the omphalo-mesenteric veins to the heart, whence it is expelled along the aorta, and thence again carried into the vascular area; thus establishing a simple circulation. In a few days arterial

branches extend from the aorta, and venæ cavæ are formed, establishing the systematic circulation. Five pair of branchial vessels are formed from the aorta in the neck, the œsophagus being between the branches on each side, and there are also four openings in the neck of the embryo on each side. This single heart, branchial arches, and openings, are permanent parts of the structure in fishes. In the mammalia, these branchial clefts soon close; the heart becomes separated by the growth of partitions in each ventricle and auricle, into two separate cavities, and the artery is divided, in like manner, into an aorta and pulmonary artery. Some of the arches then disappear; others become permanent aortic, and others permanent pulmonary branches; and the fœtus is becoming prepared for pulmonary respiration.

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

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

CHAPTER XX.

PROGRESSIVE CHANGES IN THE ANIMAL ECONOMY.

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

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

854. Besides these changes, which, being consequent on the sudden exercise of the new function of respiration, are immediate, the whole organization rapidly conforms itself to the great alteration of the circumstances in which it is now placed. As the growth

of the fœtus had been progressively becoming more and more rapid in proportion as the term approached when it was to be ushered into the world; so, on the other hand, the growth of the body is greatest in the earliest periods of its extra-uterine life, and becomes more and more slow in proportion as it advances to the full dimensions it is destined to attain. The principal anatomical changes which follow birth, besides those already stated, are the gradual obliteration of the thymus gland, and of the renal capsules.

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

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

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

858. But, in the mean time, the process of consolidation begun from the earliest period of development, is still advancing, and is producing in the fluids both greater thickness, and a diminution of their total quantity. By the gradual conversion of their

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

* For more ample details on the subject of the changes which take place in the progress of age, see the article AGE in the Cyclopædia of Practical Medicine, and also the chapter on the Decline of the System in the Bridgewater Treatise on Animal and Vegetable Physiology, vol. ii. p. 619. [Amer. edit. ii. 433.]

CHAPTER XXI.

TEMPERAMENTS.

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

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

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

862. Most of the modern physiologists, however, following the

example of Cullen, have adopted the four temperaments of Hippocrates, which are characterized by the following peculiarities:

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

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

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

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

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

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

* [The whole doctrine of the temperaments is more specious perhaps than real. The very foundation, indeed, of the predominance of particular humors, systems, or apparatuses is wholly supposititious. It is obvious, too, that the physical characteristics described, can in no wise apply to the coloured races. There is doubtless a difference in the organization or constitution of different individuals, but this is but imperfectly explained by the doctrine in question. M. Georget, indeed (*Physiologie de Systeme nerveux*, Paris, 1821), regards it as a superstition connected with the humoral pathology, and he believes that the brain, alone amongst the organs, has the power, by reason of its predominance or superiority, to modify the whole economy.]

CHAPTER XXII.

VARIETIES OF THE HUMAN SPECIES.

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

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

871. The five varieties which Blumenbach has pointed out are designated by the terms *Caucasian*, *Mongolian*, *Ethiopian*, *American*, and *Malay*. He regards the Caucasian race as the primitive stock, or as the standard and type of the rest. It appears, indeed, to occupy an intermediate place between the Mongolian race, on the one side, and the Ethiopian on the other which latter races are the most widely different from each other. The American variety has been considered as intermediate between the Caucasian and the Mongolian; and the Malay race as intermediate between the Caucasian and the Ethiopian. The various intermixtures which have taken place between these

several races, in different parts of the world, render it very difficult, at the present day, to draw those precise lines of distinction which have probably, in remoter times, characterized the primitive races now enumerated. Thus, in Asia, we find considerable mixtures of the Caucasian with the Mongolian races; whilst in Africa, the Caucasian race has in various instances been blended with the Ethiopian. The following are the circumstances by which these several varieties are characterized :—

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

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

874. 3. The *Ethiopian* or *negro race* is marked by the lateral compression of the skull, which is elongated forwards; by the prominence of the cheek bones, the narrowness and projection of the jaws, and the recession of the chin. The forehead is low, and very slanting; the eyes prominent; the nose broad, thick, and flat; the lips, the upper one especially, thick; the upper front teeth are oblique; the hair black and woolly; the legs are

long and slender; the calf especially is small, and the knees are bent inwards; the arms are longer than in the other races.

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

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

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

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

878. The branch giving origin to the *Indian*, *Germanic*, and *Pelasgic* tribes was far more widely spread, and became subdivided at a much remoter period of antiquity. Amongst the four principal languages which prevailed among the nations composing these races, namely, the Sanscrit, the ancient Pelasgic, the Gothic or Teutonic, and the Sclavonic, we may trace the most multiplied affinities. The primitive Sanscrit is still preserved as the sacred language of the Hindus, and is the model on which all the existing languages of Hindustan have been formed. The Pelasgic is the primitive source of the Greek, of the Latin, and of many other tongues now extinct, but from which most of the present languages of the south of Europe have been derived. The Teutonic has given rise to the languages of the northern and

the western nations of Europe, such as the German, the Dutch, the English, the Danish, the Swedish, together with their various dialects. From the Sclavonic tongue are derived those of the north-east of Europe, namely, the Russ, Polish, the Bohemian, and the Vandean.

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

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

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

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

883. The *Mongolian* race inhabits the remoter regions of Asia, extending from the eastern parts of the continent, where the Tartar branch of the Caucasian race terminates, to the Eastern Ocean. The different branches of this Mongolian race, such as

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

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

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

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

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

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

888. In opposition to the doctrine of the unity of species in all human races, it has been contended by Rudolphi, Virey, Des-

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

moulins, Bory St. Vincent, and others, in the most positive manner, that these races were originally different. The arguments on each side of the question are fully discussed in the work of Dr. Prichard referred to.

CHAPTER XXIII.

COMPARATIVE PHYSIOLOGY.

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

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

Sect. I.—*Comparative Physiology of Mammalia.*

1. *Peculiarities in the Human Conformation.*

891. Since man, in his zoological relations, must be comprehended in the class mammalia, it is evident that the general characters of this class must consist of those possessed by the human species in common with quadrupeds, and even with the other families of mammalia still farther removed from man in their external conformation. Whilst the points of resemblance are so numerous, the easiest mode of instituting a comparison

between them will evidently be by pointing out, not the features which they possess in common, but those in which they differ. We shall begin then with an account of the peculiarities which distinguish the human structure from that of the lower animals, and more especially from that of the quadrumanous tribes, which approach the nearest to him in their conformation.

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

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

894. In every particular connected with the mechanism of the fabric, man enjoys the most decided advantage over those mammalia which are most nearly allied to him in their physical conformation. Man is the only species amongst the mammalia whose body can maintain itself for any length of time in an erect position, and in whom the office of supporting the trunk is entrusted solely to the lower extremities. We find that every part of the osseous fabric, as well as the disposition of the principal organs of sense, are in obvious conformity with this design. The lower limbs, being the great instruments of support and progres-

sion, are larger, and of greater strength, compared with the body, than in most quadrupeds, the only exceptions being met with among those which are formed expressly for leaping, as the hare, the jerboa, and the kangaroo. In the monkey tribes the lower limbs are comparatively much weaker than in man; and in other quadrupeds the disproportion is still greater, the thigh bone being short, and almost concealed by the muscles which connect it with the trunk of the body, whilst the rest of the limb is very slender, and not covered by any considerable mass of muscle. In man the articular surfaces of the knee-joint are very broad, and admit of greater extent of motion than in quadrupeds, and the two portions of the limb can be brought into the same straight line, thus constituting firm perpendicular columns of support for the body. The long neck of the thigh bone allows of more complete rotation of the limb at the hip-joint; and this, together with the greater breadth of the pelvis, which affords an ample basis for sustaining the trunk, are circumstances peculiar to the human frame. The heel in man forms a greater projection than in other animals; and by its being extended so as to touch the ground, it forms, as we have seen, one of the points of support, by which, in conjunction with the toes, a much larger base is comprehended. The muscles which raise the heel, and which compose the calf of the leg, are of greater size and strength than in monkeys, besides acting with the mechanical advantage arising from the long lever which the heel affords for the insertion of their united tendons; and by the direction of the foot, which forms a right angle with the leg.

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

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

897. The same design may be traced in the position of the eyes, the mouth, and the face in general; and is so obvious as to

have ebeen noticed by Ovid, while describing the formation of man, in the following celebrated lines:

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

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

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

900. The great perfection of the organs which modulate the voice and produce so great a variety of articulate sounds, is another striking instance of the high destination to which the human structure has been adapted. In those tribes of monkeys which come nearest to the human conformation, the power of

uttering articulate sounds is prevented by the interposition of two sacks connected with the larynx, which receive part of the air when the animal uses any effort to expel it from the lungs.

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

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

903. The human brain is not only larger in its relative proportion to the body than in any other of the mammalia, but its absolute size is greater, if we except only that of the elephant, and of the whale. With these few exceptions, all the larger animals with which we are more commonly acquainted, have brains absolutely, and even considerably smaller than that of man. Besides the prodigious expansion of the hemispheres, we may remark in the human brain a more elaborate structure, and a more complete development of all its minuter parts. There is no part of the

brain found in any animal, which does not exist also in man; whilst several of those which are found in man are either extremely small, or altogether absent in the brains of the lower animals. Sömmerring has enumerated no less than fifteen visible and material anatomical differences between the human brain and that of the ape. The proportion of medullary to cortical substance is greater in the human brain than in that of other animals.

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

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

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

907. The projection of the bones of the face, which tends to

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

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

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

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

910. The bones of quadrupeds appear, as Blumenbach observes, to possess a less fine and delicate texture than those of man.

* [A striking proof, that the facial angle cannot be regarded as a measure of the intellect is the fact, that in children it reaches as high as 90°; several degrees higher than in the adult.]

† [Blumenbach's method, by what he called the *norma verticalis*, consisted in selecting two bones, the frontal from those of the cranium, and the superior maxillary from those of the face, and comparing them with each other, by regarding them vertically, placing the great convexity of the cranium directly before him, and marking the relative projections of the maxillary bone beyond the arch of the forehead. But this method does not indicate the depth of the maxillary bone, or of the os frontis, or their comparative areas. The view thus obtained is, therefore, partial.]

Their fibres are more easily loosened by maceration, and are of a coarser grain; this is more particularly observable in the jaw-bones and the ribs.

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

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

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

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

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

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

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

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

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

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

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

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

920. Similar varieties are met with in the structure of the intestines of different mammalia. As a general rule, to which, however, there are several exceptions, it may be remarked, that

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

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

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

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

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

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

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

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

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

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

The internal nasal cavities are also generally enlarged, and particularly the frontal sinuses.

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

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

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

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

931. In many quadrupeds some of the sebaceous glands of the integuments are very much developed. In some predacious animals, a gland exists in the orbit, described by Nuck, and of which the excretory duct opens near the last tooth of the upper jaw. It appears referable to the class of salivary glands. Another gland,

particularly noticed by Professor Jacobson, and of which the use is wholly unknown, is generally met with in the anterior and lower part of the cavity of the nostrils: this he has called *the nasal gland of Steno.*

3. *Quadrumana.*

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

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

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

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

936. In the lemur tardigradus, and in the sloth, a singular structure has been observed by Sir Anthony Carlisle, with regard

to the distribution of the arteries of the limbs. The trunks of these arteries suddenly subdivide as they enter the limb into a great number of parallel branches, which are again re-united when they arrive at the remote end of the first division of the limb; that is, about the joints corresponding to the elbow and the knée in man. After their re-union into single trunks, these arteries proceed to ramify in the usual manner.

4. *Chiroptera.*

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

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

5. *Insectivora.*

939. Among the animals arranged by Cuvier in this family, the mole presents the most remarkable peculiarities of conforma-

tion, both as regards the skeleton and the internal organs. The sternum has the same crested process as in the bat, and apparently with the same design of enlarging the surface of attachment to the powerful muscles employed in digging. But the anterior extremity of this crest is still farther prolonged into a sharp process, having the figure of a plough-share, which is situate under the cervical vertebræ, and resembles the keel-like projection we shall have occasion to notice in the sternum in birds. The cervical vertebræ are remarkable for having no spinous processes. The ligamentum nuchæ is particularly strong, and is almost wholly ossified. The clavicle is of a singular shape, being nearly cubical. The humerus is very slender in the middle, and remarkably expanded at both its extremities. The fore-paw is provided with a bone of a peculiar shape, called the falciform bone, placed at the end of the radius. The phalanges have numerous processes, and are furnished with sesamoid bones; structures which, by giving considerable mechanical advantage to the muscles that move them, contribute greatly to increase their power. The great muscles of the trunk, the pectoralis major, the latissimus dorsi, and the teres major, are of great size, and give the animal great facility in digging the ground, and throwing up the earth as it proceeds.

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

6. *Plantigrada.*

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

942. To this family belongs the bear, remarkable for possessing supernumerary canine teeth, which are small, and situate behind the principal ones. The stomach is divided into two portions by a slight contraction in the middle; the intestines are furnished with remarkably long and numerous villi; the kidneys are con-

glomerated; the tentorium is bony; the nasal cartilages are extremely mobile.

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

7. *Digitigrada.*

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

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

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

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

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

8. *Amphibia.*

949. Whiskers having the same properties are likewise found in the seal, an animal of aquatic habits, and whose conformation is modified with reference to the element it is intended to inhabit. The feet act as fins, adapted for swimming; the radius and ulna are flattened; the spine is very flexible; the pelvis very narrow. The bones have no medullary cavities. Neither the parotid nor the sublingual glands are met with in this or any other animal of the order of amphibia, belonging to the class mammalia; and the teeth are adapted chiefly to the seizing and detention of objects, and are scarcely capable of serving the purpose of mastication. The stomach is a straight cylinder, having no cardiac expansion. The intestinal canal is of great length, thus forming

an exception to the general rule of its being comparatively short in carnivorous animals. The renal veins form a kind of network, the reticulations of which intersect the furrows between the mammary processes on the outer surface of the kidneys. The proportional size of the brain of the seal is greater than in most mammalia.

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

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

9. *Marsupialia.*

952. The marsupial family of mammalia compose an interesting group of animals, which present many remarkable singularities in their internal conformation and economy. The principal of these is the apparently premature birth of their young, which come into the world at a period of their development corresponding to that to which the fœtuses of mammalia have arrived only a few days after conception. Nearly the whole extent of the integument of the fore part of the abdomen forms a kind of sac or pouch for the reception of the fœtuses in their early state, and whilst they present only a shapeless mass, destitute of external members, and totally incapable of locomotion. They become attached to the nipples of the mammary glands, situate under the integument of the pouch next to the abdomen of the mother; and they remain in this situation for a long time, imbibing nourishment from these glands, until they acquire a growth equal to that which the young of other animals attain in the uterus before birth. Two bones, peculiar to these animals, and therefore called the marsupial bones, are expressly provided for the protection of the abdominal viscera, lying in the horizontal position of the trunk above this extraordinary pouch, which performs the function of a supplementary uterus. It is farther remarkable, that the same bones occur in the skeleton of the males, where, of

course, there are no pouches; and also in those species where the fold forming the pouch is scarcely perceptible. The uterus communicates with the vagina, not by a single opening, but by two curved lateral tubes. This has been called the *uterus anfractuosus*, to distinguish it from the ordinary form, which is the *uterus simplex;* the *uterus bicornis*, which has two horns, either straight or convoluted; and the double uterus, or *uterus duplex*, which has the appearance of two horns opening laterally into the vagina, as in the mole, the hare, and the rabbit. The Fallopian tubes, in marsupial animals, are much enlarged at their extremities.

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

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

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

10. *Rodentia.*

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

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

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

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

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

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

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

11. *Tardigrada.*

963. The tardigrade mammalia are distinguished by having the same peculiar distribution of the arteries of the limbs which we have already noticed in the lemur tardigradus. They possess neither cœcum nor gall-bladder. The stomach of the sloth is complicated in its structure, being divided into several pouches;

the intestinal canal is very short; there is also at its extremity an approach to the structure of the cloaca of birds, inasmuch as the rectum and urethra have a common termination. The zygoma is furnished with a large descending process, which comes from the os malæ.

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

12. *Monotremata.*

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

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

singular shape, consisting of two hooked pieces joined together at their bases.

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

967. Sir Everard Home denied the existence of mammæ in the female ornithorhyncus; but these glands have been distinctly delineated by Meckel, and described by him as being largely developed. In a paper since read to the Royal Society, Sir Everard Home again asserted that further inquiry had convinced him of the non-existence of these glands; but in a paper subsequently read to that learned body,* Mr. Griffin describes the mammæ of the ornithorhyncus paradoxus as considerable glands, which occupy the greater part of the under surface of the animal, and have numerous excretory ducts perforating the skin in two circumscribed places, but not forming any elevations analogous to nipples. This subject has, since that period, been investigated with great care by Mr. Owen,† who found the structure to correspond very exactly with the account given by Meckel, and he is accordingly led to regard them as real mammæ. The falx, as well as the tentorium, contains a plate of bone. The external auditory passage is very long and tortuous, and there are only two ossicula in the internal ear. A singular kind of clavicle is found in the skeleton of these animals, common to both the fore extremities, and situate in front of the ordinary clavicles, bearing some analogy to the furcular bone of birds. The conformation of the ribs also exhibits an approach to that of birds. Each rib consists of two pieces of bone; a longer one joined to the spine, and a shorter connected with the sternum; the two being united by an intermediate cartilage.

13. *Pachydermata.*

968. In this natural family of animals, which was established by Storr, in his *Prodromus Methodi Animalium*, the elephant first claims our notice. In addition to the thick integument common to all the animals of this tribe, we find that remarkable organ, the *proboscis*, which is a prolongation of the nose, formed of a double cylindrical tube, extremely flexible in all directions, endowed with exquisite sensibility, and terminating in an appendix very much resembling a finger, all the functions of which it is capable of performing. The motions of this admirable organ

* December 15, 1831.

† Philosophical Transactions for 1832, p. 517. See also his paper in the Transactions for 1834, p. 333.

are executed by an infinite number of muscular fibres, collected into small bundles, which pass in a great variety of directions, and are continually interlaced with one another, so as to be adapted to the performance of every kind of movement. The enormous tusks which are given to the animal as formidable weapons of offence, are merely developments of incisor teeth, proceeding from the inter-maxillary bones in the upper jaw, and which on issuing from the mouth are incurvated upwards.

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

970. Between the eye and the orifice of the external ear, a gland of large size is situate, occasionally secreting a brown fluid, which oozes out through an opening in the skin. There are twenty ribs on each side; and there appear to be only three lumbar vertebræ. The ligamentum nuchæ is of great size and strength, for it has to support the enormous weight of the head with its ponderous tusks and proboscis. The articulation of the thigh bone with the pelvis, is destitute of the ligamentum teres, which is found in almost all other quadrupeds. The toes are five in number, but they are almost concealed by the thickness of the skin of the foot in which they are encased. The condyles of the lower jaw are simply rounded eminences. The form and structure of the teeth are very peculiar, and afford distinctive characters of the different species of the elephants, which belong more properly to natural history. In addition to the usual component parts of bones and of enamel, a third is superadded, called the *crusta petrosa*, which fills up the interstices, left by the duplications

of the enamel. The ivory which composes the tusks is exceedingly dense, and differs considerably in its structure from the ordinary bone of other teeth. It is distinguished by the curved lines which pass in different directions from the centre of the tusk, forming by their decussation, a regular arrangement of curvilinear lozenges. The tusk is constructed by the successive depositions of osseous matter from within, being secreted from the outer surface of the vascular pulp, which occupies the central part of the growing tusk. Hence, iron balls, fired at the animal, have been known to penetrate the latter soft portion, and to remain fixed in the interior of the tusk, till they were completely covered over, and imbedded in the successive depositions of ivory.

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

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

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

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

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

14. *Solipeda.*

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

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

978. The bones of the extremities of the horse are constructed on the same general model as the human, though varying much in the details of their form and relative proportions; and some parts only appearing in an imperfect or rudimental state. The scapula is of an oblong triangular shape, considerably narrower and longer than the same bone in the human skeleton, and exhibiting only faint traces of the acromion and coracoid processes. Its axis is nearly in the same line with the os humeri, which latter bone is very short, and scarcely descends below the line of the chest, and possesses scarcely any rotatory motion on the scapula.

The radius and ulna are consolidated together; the olecranon is much elongated. The carpus, or as it is vulgarly called, the knee, of the horse, is composed of seven, or sometimes eight, small bones, disposed as in the human carpus, in two rows; though with respect to their individual form, they have but little resemblance to the latter.

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

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

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

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

983. In the skull of the horse we may observe that the tem-

poral bone is divided by a suture into the squamous and tympanic portions. The occipital bone has a deep depression in the middle, where the cervical ligament is attached. The antrum maxillare and turbinated bones are of great size. The lower jaw-bone is also very large, and presents a very extended surface for the attachment of muscles.

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

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

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

15. *Ruminantia.*

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

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

988. The whole track of the alimentary canal in these animals presents us with objects of interest. The tongue is covered with

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

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

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

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

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

993. The horned ruminants have an eminence on the os frontis for supporting the horn. This process is in the stag a real bone, remarkable for the rapidity of its growth, which is annual, and for its death and separation from the skull at certain periodic intervals. The osseous bases of the horns of the ox, the sheep, the goat, and the antelope, on the contrary, are permanent, and

are invested with a horny covering, which has a structure very different from bone. The camelopard, or giraffe, on the other hand, has two osseous prominences, which remain permanently covered with the integuments, and are even surmounted by a tuft of hair. But the details relating to organs so external as the horns fall more properly within the province of natural history.

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

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

16. *Cetacea.*

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

997. The necessity of occasionally receiving air into the lungs, whilst the animal is generally immersed in water, renders it requisite that a provision should be made for their readily rising to the surface in order to breathe. Hence the movements of the tail are from above downwards; hence in the cachalot and other kinds of whale, a large quantity of oil is accumulated round the head, which gives greater buoyancy to this part of the body. Hence, also, when the animal, in seizing its prey, takes into the mouth a large quantity of water, there is a necessity of getting

rid of it, which is effected by its transmission into a sac placed at the external orifice of the nasal cavity, whence it is expelled with great force, by the contraction of powerful muscles, through a passage which conducts it to the top of the head. In this way are produced the enormous spouts of water that mark the track of the whale on the surface of the sea.

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

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

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

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

1002. The whale is remarkable for having, in place of teeth, an apparatus apparently intended for filtration, and consisting of

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

Sect. II.—*Comparative Physiology of Birds.*

1. *General Description.*

1002. The whole of this class of animals exhibits great uniformity in its comparative anatomy; insomuch that the whole may easily be comprised in one general description. The structure of every part of the frame of birds is adapted to facilitate rapid progression through the air; for which purpose the anterior extremities are converted into wings, and are not employed in any other action. The support of the body when the animal is not flying, is entrusted solely to the posterior extremities; so that birds are, strictly speaking, *bipeds*. Hence we may trace some degree of approximation to the human structure in the conformation of the skeleton.

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

1004. The neck of birds being required to be very flexible, we find the cervical vertebræ very numerous, and freely moveable upon one another. The swan has twenty-three cervical vertebræ.

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

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

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

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

1008. The muscles possess a high degree of irritability, and contract with great quickness and force. Many of the tendons become ossified in the progress of age. A remarkable arrange-

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

1009. The energy of the digestive functions in birds corresponds with that of respiration, and muscular irritability. The stomach may be considered as consisting of three cavities; the first of which, termed the *crop*, is rather a dilatation of the œsophagus, furnished with numerous glands disposed in a regular arrangement of rows; the second is the *ventriculus succenturiatus*, or *pro-ventriculus*, situated lower down, and just at the entrance of the proper stomach. It is furnished with a still more complex glandular apparatus; and hence has been termed the *bulbus glandulosus*. Its form and structure vary much in different genera of birds. The third is the proper stomach, which resembles in the structure of its coats the simple stomachs of the mammalia, being thin and membranous in those birds which feed on insects and flesh. But in all granivorous birds the coats of this stomach are farther armed with a thick cuticular lining, of nearly the density of horn, which is surrounded by four immensely thick and powerful muscles, capable of exerting a strong com-

pression on the contents of the stomach, and a slight degree of lateral motion, and thus performing the office of trituration. Such is the structure of what is called a *gizzard*. Between these opposite structures there exists, in different species of birds, a great number of intermediate gradations, corresponding to the peculiar nature of the food to which nature has adapted their organization. The trituration of the grain is assisted by small stones voluntarily swallowed by the animal, and in the selection of which the animal is directed by a principle of instinct.

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

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

1012. The heart of birds is furnished, as in the mammalia, with a double set of cavities; the one subservient to the general or systemic, and the other to the pulmonary circulation. The valves of the right ventricle are supplied by a strong triangular muscle,

which gives additional impetus to the blood propelled into the pulmonary artery. Jacobson has discovered a singular distribution in the abdominal veins; those returning the blood from the hinder extremities being ramified through the kidneys and liver, previously to their termination in the vena cava.

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

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

total bulk of the brain, compared with the size or weight of the body, is generally greater than in the mammalia.

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

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

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

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

1019. The evolution of the chick from the egg being a subject of great interest, has long engaged the attention of physiologists. The following is an outline of the history of these changes in the common fowl. The ovulum, or first rudiment of the egg, is formed in the ovary, and consists simply of a bag containing the yolk; this afterwards becomes covered in its progress along the oviduct, by successive layers of albuminous substance, which composes the white of the egg, so called from the colour it assumes when coagulated. The white of the egg is invested with a firm membrane, which is easily divisible into two layers; and

there are also other membranes dividing the mass of albumen into concentric layers. The membrane of the yolk, the *membrana vitelli*, or *yolk-bag*, is connected with that of the white, or the *membrana albuminis*, by a kind of ligament, which extends from the two ends or sides of the yolk, to those of the white; these, when partially stretched and torn by the motion of the yolk, have a flocculent appearance, and form what are called the *chalazæ*. They appear to act as ligaments to the yolk, keeping that surface uppermost in which the chick is situated, so that it may receive warmth from the hen during incubation. In the lower part of the oviduct the egg acquires a calcareous covering or shell, which is secreted by the inner membrane of that canal, and which is composed of nine-tenths carbonate of lime, the remaining portion being phosphate of lime and animal matter. Between the two membranes which line the shell, a small quantity of air is contained at the larger end of the egg.

1020. A small, round, milk-white spot, called the *cicatricula*, is formed on the surface of the yolk-bag during incubation. It is surrounded by two or three concentric circles, called the *halones*. Previously to the appearance of the embryo, a small shining spot of an elongated form, with rounded ends, but contracted in the middle, is seen within the cicatricula. This is called the *areola pellucida*. In the centre of this may be discerned, on the second day, a gelatinous filament, bent into a curve. This is the *primitive trace*, or earliest perceptible rudiment of the chick, in which the first organs that can be discovered are the two lobes of the brain, and the primitive filaments of the spinal cord, with caudal dilatation. Vessels begin to appear on the surface of the yolk-bag, being spread on a separate membrane, and presenting what has been called the *figura venosa*, or *area vasculosa*, the marginal vessel at the remotest part being termed the *vena terminalis*. These veins correspond to the mesenteric veins; they are collected together, and form the vena portæ, whilst the arteries are derived from the mesenteric artery of the chick. The heart may next be perceived, as three red pulsating points, constituting the *punctum saliens*. These points are the rudiments of the auricle, ventricle, and aorta. Next, the separate vertebræ may be distinguished, then the eyes, and afterwards the stomach, liver, and intestines. Then a vascular membrane, the *allontois*, is rapidly formed, having the form of a bladder communicating with the cloaca. It soon extends over nearly the whole of the internal membrane of the shell, and is covered with numerous ramifications of arterial and venous vessels, derived from the internal iliacs of the chick; the former contain carbonized blood, and are therefore dark coloured; the latter, which conduct back the same blood after it has received the influence of the air at the surface, have a bright scarlet hue, and unite in forming the umbilical vein of the chick. Hence it is

evident that this membrane performs a function analogous to that of the placenta in mammalia, and to that of the future air-cells of the lungs, or, in other words, that it is the organ of embryonic respiration. The chick is nourished by the matter of the yolk, which is partly absorbed by yellow vessels (*vasa vitelli lutea*) having a fringed appearance, and flocculent extremities, floating in the yolk, and partly by the direct passage of this matter into the intestine by means of a canal of communication, called the *ductus vitello-intestinalis*. The white of the egg also gradually disappears, being absorbed into, and mixed with the yolk. Towards the latter periods of incubation, the whole of the yolk-bag is taken into the abdomen, and soon disappears. On the twenty-first day of incubation, the chick, being fully formed, breaks the shell which confines it, and enters into the world; for which temporary purpose it is provided with a hard beak, which is afterwards lost.

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

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

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

1023. The tongue of the woodpecker is provided with a singular apparatus for darting it forwards with great rapidity; this

is effected by a long cartilaginous band, which passes completely over the top of the cranium, and is fixed to a groove on the right side of the upper jaw.

Sect. III.—*Comparative Physiology of Reptiles.*

1. *Reptiles in General.*

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

There is ground for believing, according to Geoffroi St. Hilaire, that crocodiles and turtles possess, in addition to the ordinary pulmonary respiration, a partial aquatic abdominal respiration, effected by means of two channels of communication which have been found to exist between the cavity of the abdomen and the external surface of the body, and also that some analogy may be traced between this aquatic respiration in reptiles, by these *peritoneal canals*, and the supposed function of the swimming bladder of fishes, hereafter to be described, in subserviency to a species of aerial respiration.

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

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

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

2. *Chelonia.*

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

1028. The cavity in which the brain is contained is very small compared with the size of the skull, the greater part of

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

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

1030. In the internal ear, we find a tympanum, Eustachian tube, and semicircular canals, together with ossicular, and also stony concretions in the vestibule. The eye has a bony ring at the anterior part of the sclerotica, as in birds. There are large lacrymal glands, and a very moveable membrana nictitans.

3. *Sauria.*

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

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

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

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

1033. The chameleon has comparatively a large head; but its brain is only of the size of a pea. Its lungs have numerous projecting processes. The tongue is constructed in a manner which bears some analogy to that of the woodpecker in the mechanism by which it is darted forwards to a considerable distance from the head, and suddenly retracted. It terminates in a sort of club, which is moistened with a glutinous secretion, for seizing flies and other insects, and its upper surface is hollowed. The eyes project considerably from the head, and admit of being turned very freely in their orbits. The most singular circumstance in the constitution of this animal, is the change of colour of its skin under various circumstances of temperature or excitement. These changes appear to be connected with the variable activity of respiration, which quickly influences the

colour of the blood circulating under the very transparent skin; and which is visible to a greater depth, in consequence of the ample extension of the lungs along the sides of the abdomen: when the lungs are inflated, indeed, the whole body appears as if it were semi-transparent.

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

4. *Ophidia.*

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

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

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

1038. Serpents that are not venomous have usually four maxillary bones in the upper jaw, beset with small teeth, placed in two rows, widely separated from one another. The external row is not found in venomous serpents, but in their place large

tubular fangs are met with, which are the terminations of the ducts from the poison bags, and which convey the venom into the wound inflicted by the tooth. This poison is secreted by glands, situated below the eyes, and surrounded by very strong muscles.

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

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

5. *Batrachia.*

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

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

the skeleton. There are properly no teeth; but the margin of the jaw is serrated. The urinary bladder exists, and is even sometimes double.

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

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

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

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

* [Dr. J. J. Allison, of Philadelphia, has also observed these pulsating organs in the tadpole, the frog, in the sauria, ophidia, and chelonia. Amer. Journ. of the Med. Sciences, for Aug. 1838.]

Sect. IV.—*Comparative Physiology of Fishes.*

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

1046. The osteology of fishes presents a very complicated subject of study, not only from the great number of pieces of which their skeleton is composed; but also from the great variety of forms exhibited in the different genera and species of this class. Fishes, with regard to their skeleton, admit of a great primary division into the cartilaginous and osseous. The former, or the *chondropterygii*, possess no real bones, but merely cartilages, having the form of bones, of a homogeneous and semitransparent substance, sometimes, however, as in the rays and sharks, presenting on its surface small calcareous granules, very closely compacted together. In a few fishes arranged under this division, as the sturgeon, and the chimera, we meet with several true

bones in the head and shoulder, while the rest of the skeleton is cartilaginous. Even among the strictly osseous fishes, the density of the bones of some species is inferior to that of others, the calcareous substance, or phosphate of lime, being deposited in fibres, or layers, in the cartilage which serves as the basis of the bone. The truly osseous fishes have bones as hard and as dense as other vertebrated animals; they are even more homogeneous in their texture, and present no appearance of pores or of fibres, as are seen in the bones of the mammalia. We never find in them any medullary cavities.

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

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

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

1050. The bones of the head are exceedingly complex, and the mere enumeration of them would require a more lengthened discussion than can here be afforded. The bones composing the

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

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

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

1053. The œsophagus is generally very short and capacious; it is continued into the stomach without any marked line of se-

paration; and part of the food is often retained in the œsophagus undigested, until room can be made for it in the stomach. In a few fishes, the parietes of the stomach are muscular, so as to entitle it to be considered as a gizzard. The intestinal canal is generally very short; its internal coat is more or less villous; there is never any cœcum; the only distinction between the different portions of the canal is formed by a valve near its extremity; but this is not succeeded by any dilatation.

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

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

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

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

1058. The circulation in fishes is conducted upon a very different plan from what it is in reptiles. There is, as in warm-

blooded animals, one complete circulation for the body in general, or a systemic circulation; and another for the organs of respiration; and besides this, a partial circulation for the hepatic system of organs; but what more particularly characterizes this mode of accomplishing that function is, that branchial circulation is the only one which is effected by a muscular apparatus, that is, by a heart. The systemic circulation has no such organ for communicating to it a mechanical impulse.

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

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

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

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

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

1064. Great variety is met with in the size, position, and direction of the eyes of fishes. In general, however, they are large. There are neither eye-lids nor lacrymal organs, and the globe of the eye has but little mobility. In the ray and shark tribes, it is supported on the end of a moveable cartilaginous pedicle, articulated with the bottom of the orbit. The anabliss has the cornea divided into two by an opaque line, and two perforations exist in the iris, but there is only one crystalline lens, vitreous humor, and retina. The crystalline lens is completely spherical, and of great size, so as to leave but little space for the vitreous humor. It is composed of concentric laminæ, which are of greater density as they approach the centre. A falciform ligament, commencing at the entrance of the optic nerve, following its curvature downwards, and containing vessels and nervous filaments, is observable; its extremity is attached to the capsule of the crystalline lens. In some fish this ligament has a black colour, like the marsupium of birds. The sclerotica is often supported by osseous or cartilaginous plates, as in birds. The pupil is incapable of altering its dimensions; in the rays and flat fish, its border is fringed with palmated processes. The cornea is nearly flat, and there is but little aqueous humor.

1065. There is found in the eyes of fishes a peculiar body, the *membrano vasculosa Halleri*, having the shape of a horse-shoe, situated between the internal layer of the choroid coat, or *tunica Ruyschiana*, and the middle layer; it gives origin to a vascular membrane, called the *campanula*, which proceeds towards the lens, and has some analogy with the marsupium.

1066. The gastrobranchus appears to be wholly destitute of any organ of vision. In the blind murena, no trace of an eye can be perceived externally, but a rudimental organ exists beneath the skin.

1067. The ear of fishes consists only of the parts belonging to the labyrinth; and these organs are generally suspended in a cavity of the cranium, which is a part of that in which the encephalon is contained. The two vertical semi-circular canals are suspended to the top of the skull by a vertical ligament. The oily or mucilaginous fluid which surrounds the brain has free access to the cavities which surround the membranous labyrinth. The three semicircular canals are dilated into ampullæ, which receive the filaments of the auditory nerve. There is an appendix to the *sinus medianus*, or principal vestibular sac, termed the *utricle*, and a smaller one termed the *cyticule*. The hard calcareous bodies consist of one in each of these cavities, being three in number. There is no part corresponding to the cochlea.

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

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

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

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

* Phil. Trans. for 1832 and 1834.

and has also rendered needles magnetic by the electrical discharge from the fish.*

1072. It appears that the power of producing these electrical discharges is quite voluntary, and dependent on the nervous influence; for it does not take place every time that the fish is touched, and it wholly ceases on the destruction of the brain, or the division of the nerves. The animal appears to have the power also of determining the direction of the discharges; and often, when irritated, it refrains from giving shocks. The destruction of the electric organ on one side does not interrupt the action of the opposite organ. Dr. Davy states, that the dorsal surface is charged with positive, and the ventral surface with negative electricity, and that unless both surfaces be simultaneously touched, no shock is felt; and Matteuci and Colladon† arrived at the same conclusion by experiments made with the galvanometer, as to the direction of the electric currents. Electric fishes, when vigorous, exert this power as strongly in the air as in the water. We are quite in the dark with regard to the theory of these phenomena. Matteuci imagines that the source of electric power in these fishes is in the brain; and that the purpose served by the complex arrangement of parallel plates, with intervening fluid, which composes the structure of the electric organs, is that of mere accumulation, analogous to the property of the Leyden phial.

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

Sect. V.—*Comparative Physiology of Mollusca.*

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

1075. The mollusca have neither articulated skeleton nor vertebral canal. Their nervous system does not present a central spinal cord, but merely a certain number of medullary masses, dispersed in different situations in the body, and of which the

* [See some observations by Dr Faraday on the electric conditions of the Raia torpedo and Gymnotus electricus, in Lond. Med. Gazette, Jan. 26, 1839. p. 647.]

† Séances de l'Acad. des Sciences, Oct. 1836.

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

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

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

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

1. *Cephalopoda.*

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

In these animals, the mantle is folded so as to form a sac enveloping all the viscera; its sides being more or less extended into fins. The head alone protrudes from the sac; its form is round, furnished with large eyes, and with long processes or tentacula, flexible in every direction, endowed with great muscular power, and having on the surface a great number of suckers, by which they are capable of adhering with great force to the objects to which they may apply them. These tentacula, or feet, are employed by the animal in walking, which it does with the head downwards; in swimming, which it executes with the head turned backwards; and also in seizing hold of bodies, for which action they are well adapted. Between the basis of the feet is placed the mouth containing strong horny mandibles, resembling in their form the beak of a parrot. The excretions pass out by a funnel-shaped aperture, situate at the mouth of the sac, and near the head.

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

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

1082. A singular secretion is prepared by a gland in this animal, of a deep black colour, resembling ink, which, when effused, darkens the surrounding water to a considerable distance, and gives the animal an opportunity of escaping from its pursuers. The brain is large; a nervous ganglion surrounds the œsophagus. The optic ganglions are very large; and the nerves form plexuses in the abdomen and in other parts. The eye is similar in its conformation to that of the higher classes of animals; but the

ear is constructed in a still simpler manner than that of fishes, having neither simicircular canals nor external meatus, but consisting merely of a membranous sac lodged in a cavity near the brain, in which a small cretaceous body is contained.

2. *Gasteropoda.*

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

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

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

Many of the gasteropodus mollusca present the curious phe-

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

3. *Acephala.*

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

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

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

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

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

1089. One of the most singularly constructed of the animals

referred to this division of mollusca is the ascidia. The mantle and its envelope, which is a thick and cartilaginous tunic, form together a sac, everywhere closed, excepting at two orifices, the one corresponding to the termination of the intestine, the other leading into a cavity, of which the sides are the branchiæ, and at the bottom of which is placed the mouth, the principal viscera subservient to nutrition occupying a second cavity, and the heart being lodged in a third. The principal nervous ganglion is situated between the two external orifices of the sac.

Sect. VI.—*Comparative Physiology of Articulata.*

1090. This great division of the animal kingdom comprises all those tribes possessing what may properly be called an external skeleton; that is, a series of rings or hollow cases, of a hard texture, which enclose all the important organs of the body, and which, by their muscular connexions, allow of various kinds of movements, at the same time that they afford protection to all the softer tissues of which those organs are composed. The best idea that can be formed of this mechanical construction may be obtained by examining the body and the limbs of a lobster, in which it will be seen, that contrary to what obtains in vertebrated animals, the harder parts are external, and the muscles are within them, a construction allowing of very free movements of the limbs.

1091. A remarkable degree of uniformity prevails with regard to the distribution of the nervous system in all these animals. The brain, which is situated above the œsophagus, but is still in the head, as in the higher classes of animals, is exceedingly small; and after sending out filaments of nerves to the different parts about the head, is connected with a double nervous cord, which encircles the œsophagus, and runs along the under side of the animal, being joined at intervals by nodules or ganglia, from which, as from new centres, other nervous threads radiate, and are variously distributed to the different vital organs, and to the limbs. Each of these nervous ganglia appears to perform the office of a subordinate brain in relation to the system of nerves which proceeds from it, and to the parts of the body supplied by those nerves, so that when the animal is divided into several portions, each portion seems to possess its own independent vitality. The form and structure of the digestive organs is very various; but jaws are always found, and their motion is lateral instead of vertical, as in vertebrated animals.

1. *Annelida.*

1092. The first class of articulated animals are the annelida,

or worm-shaped animals. They are remarkable for possessing red blood, which circulates in a double system of complicated vessels, without any heart, or muscular ventricles. The body is soft, more or less elongated, and composed of a great number of segments. The foremost of these, which may be regarded as the head, contains the largest of the ganglia, or brain, the mouth, and the principal organs of the senses. The branchiæ are generally external, and sometimes uniformly spread on the surface of the body; and at other times are confined to the anterior divisions. Tufts of hair or bristles supply the place of feet. The mouth is either furnished with hard jaws, or else extended in the form of a tube.

1093. The leech, which is referable to this class, has a very capacious stomach, nearly of the size of the whole body, or rather a series of pouches, or dilatations proceeding from each side of the central cavity.* Tentacula, situate on the head, are their principal organs of touch; and the small black points, observable in some tribes, have been regarded as organs of an imperfect kind of vision. The earth-worm has a remarkably complicated apparatus for circulation, consisting of a great number of dilatations of the dorsal vessel, forming a series of hearts.†

2. *Crustacea.*

1094. The articulated form is more perfectly developed in the crustacea than in the annelida. Their blood is white, and is circulated by the aid of a muscular ventricle, or heart, situated in the back, propelling it through an arterial system; whence it returns by a system of veins, which collect in a trunk passing along the lower part of the abdomen. In some species the heart assumes a very elongated shape. There are always organs termed *antennæ*, or feelers, situated in front of the head; and these are generally four in number. The jaws are of complicated structure. It is only in a few species that an internal ear is met with, and it then consists of a sac full of fluid, in which a calcareous concretion is contained. The eyes are generally two in number, often placed at the end of pedicles, and consisting of a great number of facets, each provided with a separate cornea, retina, and branch of the optic nerve; and the whole constituting what is termed a composite eye. The branchiæ are of a pyramidal form, composed of plates, or filaments, or feathery tufts, generally situated at the base of the legs.

1095. The larger genera of this class, as the lobster, have a horny stomach, with strong teeth implanted in its coats, for the

* See a description and delineation of this structure in the Bridgewater Treatise on Animal and Vegetable Physiology, ii. 103. [Amer. edit. ii. 77.]

† Ibid. ii. 255. [Amer. edit. ii. 184.]

evident purpose of breaking and bruising the shells that are swallowed. All these animals cast off their shells several times in the progress of their growth, a new shell being successively formed of larger dimensions than the preceding, and adapted to the increased size of the animal.

3. *Arachnida.*

1096. The third class of articulated animals, or the arachnida* have been separated from that of insects with which they had been before associated; being distinguished by the following peculiarities in their conformation and economy. They have a distinct circulation of the blood by means of an elongated dorsal vessel performing the office of a heart, propelling its blood into a system of arteries, and receiving it back again from a system of veins. They are without antennæ, but are provided with palpi. They have pulmonary cavities subservient to the respiration of atmospheric air. The head is united with the trunk without the intervention of any neck. The mouth is armed with jaws; and there are several simple eyes situated on the upper part of the head.

4. *Insects.*

1097. Nothing can exceed the endless variety of forms displayed by this class of the animal creation. Their internal anatomy and economy, however, present many points which are common to the whole class. There is no other trace of a heart, than a long cylindrical tube extending along the back, and termed the *dorsal vessel;* but which seems to be closed on all sides, and neither to give out, nor to receive communicating branches of any sort. This vessel appears to contain a fluid, which is irregularly undulated backwards and forwards, by a kind of pulsation, or occasional contraction of one part of the canal, and dilatation of another. It had been supposed, in the absence of any visible blood-vessels, that nutrition in insects is performed by a kind of gradual transudation, or *imbibition*, as it has been termed. Professor Carus, however, has lately made the discovery of a distinct circulation in the vessels of the larvæ of several insects, and other observers have found a system of partial circulation in even later periods of insect life. But, in general, in the last stage of transformation, all these vessels, excepting the dorsal vessel, become obliterated.* There being neither branchiæ nor pulmonary organs where the nutritious fluids could receive the vivifying

* The dorsal vessel of the sphinx ligustri is delineated in the Bridgewater Treatise on Animal and Vegetable Physiology, ii. 245. [Amer. edit. ii. 177.]

influence of the air, a complex mode of respiration is resorted to. Apertures are found in different parts, generally along the sides of the body, and which are called *spiracles* or *stigmata*. These are the commencements of elastic tubes, which remain continually open, and which are subdivided and ramified like the blood-vessels of other animals, for the purpose of conveying air to every part of the system. These tubes are termed *tracheæ*.

1098. Insects are unprovided with glands for effecting secretions; that purpose being answered by means of long spongy vessels, which appear capable of absorbing the materials they require from the general cavity in which they float.

1099. The temperature of insects, like that of other animals said to be cold-blooded, varies with that of the surrounding medium; but is generally one or two degrees higher. In bee-hives and ant-hills, a much higher temperature prevails. This is proved by an elaborate series of experiments made on the temperature of insects, and its connexion with the functions of respiration and circulation, by Mr. Newport.*

1100. Their nervous system is formed upon the general model already described (§ 1091). The digestive organs admit of the greatest possible variety, according to the habits and particular kinds of food consumed. To specify all these diversities would far exceed the limits assigned to us in this work. The external organs connected with the limbs, the antennæ, the mouth, and the different functions of sense, fall more properly under the consideration of the naturalist, inasmuch as they furnish the best characters for the distinction of genera and species, and for perfecting their systematic classification. The subject is rendered infinitely more complex in consequence of the metamorphoses which the same insect undergoes in passing through the different stages of its existence, from the *egg* to the *larva*, the *nympha* and the *imago*, or the perfect insect. But for the history of these changes, we must again refer to the naturalist, to whose province it more strictly belongs to record them. We must content ourselves with mentioning in this place a few of the more striking peculiarities of internal conformation which are observable in some of the insect tribes.

1101. The first that we shall point out is, the remarkable structure of the digestive organs of the orthoptera, an order of insects which comprehend the blatta, or cockroach, and the mantis or leaf insect, the ear-wig, the locust, the grasshopper, and the cricket. Their stomachs bear some analogy to those of ruminant quadrupeds, in complication at least, if not in office. The first stomach, or crop, is membranous; to this succeeds a muscular stomach, or gizzard, the internal surface of which is armed

* Philosophical Transactions for 1837, p. 25.

either with scales, or with horny teeth. Around the pylorus there extend two or more blind pouches, furnished at their extremities with numerous vessels conveying bile. Many similar biliary ducts are inserted in the course of the intestinal canal. It has been strongly suspected that the insects in which these complex stomachs are found, actually possess the power of ruminating their food.

1102. The abdominal cavity of the working bee presents us with two stomachs, together with the intestine and the poison bladder. The anterior stomach in which the œsophagus opens, is the receptacle for the honey, which is occasionally returned into the mouth in order to be stored in the honey-cells, as a magazine of food for the winter. The next stomach is destined to contain the pollen, or material gathered from the antennæ of flowers. Its inner coat has a great number of circular folds. Wax is a secretion of a peculiar kind from the bee.

1103. The alimentary canal of the caterpillar, before transformation, consists of a straight and capacious tube, of which the anterior portion is somewhat dilated into what may be considered as the stomach; and of which the posterior portions form a cloaca; the biliary vessels, which are four in number, and very long, are inserted very far behind. When the caterpillar is transformed into a butterfly, this alimentary canal is much diminished, both in its diameter and length; the first stomach, or crop, is situated on the side of the tube; there is next a second stomach full of irregular dilatations, a slender but long intestine, and a cœcum near the cloaca.*

1104. The nervous system undergoes corresponding changes during the transformation of insects, the ganglia uniting in several places, so that their number is much diminished.† The external senses of insects have for the most part a considerable range of action. Organs of vision are almost constantly present, but those of the other senses are but imperfectly known. The principal organs of touch are the *antennæ*, which probably also perform other offices relating to sensation, of which we have no certain knowledge.

Sect. VII.—*Comparative Physiology of Zoophytes.*

1105. The animals which occupy the lowest division in the scale of life, and constitute an approach to vegetable, namely, the class of zoophytes, present us with much simpler forms of

* These successive conformations of the digestive organs, in the *sphynx ligustri*, or privet hawkmoth, are delineated in the Bridgewater Treatise on Animal and Vegetable Physiology, ii. 217. [Amer. edit. ii. 157.]

† Ibid. ii. 547.

organization than any of those which have passed under our review. Yet amongst these we may trace gradations in the mode in which the more refined organs of the animal economy successively disappear, and their functions are supplied by other parts, and also in the gradual simplification of those functions, till we appear to arrive at an approximation to mere vegetative existence. The great characteristic of the more perfect animals, the circulation of the fluids in vessels which distribute them to every part for the purposes of nutrition and secretion, is wanting in zoophytes; or if any traces of a circulation can be discovered, it is exceedingly partial and limited in degree. There is a well marked disposition in all the organs to assume a symmetrical arrangement about a common centre; being either disposed in radii proceeding from the centre, or arranged in a uniform manner round the circumference of a circle. In those instances in which a nervous system can be traced, which is the case only among the higher order of echinodermata, the disposition to assume this radiating form is particularly observable.

1106. Many amongst the lowest orders present us with the singular spectacle of compound animals, associated in great numbers for the purposes of a common defence and habitation, and having even nutrition in common. These more particularly constitute an approach to the vegetable kingdom.

1. *Echinodermata.*

1107. The zoophytes arranged in this division, which are chiefly the asterias, or star-fish, the echinus, and the holothuria, present us with some appearance of an external skeleton, or hard encasement, consisting of parts which are often articulated together, an imperfect vascular system, and the appearance of a system of nerves.

1108. The rays of the asterias are composed of numerous pieces, which have been compared to vertebræ, are slightly moveable upon one another, and allow of a slow flexion of the entire ray. It is hollowed below into a longitudinal groove, abounding in perforations for the passage of numerous rows of short tentacula, which perform the office of feet, for the progressive motion of the animal, and which also absorb water, and convey it into the general internal cavity for the purpose of respiration. The centre of the star is occupied by a large stomach, the entrance to which, or the mouth, is below, and which sends out two prolongations, or cœca, to each ray; these are ultimately ramified into minute vesicles, suspended by a membrane which performs the office of a mesentery.

1109. The structure of the echinus is still more complicated. The calcareous covering of the body has a globular shape, but

is composed of several angular pieces joined together, and perforated by rows of lobes, through which the short feet, or tentacula, protrude. Besides these, there are a multitude of spines articulated to the surface of the shell, and subservient to voluntary motion. The mouth is armed with five teeth, inserted in a complicated apparatus of jaws, resembling a pentagonal lantern, provided with numerous muscles, and suspended over the great opening in the centre of the lower surface of the shell. The intestinal canal is of great length, and forms a spiral tube attached to the interior of the shell by a mesentery. A double vascular systems extends the whole length of this canal, and is partly spread over the mesentery.

1110. The holothuria resembles in its structure the echinus, but it has a cylindrical instead of a globular form. The respiratory organ is ramified like the branches of a tree, and fills and empties itself at the pleasure of the animal. The mouth has no teeth, and is only protected by a circle of calcareous plates. The intestine is very long, and makes many folds, being also attached to the sides by a mesentery. A partial circulation takes place in a double system of a very complicated arrangement of vessels, which has relation exclusively to the intestinal canal, and of which some of the branches are interlaced with the arborescent respiratory tubes already described.

2. *Entozoa.*

1112. Very little is known concerning the physiology of intestinal worms; the information that has been collected being chiefly of a negative kind. They have no visible respiratory organs, and no apparent nervous system or organs of sensation: and still less can we discover any traces of a circulation. The only very distinct organs are those belonging to the functions of nutrition and of reproduction. Some naturalists, indeed, allege that they have detected some filaments of nerves; but the real nature of these filaments is still very doubtful.

1113. The alimentary canal may in most intestinal worms be recognised without much difficulty; it is sometimes enclosed in an abdominal cavity, but at other times apparently passes through the solid parenchyma of the body. In some, as in the tænia, or tape-worm, we may discern ramified vessels for the distribution of the nourishment; but these are not seen in others. The simplest animal of this tribe is the globular hydatid, which consists altogether of a vesicular sac filled with a transparent fluid, and with an indistinct mouth; but without any other apparent external organ. This tribe of entozoa exhibit the simplest example of the gemmiparous mode of reproduction; the young appearing as gemmæ, or buds, which at certain periods spout from the

homogeneous parenchyma composing the body of the parent, and by a sort of vegetative growth, gradually assume the form of the original animal, and are detached when capable of exercising an independent life.

Some of the entozoa, as the tænia, or tape-worm, are capable of being multiplied like plants, by division; each segment resulting from the division being converted into an independent animal, acquiring whatever parts may have been deficient, and after a time admitting of further subdivision, with a repetition of the same phenomena.

3. *Acalepha.*

1114. These are either fixed on rocks, or float in the sea; they exhibit more or less of a fibrous texture, and contain vessels which are excavated out of the substance of the body itself, and are not contained in any distinct cavity.

1115. The actinia, or sea anemone, is provided with numerous hollow tentacula surrounding the mouth and stomach. The space between the stomach and the outer skin is divided into compartments by vertical partitions, and the fluid contained in these compartments may be projected into the tentacula so as to render them turgid.

1116. The medusa has a hemispherical form, and a gelatinous consistence. The mouth, which is situated in the centre of the flat disc below, is surrounded by fringed tentacula. It leads into a singularly-shaped cavity, which is the stomach, formed of four arches proceeding like radii from the centre, and terminating in tubes which are variously divided, and the branches derived from them freely communicating with one another by anastomoses. These are apparently for distributing the nourishment which has been prepared by the stomach, but not for any real circulation. There are four large cavities in the body which appear to be subservient to respiration.

1117. In some species, forming the genus *rhizostoma* of Cuvier, there is no central mouth, but a canal commences by an open orifice from the extremity of each of the fringe-like processes of the tentacula, and these, uniting with others in their course upwards, form at length a single tube or œsophagus, which terminates in the central stomach already described.

Most of the animals of this order, which are found fixed on rocks, are propagated by means of spores or gemmules, constituting one of the modes by which the gemmiparous form of reproduction is effected. These gemmules are minute bodies, formed either on the surface or in some special internal organ of the parent, and which are immediately detached and swim with a spontaneous and independent motion in the circumambient fluid,

by means of cilia or short filaments, which are in rapid and incessant vibration. They pursue these motions for a certain time till they find a convenient place for their future habitation, where, when they are once fixed, they generally remain ever after, growing to the dimensions and exercising all the functions of the parent animal. In the acalepha, which are not stationary, the gemmules retain their liberty of moving during the whole period of their existence.

4. *Polypi.*

1118. The organization of this numerous order of zoophytes presents, in every essential particular, great uniformity, and bears a great analogy to that of the actinia. The gelatinous sac or tube, constituting the digestive cavity, is closed at one end, the opening at the other end being the mouth, which is surrounded by a circle of tentacula; and the nutritive fluid passing by imbibition through the coats of the general sac or stomach for the purpose of nourishment. The hydra may be taken as the type of this tribe of animals. It consists of a mere stomach provided with flexible tentacula for catching food and for progression. This sac may be inverted or turned inside out, without detriment to the animal, digestion being then performed by the new cavity, which is the result of the operation. These animals present the simplest examples of gemmiparous generation (§ 777).

No further discovery can be made respecting the organization of these animals, even by applying the microscope, which shows only a semitransparent substance interspersed with opaque grains. The greater number secrete on their outer surface a calcareous or a horny substance, which serves for their mechanical support, but at the same time fixes them on the spot to which they adhere.

1119. The most remarkable feature in their history is their disposition to congregate together in vast numbers, so as to compose by their united architecture whole rocks and even submarine mountains, rising from the bottom of the ocean. Some of these animal republics exhibit amongst the individuals thus associated together communications of nutritious vessels, so that the materials for the sustenance of each passes into the bodies of the neighbouring polypi, and is applied to the purposes of their economy. All these fixed polypi are propagated by spores or gemmules in the manner already described in our account of the stationary acalepha.

5. *Infusoria.*

1120. These being all microscopic animalcules of extreme

minuteness, it is scarcely possible to arrive at any exact knowledge of their internal organization or economy. Many, and probably all, are possessed of distinct organs for the reception of food, for reproduction, and for voluntary motion; but conjecture alone can fill up the imperfect outline, or suggest any plausible hypothesis as to their powers of sensation, which, however, we are unwilling to refuse to any being which appears to possess the properties and attributes of animality, especially since the splendid discoveries of Ehrenberg have made us acquainted with the complex organization observable in some of the minutest of this prodigiously diversified tribe of beings. It is remarkable, indeed, that those very animalcules, as the monads, which had been ranked by naturalists among the *agastrica*, or beings totally without alimentary cavities, are now found to have a very considerable number of stomachs, and to be entitled accordingly to the title of *polygastrica*.

It is chiefly amongst the various tribes of infusoria that the simpler modes of generation, such as that termed *fissiparous*, are exemplified. In the monas, for instance, a groove is seen to form around the equator of their globular bodies, which groove, gradually deepening, changes their form to that of an hour-glass, and the connecting ligament of the two portions being soon broken, the segments move away from one another, each commencing its independent existence, and being capable of performing all the functions of the undivided monad. In the bell-shaped vorticella, the division commences at the mouth or wide extremity of the bell, and gradually extends in a longitudinal direction towards the insertion of the stem, dividing the body into two equal portions, each being now a distinct and individual animal. The gonium divides itself into four instead of two portions, each portion being again subdivided into four others, the new animalcules assuming rapidly the dimensions and appearance of the one of which they originally formed a part. Other species are propagated by means of gemmules; and some of the infusoria are apparently oviparous.

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CHAPTER XXIV.

HISTORY OF PHYSIOLOGY.

1121. The study of the history of any science furnishes to the mind a body of knowledge not merely ornamental or superfluous, but one that is fraught with instruction and utility, and is conducive to the just comprehension of the subject to which it relates.

It is scarcely ever necessary, indeed, for the understanding of any proposition, that the student should follow the same laborious course and travel through the same tortuous mazes by which the discovery had originally been achieved; for the acquisition of any body of knowledge already systematized by the labours of our predecessors, is in general most readily attained by the synthetic method. But as soon as this point has been reached we can conceive no course of study more calculated to improve that knowledge, and to invigorate the faculties by which it may be extended and perfected, than reverting to the analytic process, and following the series of discoveries in the order in which they have actually occurred. From an historical survey of the successive steps by which science has proceeded from a rude origin to its present state of advancement, and which mark its varied progress and even occasional retrogressions at different periods, according to the prevailing disposition of the age, either to a servile submission to authority or to the hasty adoption of crude and visionary theories, we are enabled to derive most important rules for the conduct of the understanding in the search after truth.

The history of each particular branch of science may, indeed, be regarded as a separate chapter in the history of the human mind. It indicates the sources of its activity and of its strength, and also of its weakness and fallibility; it holds out the most powerful incentives to exertion; it exhibits much to admire and to emulate, and, at the same time, discloses enough to check pride and teach humility.

1122. The history of physiology must necessarily comprise a large portion of the history of anatomy, which consists in the mere knowledge of the organs and minute structure of the body, such knowledge being, in fact, the foundation on which the higher science of the philosophy of life is built. It is scarcely possible, indeed, to study mere organization, without extending our views to the functions that we see performed, and to the energies that are exerted by the living organs. Our object will therefore be in the present place, to inquire how far these higher qualities of mind have been displayed by the cultivators of this department of knowledge at different periods, so as to mark the progress of the philosophy of life, as contradistinguished from the more mechanical, though equally useful labours of the mere anatomist.

1123. The phenomena which constitute the subjects of physiological inquiry must, indeed, have attracted the attention of mankind long before any accurate knowledge had been acquired of the structure of the organs whose actions give rise to these phenomena. Life in its different forms must have been familiar to all; and every savage and warlike people must have been conversant with the diversified aspects of death, which they

inflicted in such various modes. Speculations on the nature of the vital principle, and the physiological conditions on which it is dependent for its origin, maintenance, and decay, must have been formed and pursued in every state of society, removed but one degree from barbarism; and such speculations must have stimulated inquiry into the internal mechanism with which that principle is associated, and the hidden springs which regulate its course.

1124. Opportunities must frequently have occurred in the rudest ages, of observing the different parts of the structure of the bodies both of men and animals. The curiosity even of the savage could not fail to be attracted by the remarkable appearance of the internal organs, in the animals which he slaughtered for food, or prepared for sacrifice. Although deterred from the actual examination of the human body, by an instinctive repugnance, or superstitious terror, various casualties occurring in battle, or arising from accidents, would occasionally afford an insight into the human frame. Human bones, and sometimes entire skeletons, would often present themselves to those who revisited the fields of carnage. Thus would the principal bones, and the most conspicuous viscera of the human body, soon become known, and they would be designated by particular names. Evidence to this effect may be collected from the rudest and most ancient languages; from which we may infer that a certain progress must have been made in this kind of knowledge, long before it had been so arranged and methodized as to deserve the name of a science.

1125. The prevailing custom amongst most of the ancient nations, of consigning all dead bodies to destruction by fire, was one of the greatest obstacles to the advancement of anatomical and physiological knowledge. But opportunities were on the other hand afforded of learning the structure of certain animals, by the religious rites, during the celebration of which these animals were sacrificed, and especially by the examinations which were made by the priests of the yet palpitating entrails of their victims, for the purpose of prognosticating future events. Inferences were thus drawn by analogy as to the organization and functions of the human body. The Egyptians, indeed, who composed the most ancient nation of whose manners and customs we possess any authentic records, were supposed to have acquired considerable knowledge of the human structure from the practice of embalming the dead. This operation was performed by a particular class of men, and consisted in taking out a portion of the viscera, washing them with antiseptic fluids, and filling the cavities with aromatic substances. But as this process appears to have been conducted in the rudest manner, it required no skill in anatomy, and was but little calculated to improve the science.

It was in the hands of a few persons only; and such was the contempt and abhorrence in which these persons were held by their countrymen, that whatever knowledge they might have acquired by the practice of their art, was not likely to be communicated to others.

1126. Whatever splendour may have attended the pride of power or extent of empire in these rude and unenlightened ages, the dawn of science was coeval only with that of liberty. The same energies by which man had thrown off the yoke of tyranny, animated them likewise with the desire of knowledge; and nations had no sooner emancipated themselves from despotism, than they began to emerge from barbarism and ignorance. The Greeks, who were the most free, were also the most polished of all the nations of antiquity, and far excelled them in every species of science and of art. So great was the ardour of their philosophers in the pursuit of knowledge, that they frequently travelled into distant countries to collect useful information, and impart it to their pupils. Even in the time of Homer, the Greeks seem to have possessed much general knowledge both of anatomy and physiology, as may be collected from the writings of that poet. He relates that the stone which was hurled at Æneas by Diomed, not only crushed the thigh-bone, but also tore the ligament of the acetabulum. Merion is represented as being wounded in one of the large veins which return the blood to the heart, or venæ cavæ; and Ulysses aimed a blow at the Cyclops at the part where the liver adheres to the diaphragm. It has even been supposed that Homer has purposely often wounded his heroes that he might have opportunities of displaying by the minuteness of his descriptions, his accurate acquaintance with anatomy.

1127. But though curiosity was roused, and a multitude of detached facts had been observed and collected, it was long before the proper methods of investigation were known, and the true principles of inquiry established. Although it appears that the studies of anatomy and physiology were prosecuted with considerable ardour in the school of Pythagoras, yet as they were regarded merely as a part of natural history, the information relating to these subjects was not sufficiently connected or concentrated to be embodied in one science. Alcmeon and Empedocles, who cultivated anatomy, belonged to this school; but the most remarkable of the pupils of Pythagoras, belonging to the Eleatic sect, was Democritus of Abdera, a man whose eccentric manners, as well as penetrating genius, and undisguised contempt for the follies of mankind, have procured him so much celebrity. He is said to have devoted considerable time to the dissection of animals, especially with a view to discover the origin and course of the bile. His fondness for seclusion, and his perseverance in a pursuit which appeared to his countrymen

to be without any rational object, led them to suspect the soundness of his intellects; and Hippocrates was sent to visit him in his solitary abode. He found the philosopher seated on a stone, under the ample shade of a plane tree, with a number of books arranged on each side, one on his knee, a pencil in his hand, and several animals which he had been dissecting lying before him. His complexion was pale, his countenance thoughtful; at times he laughed, at times shook his head, mused for a while, and then wrote, then rose up and walked, inspected the animals, sat down, and wrote again. Hippocrates, who perceived the nature of his inquiries, observed him for some time in silent admiration, proclaimed to the bystanders the importance of his researches, and declared to them his regret that want of leisure from his own professional employments did not allow him to engage in similar pursuits.

1128. But it was only from men whose minds are capable of enlarged views, and can perceive the bearings and connexions of the several parts of the subjects they embrace, that a powerful impulse is given to science, such as to make it almost the creation of their hands, that it is raised to its proper rank among the departments of human knowledge. Such was the vigorous mind of Hippocrates; and so great was the improvement which medicine derived from his genius, that the foundation was thus laid for the more rapid progress of all the sciences connected with it in succeeding times. Hippocrates was born in the island of Cos, in the first year of the 80th olympiad, or 460 years before Christ; an era which is therefore remarkable in the history of medical science. It appears that at that period a knowledge of medicine had been in a great measure hereditary in certain families, amongst whom the information which had descended from the successive generations was thus retained and augmented. This was the case in the family of Hippocrates, who is said to have been the fourteenth descendant from Esculapius, on his father's side; while his maternal ancestry could be traced to Hercules. He had been instructed in all the learning of those times; but particularly dedicated himself to the cultivation of medicine, which he formed into a distinct science, collecting and arranging all the information on the subject that was then known. Not satisfied with the knowledge which he could acquire in his native place, he travelled for several years through different parts of Greece and Asia Minor. He visited the temple of Diana at Ephesus, and was at the pains of transcribing and arranging the records of cases and of successful methods of cure, which it was the custom to deposit on tablets in these temples. On retiring to his native island, after the laborious proofs he had given of his diligence and ardour, he continued to exercise his profession, and enjoyed the highest and most extensive reputation. Such was

the estimation in which his talents were held, that even princes were solicitous to allure him to their courts; but he was so strongly attached to his native country, that he resisted every temptation which the splendour or the favour of monarchs could hold out.

1129. Excepting one or two particular treatises, which bear his name, but the authenticity of which is dubious, the writings of Hippocrates are to be regarded rather as medical than physiological; but he seems to have been the first who formed a clear conception of the value of anatomy and physiology as the basis of medical reasoning. Originality of thought, combined with accuracy of observation, forms the characteristic feature of his writings; which contain, however, many traces of the Pythagorean philosophy, with which he seems to have been early imbued. He formed the bold conception of the existence of a principle, which he calls φυσις, or nature, exercising a general direction and superintendence over all the actions and movements of the body, and endowed for that purpose with a species of intelligence directed to beneficial ends. As subservient to this great and prime agent, he imagined that the functions were carried on by means of other subordinate powers or faculties; and also that they were subjected to the influence of the stars. He regarded the body as being composed of three kinds of substances, namely, solids, fluids, and spirits, and ultimately resolvable into the four primary elements of earth, water, air, and fire, the predominance of each of which in particular individuals gave rise to the prevailing temperaments, characterised by the peculiar combinations of the four qualities of dry, moist, cold, and hot. Hence arose his doctrine of temperaments, already noticed (§ 862). The anatomical details which are interspersed throughout his works are numerous, but do not exhibit any profound knowledge of the subject, besides being in many instances incorrect. The confession which he made on his visit to Democritus shows that he had not devoted any considerable portion of his time either to physiology or to practical anatomy. It is very apparent, indeed, that he never dissected a human body; and much could not be learned from the occasional dissection of brutes. So far was he from having any idea of the real nature of the circulation of the blood, which some have done him the honour to suppose he had discovered, that he seems to have imagined that the arteries contained air, and he was at a loss to determine whether the veins took their origin in the liver, the heart, or the brain. He includes under the same name the ligaments, the tendons, and the nerves, and makes no distinction between their respective offices in the economy. But these imperfections were more to be imputed to the unavoidable disadvantages of the times, than to his own deficiency either of

industry or of talent; for wherever he had opportunities of displaying these qualities, and of exerting the whole force of his original mind, he far surpassed all his cotemporaries. Hippocrates must indeed be regarded as the father of physiology, as well as of medicine; and his name will ever be cherished by posterity, as one of the most illustrious in the annals of science.

1130. Amongst the Athenian philosophers who paid attention to physiology, Socrates must not be passed over in silence; since he cultivated the science with a view to establish upon it, as upon the most solid foundation, the principles of natural theology. Plato, the friend and pupil of Socrates, likewise devoted a portion of his time to the study of animal structures, and indulged in a variety of fanciful speculations concerning the uses and functions of the vital organs.

1131. Aristotle, the tutor of Alexander the Great, whose transcendant genius embraced the whole domain of human science, prosecuted this, as well as every other branch of the history of nature, with an ardour and perseverance that have rarely been equalled, and never surpassed. Gifted with a mind of extraordinary acuteness and comprehension, he appears to have concentrated within it all the learning of his age, which, moulded and transformed by the power of his genius, assumed new forms of arrangement, yielded new products of generalization, and spread its luminous irradiation over every department of human knowledge. At the request of his pupil he undertook an extensive treatise on the natural history of animals; he was liberally furnished with specimens of all kinds, and empowered to command the services of numerous assistants, from every part of the vast empire of Alexander. He spared no labour in the prosecution of this undertaking, and in making the most profitable use of the resources thus placed at his disposal; and contributed in no small degree to the advancement of our knowledge of the animal economy in the diversified forms of life presented by nature. Yet with all the advantages he possessed, it would appear that his knowledge of human anatomy was exceedingly imperfect. He even acknowledges that the internal parts of the human body are but little known; and points out the probable advantages that might result from the examination of animals which have the nearest resemblance to the human species, for supplying these deficiencies. But his work on the history of animals, περι ζωων ιστοριας, is unrivalled by the magnitude of the field which it embraces, and by the vast information it contains. To him belongs the merit of arranging the facts in the order, not of their zoological, but their physiological relations; referring every organ to the functions it performs in the animal economy, and thus anticipating the very principle on which, in recent times, Hunter, Blumen-

bach, and Cuvier have founded their more rational and philosophical views of comparative physiology.

1132. The encouragement given by the Ptolemies, the successors of Alexander in Egypt, to every kind of learning, tended greatly to the advancement of anatomy and physiology. Permission was granted by these monarchs to dissect the human body, which none would otherwise have dared to attempt, in opposition to the prejudices of the Egyptians, which were no less violent against dissection than those of the Greeks.

1133. One of the earliest of the physiologists of this period was Erasistratus, the grandson of Aristotle, and the pupil of Chrysippus. Under the patronage of Nicanor, king of Sicily, he enjoyed frequent permission to dissect the bodies of those who were executed, and is even reported by Celsus to have had criminals delivered to him for the purpose of their being opened while alive, in order that the natural living state of the internal organs might be examined. This account, however, deserves to be regarded rather as a popular tale, which has no other foundation than irrational prejudices against dissection, and was propagated by idle credulity, and a passion for exaggerated scenes of horror. The works of Erasistratus are now lost; but from the quotations of later authors, he appears to have greatly advanced the knowledge of the structure of the human body, more especially by pointing out the circumstances in which it differs from that of other animals, whose anatomy had been previously studied as making the nearest approach to the organization of man.

1134. Another no less distinguished anatomist of the same period was Herophilus of Chalcedon, who also flourished at Alexandria. He was the disciple of Praxagoras, and was considered as the founder of the medical school at Alexandria. He was much occupied in the dissection of human bodies, and directed his attention particularly to the nervous system. One of the sinuses of the brain, which he is said to have more particularly described, bears to this day the name of the *torcular of Herophilus*. He is stated to have been the first anatomist who taught osteology from the human skeleton. He distinguished the nerves from tendons and ligaments, with which they had, before his time, been confounded. He also paid minute attention to the varieties of the pulse, and thus laid a foundation for a knowledge of the important function of the circulation.

1135. Few physiologists of any note are recorded as having flourished from the time of Herophilus to that of Galen. The names of Lycus of Macedonia; of Marinus, who lived in the reign of Nero, have been transmitted to us as the author of some elaborate treatises on the muscles; and also of Rufus Ephesius, who wrote a work entitled *Onomasia*, which was considered as the best system of anatomical knowledge extant at that period.

1136. Galen, the most celebrated and indeed the last of the physiologists of Greece, was born at Pergamos, in Asia Minor, about 131 years before the Christian era. His father was imbued with the love of letters, and was anxious that his son should receive the benefit of a learned education, which the early promise he gave of superior talents showed that he was well qualified to turn to advantage. He was placed under the tuition of the best philosophers of the time, and studied in all the schools with extraordinary diligence. His father died long before he could form any probable anticipation of the future fame of his son. It was two years after this event, that young Galen, who was now in his nineteenth year, first turned his attention to medical pursuits, of which he soon became passionately fond. As Alexandria was still the most celebrated school of medicine in the world, he travelled thither with a view of prosecuting his studies; in order to reap every advantage which foreign countries could afford, he visited in succession different parts of Asia Minor and the islands in the Ægean Sea. Anatomy was ever his favourite pursuit; but being debarred from the advantage of examining human bodies, the dissection of which had then been prohibited, even at Alexandria, he had recourse to that of such animals as were supposed to have the greatest resemblance in their structure to man. He has written very fully on every part of anatomy; so that his works may be considered as a system, exhibiting every thing which was known on the subject in his time. He was much impressed with the importance of anatomy as the basis of medicine and surgery, and enforces his opinion with singular acuteness and energy. This is evinced by the following passage in his second book of Academical Administrations:

"What can be more useful in wounds which are received in battle, in the extraction of darts, excision of bones, the reduction of luxations, the opening of fistulæ, than to be well acquainted with the anatomy of the limbs? It is of more use to be acquainted with the exterior than the interior parts of the body, as the shoulders, back, breast, the ribs, the belly, and the outward covering of the neck and head; for we are often required to cut into abscesses and sinuses. In the excision of bones it is necessary to cut and dissect; and if we do not know where the artery, vein, or nerve may be, we are more likely to be the cause of death than of health to the patient."

1137. Galen is entitled to great praise for having applied himself to the investigation of physiology in connexion with anatomy; so little had hitherto been known on this subject, that we cannot be surprised at the mixture of error which his works exhibit; but although he may often have proceeded on false principles and fallacious hypotheses, yet the reasonings themselves which he employs are always clear and conclusive. His account

of the uses of the hand, for example, is remarkably perspicuous and correct. He succeeded in establishing by experiment the fact that arteries contain blood, and thus refuted the doctrines of the Alexandrian school that they are merely filled with air, which they serve to distribute throughout the body. It is interesting also to trace the effect which these subjects of contemplation produced on Galen's mind. After reviewing the structure of the hand and foot, and their adaptation to their respective functions, he breaks out into the following apostrophe, admirably characteristic of a mind imbued with the genuine spirit of piety:

"I esteem myself as composing a solemn hymn to the author of our bodily frame, and in this I think there is more true piety than in sacrificing to him hecatombs of oxen, or burnt-offerings of the most costly perfumes; for I first endeavour to know him myself, and afterwards to show him to others, to inform them how great is his wisdom, his virtue, his goodness."

1138. The great reputation which Galen had acquired, instead of promoting, tended rather to impede the progress of anatomy and physiology during several succeeding centuries. Where no hope was entertained of emulating the fame of one who was regarded as an infallible oracle, all motive to exertion was repressed. But other causes of a political nature also contributed to the decline of anatomy, as well as of other branches of learning, from the time of Galen to the downfall of the Roman empire, and during the ages of intellectual darkness which followed. Learning, however, still continued to be cultivated at Alexandria, until the capture of that city by the Saracens, in the year 640, when its magnificent library was burnt.

1139. Anatomy and physiology began slowly to revive among the Arabians; but no addition seems to have been made by them to the knowledge which the Greeks had possessed on these subjects. The Arabian physicians were satisfied with what Galen had taught them; and as the rites of the Mahometan religion prohibited all contact with a dead body, an effectual bar was opposed to all improvement in anatomical or physiological knowledge. The work of Avicenna on anatomy is merely a compilation from Galen and other Greek authors; and whenever he ventures to differ from his authorities he is generally wrong. For more than a thousand years after the time of Galen, anatomical and physiological science may be considered as nearly stationary; for scarcely any discovery of the least importance was made during the whole of that period.

1140. The expeditions of the crusaders were the means of introducing into Europe some knowledge of the literature of the Arabians; and the light of science, after a long period of darkness and ignorance, began at length to dawn. In the fourteenth century, anatomy was revived by Mundinus, a Milanese, who

had become acquainted with the writings of Galen through an Arabian translation, and who published a system of anatomy in 1315.

1141. The destruction of the Greek empire by the Turks, in the succeeding century, tended to diffuse throughout the west of Europe, whatever portion had remained of the literature of the east. The learned of every profession fled from Constantinople, which had fallen into the hands of barbarians, and sought an asylum in Italy, where they disseminated the seeds of knowledge. The writings of Galen and of the ancients, could now be read in the original; their superiority to the Arabian authors was soon discovered; and such implicit deference was paid to their opinions, that for many ages no one would venture upon the slightest innovation. The improvement of anatomy was therefore exceedingly slow. It was promoted, however, by the exertions of eminent painters, such as Raphael, Albert Durer, Titian, and above all, Leonardo da Vinci, whose drawings evince considerable knowledge in that study.

1142. The sixteenth century was more auspicious to the progress of anatomy, which was beginning to be cultivated with ardour in Germany and France, as well as in Italy. Berengarius of Carpi, professor at Bononia, acquired such reputation by his skill in dissection, that he was regarded as the restorer of this science. The structure of the ligaments and bones was successfully studied by Charles Stephens; that of the blood-vessels by Fernelius; and that of the muscles by Andernach. Sylvius was also at this time celebrated as a teacher of anatomy.

1143. But the extravagant veneration of antiquity, that spell which has for so many ages held the medical world in thraldom, was at length broken by Vesalius, who boldly ventured to call in question the authority of Galen. This extraordinary man was born at Brussels in 1514, of a family which has for a long time cultivated medicine. He united to remarkable talents, a degree of ardour and perseverance which enabled him to overcome every difficulty; and his progress in the study of anatomy, for which he had very early shown a partiality, was commensurate with these great qualities. He commenced his studies at Louvain, and prosecuted them in Italy. In a short time he made himself master of the Hebrew, Greek, and Arabic languages; so that before he had attained his twentieth year, he had already read the works of Galen and Avicenna in the original. Such was his zeal for anatomy, that it is reported he used to rob the gibbets, and dissect the bodies in his bed-chamber. In a few years he excelled his teachers, Fernelius and Sylvius, who were esteemed the first anatomists of their time. He soon detected many errors in Galen, some of whose descriptions of parts had been taken from quadrupeds, and applied to man. These errors

he ventured to disclose and to correct in his publications; but his boldness in appealing to nature from the authority of Galen, drew upon him the enmity of all the admirers of that great master. He was assailed from all quarters with the bitterest invectives; and Sylvius himself has not scrupled, in the heat of controversy, to brand him with the epithet of *Vesanus*, or madman, in allusion to his real name. The criticism which Vesalius had passed on Galen, was retorted by his enemies upon himself; and it must be confessed that in the plates which Vesalius published, some errors of the same kind were detected. But still their general accuracy was undeniable. The work of Vesalius was soon acknowledged to be unrivalled, and its author eventually enjoyed a complete triumph over all his opponents.

His fame reached the eyes of Charles V., who appointed him his physician; but after being raised to that distinguished station, he was soon doomed to experience the inconstancy of fortune. Having obtained permission to examine the body of a Spanish gentleman, whom he had attended in his last illness, he began to lay open the chest, when the bystanders imagined they perceived a tremulous motion of the heart. This circumstance soon got wind, and probably with much exaggeration, reached the ears of the relations of the deceased, who, seized with horror, denounced Vesalius as a murderer; and coupling this charge with that of impiety, arraigned him at the tribunal of the Inquisition. Where superiority of knowledge was esteemed a crime, Vesalius, however unjustly he might be accused, was certain of condemnation. By the influence, however, of Philip II., who had then succeeded to his father Charles V., Vesalius was permitted to commute his punishment to a pilgrimage to the Holy Land, the merit of which, it was thought, might sufficiently atone for the heinousness of any crime. This journey he was accordingly obliged to perform; and on his return he was invited by the senate of Venice to teach anatomy, but he perished by shipwreck before he reached that city, when he was about fifty years of age.

1144. The impulse which had been given by Vesalius to the progress of anatomy, continued to operate; and many were the inquirers who pressed forward in the path in which he had so nobly led the way. The barriers to investigation had been removed; nature was open to inquiry; and men had only to observe and to think for themselves. Every year was now adding some new discovery; and it becomes no longer easy to trace the order of their succession, or to ascribe each to their proper authors. We shall endeavour, however, briefly to enumerate those which are most worthy of being noted.

1145. In the year 1561, Fallopius published, in Italy, his *Observationes Anatomicæ*, a work of much merit, and the fruit of great industry. About the same period also, Eustachius arrived

at great eminence as an anatomist, and published a set of plates which he himself engraved; their beauty and accuracy excite astonishment even in the present day.

1146. Fabricius ab Aquapendente, a professor of anatomy at Padua, was also one of the most distinguished anatomists and physiologists of that period. He published a splendid volume on the formation of the fœtus, and bestowed much pains in investigating the mechanism of the motions of animals. He was the first who delineated and drew the attention of the public to the valves of the veins, which, had indeed, been imperfectly seen by Stephens, Sylvius, and Vesalius, and the existence of which had been denied by Fallopius and Eustachius. It was this discovery, perhaps, more than any other, which paved the way for that of the real course of the blood in its circulation; a discovery which was reserved for the illustrious Harvey; and which has justly rendered his name immortal. As it may be interesting to review the steps which led to this important physiological discovery, we shall retrace its history to a period somewhat more remote.

1147. It is perfectly well ascertained, from an examination of the works of Galen, and of others who have copied from him, that the ancients had not the most distant notion of the real nature of the circulation. The blood was believed by them to have its origin in the liver, and to be undulated alternately in opposite directions in the veins; they imagined that the finer part of it transuded through the septum, or partition separating the cavities of the heart, from the right to the left side, where it mingled with the air received into the lungs, and forming a vital spirit, was moved by a sort of flux and reflux along the arteries.

1148. On the revival of anatomy in Europe some vague notions of the pulmonary circulation appear to have suggested themselves to many eminent men. Vesalius demonstrated that the blood could not possibly pass from the right to the left ventricle through the septum of the heart. Realdus Columbus, who was professor of anatomy at Padua, and had been a pupil of Vesalius, distinctly traced the passage of the blood through the vessels of the lungs. The same fact had, however, been already discovered by Michael Servetus, who was born in Aragon in 1509, and who is more celebrated as a theologian than as a physiologist. Further progress was made by Andrew Cæsalpinus, an Italian physician, who speaks of a communication existing between the veins and arteries at their remote extremities, and notices the effect of the valves of the arteries and of the auricles as calculated to prevent a reflux of the blood; but he is quite at a loss to reconcile this observation with the common notions, which he had imbibed, and to which he still adhered, of the functions of these vessels. But notwithstanding these apparent approximations to the truth, it is probable that many ages would have elapsed before the complete

discovery of the circulation, if some bold and penetrating genius, such as that of Harvey, had not arisen.

1149. This illustrious man was born in the year 1578; and the circumstances of his family gave him the advantage of a liberal education. After six years spent at Cambridge, where he was instructed in all the philosophy of the times; finding that the university furnished but very imperfect means of studying either anatomy or medicine, he repaired, at the age of twenty-one, to Padua. Here he became the pupil of Fabricius, who was at the time demonstrating to his students, with all the enthusiasm of a discoverer, the newly observed valvular structure of the veins. The attention of Harvey being thus directed to this remarkable conformation, he became anxious, on his return to England, to prosecute the inquiry into the purposes which were accomplished by it. He was obliged, for this purpose, to make many experiments on living animals; and these revealed to him the real course of the blood in its circulation; a discovery which ranks unquestionably as the noblest and most important ever made in Physiology. Harvey taught this new doctrine in his lectures about the year 1616; but did not publish any account of it till the year 1628. On its being made known to the world, it met with the most violent opposition; and so inveterate were the prejudices of the public, that the practice of Harvey was considerably diminished in consequence of his discovery. It was remarked that no physician who had passed the age of forty would admit the truth of a doctrine so much at variance with all the systems in which he had been educated. Envious of his growing reputation, many of his cotemporaries had recourse to all kinds of sophistry with the view of detracting from his merit. They at first vehemently contested the truth of the doctrine; but afterwards, when forced to admit it by the decisive evidence adduced in its support, they changed their ground of attack, and alleged that the merit of the discovery did not belong to Harvey, the circulation having been known even to the ancients. But vain were all the efforts of envy and detraction to lessen that fame, which will command the admiration of all future ages. The physiological researches of Harvey were not confined to the function of circulation; but extended also to that of generation, and to the evolution of the ovum, on which he made a series of very valuable observations.

1150. The beginning of the seventeenth century was an important era in anatomy, for it was also marked by another brilliant discovery, namely, that of the lacteals by Aselli in 1622. It appears, from the testimony of Galen, that Erasistratus had noticed white vessels on the mesentery of kids; but the observation was not followed up, and these vessels were supposed to have been merely veins. Aselli was born at Cremona, and was professor

of medicine at Pavia. He observed on the mesentery of a dog numerous vessels, filled with a white fluid; he was immediately convinced that he had made an important discovery, and uttered in the fulness of his feelings, the exclamation "Ευρηκα." Perceiving similar vessels upon the surface of the liver, and entertaining some theoretical views concerning the functions of that organ, he too hastily concluded that the lacteals terminated in the liver. Aselli published an account of his discovery with coloured prints in 1627.

1151. It was not till about thirty years after this discovery of Aselli, that the lacteals were traced by Pecquet, a French anatomist, into the receptaculum chyli, and thence into the thoracic duct, which he also followed to its termination in the great veins near the heart. These observations were published in the year 1651. All these discoveries were made in brutes; and it remained to be shown, that similar structures existed in man. This was accomplished by Veslingius, who had already demonstrated the human lacteal vessels, in the year 1634; and the human thoracic duct in 1649. These parts were afterwards more fully investigated by Peirish and Vanhorne. Shortly afterwards, the general absorbents of the body were discovered by Olaus Rudbeck, a Swede, who was born at Avosa, in the year 1630. This discovery was also claimed by Thomas Bartholin, who was born at Copenhagen in the year 1616: but by his own account he had not seen these lymphatic vessels till December 1651, whilst Rudbeck had not only observed them, but had distinguished their peculiarities the year before; Rudbeck had also traced them to the thoracic duct, which Bartholin had failed to do. Dr. Joliffe, an English physician, has also contended for the honour of this discovery; but from a comparison of dates, the priority is clearly in favour of the Swedish anatomist. When we consider the minuteness of these vessels and the transparency of their coats, we are able to appreciate the difficulty of detecting their existence, and our surprise must cease at their having remained unknown for so many ages.

1152. No discovery of equal importance to those we have mentioned has been made in anatomy since that period. Many parts of the body, which were unknown in Harvey's time, have indeed been brought to light; but the principal improvement has consisted in a more accurate knowledge of the composition and minute structure of the several organs. For this we are chiefly indebted to the invention of new anatomical processes, both of investigation and of demonstration. Two principal means were employed in these researches; the one was the microscope, the other the practice of injections.

1153. The microscope was first applied to the purposes of anatomical inquiry about the year 1661, by Malpighi, who was

born near Bologna, in the year 1638. He examined, by the aid of this instrument, the minute organization of all the vital parts; and more particularly the glands. These researches into the intimate texture of various parts of animals were prosecuted with great ardour by Leewenhoek, a Dutch anatomist, about the year 1680. In exploring this new field of inquiry, which opened views so remote from common apprehension, his enthusiasm has often carried him beyond what was real, both in the power of the instrument, and in the results it afforded. But still much has been effected, and the boundaries of the science have been greatly enlarged by the skilful employment of the microscope.

1154. The arts of preserving the parts of animals when dissected, by drying and varnishing them, and by other modes of preparation, had long been practised; and in these Vanhorne is said to have attained superior excellence. But the most valuable invention of this kind was that of injecting into the vessels certain fluids which would, after a time, become solid, and admit of the course of these vessels being easily traced. The injecting syringe used for this purpose was invented by De Graaf, a Dutch anatomist, about the middle of the seventeenth century; and soon after, the proper materials for injection were discovered by Swammerdam. The art of injection was carried to a very high degree of perfection by Ruysch; but with a degree of selfish illiberality which cannot be too strongly condemned, he kept secret the methods he employed.

1155. The advancement of Physiology was greatly promoted both by the practice of this art, and by the dexterous employment of the microscope; and discoveries in this science have succeeded one another so rapidly from the period of their invention, that in giving an account of them, it is scarcely possible to preserve an unbroken narration; and it would be impossible, in this sketch, to recount the numerous minor improvements which have been made in our knowledge of this department of science from the epoch down to which we have now brought its history. Much error was still mingled with the acquisition of real knowledge on these subjects; and it has required the exertion of the more severe and scrutinizing spirit of inquiry which characterizes the philosophers of a later period, to winnow the grain from the chaff, and refine the pure metal from the superfluous ore which had been dug up along with it from the mine. Physiologists were slow in recognising the peculiarities which appertain to the vital powers, and those of the beginning of the eighteenth century long persisted in ascribing the phenomena of life to the operation of the same laws which regulate those of inanimate nature. Hence the history of physiology is occupied at that period, chiefly by the contentions which arose between the rival sects of chemists, and mathematicians; each striving to apply to physiology the princi-

ples and methods of investigation which prevailed in their respective sciences. Much ingenuity was wasted in these unprofitable researches; for although some important fact was occasionally brought to light by the prosecution of elaborate inquiries, prompted by endeavours to support each favourite speculation, yet not one of these hypotheses could long maintain its ground, nor could it be said that a single general principle had been established.

1156. A new light was now thrown on the subject of physiology, which tended to dissipate the clouds of error in which it had been obscured by the dogmatical tenets of both the chemical and the mechanical sects; and to effect a complete renovation in the science. The new doctrine which thus superseded the former, originated in Stahl; who, although educated in the school of the chemists, soon shook off the trammels of his instructors, and with the vigour of native genius began to reflect for himself. He perceived the futility of their doctrines, and strongly impressed with the wide differences observable between the phenomena presented by organized beings, and those which the same bodies exhibit when devoid of vitality, conceived that they were governed by some agency opposed to the ordinary physical powers of matter; and to this agent he gave the name of *anima* (see § 101), ascribing to it endowments allied to intelligence, which controlled all the changes in the system, and of which the operations were always directed to salutary ends. This hypothesis, gratuitous and unphilosophical as it was, had the beneficial effect of directing the attention of physiologists to the phenomena which peculiarly characterise the living state, and prepared them for the study of the laws of these vital phenomena. Much praise is also due to Hoffmann, who, although too hasty in his conclusions to inspire confidence in their correctness, appears to have been amongst the earliest of the followers of Stahl, who entertained proper views of the principles and objects of physiology. Boerhaave was celebrated at this time for the extent of his information, the soundness of his judgment, and his talent in the art of instruction. His doctrines had extensive influence in the schools of medicine; but being destitute of the solid support of facts, they did not long survive their propounder.

1157. But the great founder of modern physiology is unquestionably Haller, whose labours in this field of inquiry are so prodigious in extent, and so fruitful in results, that the publication of his Elements, to which it may be perceived we have had occasion in the course of this treatise perpetually to refer, must be considered as forming an important era in the history of the science.

1158. The attention of physiologists was beginning to be more particularly directed to the functions of the nervous system; and the labours of Whytt at this period had tended much to give it

this impulse. Amongst the host of names which claim our notice as having contributed their share in the rapid progress of discovery, since this time, we can point out only a few of the most illustrious. William Hunter, the Monros, and Cullen, are amongst those most eminent for the services which they have rendered to physiology; but perhaps the largest contributor to the mass of facts collected in modern times was John Hunter. The merits of Bichat were also of the first order; and considering how early his career was cut short by the hand of death, the additions which he has made to the stock of facts, and the influence which his opinions have had on the progress of the science, must excite astonishment. Germany and Italy, as well as France, have been prolific in ardent devotees and successful cultivators of physiology; and although it might be invidious to point out particular names, we should be sorry to omit those of Spallanzani, Blumenbach, Sömmerring, Meckel, Gmelin, and Müller; nor should the justly earned fame of Cuvier be passed over in silence, even in this brief and imperfect retrospect of the benefactors of our race, for such we must esteem all those who enlarge the sphere of human knowledge, and thereby confer the most solid accession to the power and happiness of man.

APPENDIX.

ON 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 analysed; 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 him far behind in every competition, where the exercise of this faculty was essential to success. This observation gave rise to others; it suggested the notion, that other intellectual endowments might also be indicated by the features; and Gall, by degrees, came to imagine that he had discovered a number of external signs, which respectively indicated a decided turn for painting, for music, for mechanical arts, or other objects. He had by this time commenced the study of medicine; and, in the course of his academical instructions, he heard much about the functions of the muscles and viscera; but nothing was taught about those of the brain and its different parts. It then occurred to him, that the differences he had already

noticed in the external configuration of the head, as connected with certain dispositions of mind, were occasioned by differences in the form of the brain. Delighted with the prospect which this idea opened to him of discovering the functions of particular parts of this organ, and of obtaining an insight into the connexion between the mind and the body, he formed the resolution of prosecuting the research, till he had either accomplished his object, or satisfied himself that it was not to be attained by that method. Natural history, which had long been his favourite study, furnished ample scope for the extension of these inquiries. He had been in the practice of collecting plants and animals of various kinds, and of arranging them, not according to the artificial methods of classification detailed in books of science, but according to their more obvious resemblances. He now studied the relations between their external forms, and their natural habits and dispositions. Dogs showed him the greatest diversities in their capabilities of being educated. He remarked that some were naturally expert at the chace, while others, of the same breed, could not be trained without the utmost difficulty; that some perpetually lost themselves, while others found their way home from great distances. In birds, he observed that one would listen with attention to a tune which it heard, and immediately learn it; while another of the very same brood would sing nothing but the note that was natural to it. Whence, he would ask himself, can arise this wide diversity among individuals?

The solution of this difficult question was not to be hoped for, unless by means of observations conducted on the largest possible scale. He therefore set about examining all the skulls he could lay hold of, that had belonged to individuals whose history was known. He looked out for all persons in any way distinguished for a particular talent or moral quality. He examined their heads with great attention, and noted the peculiarities in their shape. He also collected observations on other individuals, who were remarkable for the weakness of any faculty, and then compared together the positive and negative indications. On the other hand, when he chanced to meet with a head that presented some singularity in shape, he was at much pains to obtain information as to the moral and intellectual character of the person to whom it belonged. When he had no other resource, he did not scruple, as Dr. Spurzheim informs us, to address his questions directly to the person in whose head he observed any distinct protuberance. We are also told, that he was in the habit of collecting around him the boys he met with in the streets of Vienna, and of inducing them, by petty bribes, to confess their own faults, and betray those of their companions. He excited them, for instance to fight together, in order to discover which 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 hap-

pened 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 craniosco-pical 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 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 Physiogno-*

nical 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 Walton 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 by 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 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 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 savave 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 development 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 development 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, Sömmerring, 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 he 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 at 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, Sömmerring 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 conceived that the different motions or oscillations of this fluid are the immediate material cause of our sensation.

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 secretes 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, showing 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 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 meet 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 *viee 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 paroxysms 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 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, Sömmerring, &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, 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 shown to us by anatomy, can teach us *à 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 shows 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 development. The coincidence is so uniform as to justify the general inference, that wherever any organ is met with in a higher state of development, 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 development of different parts of the brain. It is reasonable to suppose, that the organs 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 development. 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 succeseive 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 development, 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 development 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 situate 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, situate behind the orbits, indeed, require some exercise on the part of the organoscope, in order to be exactly determined. The development 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 part of the brain, which *is* situate 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 development of their respective nerves, shows 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 and 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 man 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 *ghrist*, 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 situate 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 man 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 development of the cerebellum is simultaneous with that of the genital organs at the period of puberty, and early castration prevents its development, 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 situate 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 monkeys. 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 monkeys have much attachment to their progeny. The Doctor pursued this idea, and found that it applied perfectly to the observed appearances, as the development 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 situate on each side of the former, immediately under the *lambdoidal suture*, and gives a fulness 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, situate 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, especially 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 development 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 organ 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 merchandise; 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 situate 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 situate 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 too 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 opinions 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 situate on the superior middle part of the forehead. In most ani-

mals 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 has 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 situate 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 development 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 situate 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 development 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 perfecton.

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 situate 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 development of this organ, which is situate 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 occupied 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 situate 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 situate 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, Kästner, 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 Haydn, 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 eye-lid 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* (situate 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.*

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 treat his subject by description chiefly, and one in whom Eventuality is large and Individuality small, will narrate actions, but deal little in physical description."†

Two other primary faculties are mentioned by Mr. Combe; one, which he terms *Alimentiveness*, or the desire of eating and drinking; and another, which had 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 development 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

* System of Phrenology, fourth edition, p. 381. † Ib. 518.

to the latter; for crimes are considered as flowing from the abuse of certain 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 the development, 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 operation 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 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.

Dr. 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 *à 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 examina-

tion 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 insiduous minings of scepticism, and bidding defiance to the rude assaults of argument. The appeal to thé 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 induction 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 confirma-

tion 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 inductions,

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 development, 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 Encyclopædia 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,"* 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 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."† 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 *à 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."‡ 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 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 on 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

* Phrenological Journal, i. 166. † Ib. i. 168, 169. ‡ Ib. 166.

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*, *acquisitiveness*, *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."* 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 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 development, 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

* Illustrations of Phrenology, p. 92.

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 psychology 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 development, 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 sytem 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 be laid hold of in the different proportional development 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 development 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 psychial properties in co-extension 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."*

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 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, and a scrupulous rejection of error, would have shown 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 cata-

* Treatise on Insanity, p. 465 to 474.

logue ? 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."*

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 professedly 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 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

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

discarded as an hypothesis without foundation. At present, most inquisitive persons seems 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 amongst 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 Salpétrière, 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 Salpétrière, 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 hunderds of brains without finding any thing that appeared to him favourable to the phrenological theory."*

* Treatise on Insanity, pp. 476, 477.

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."* 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 development, and 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."†

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

* Phrenological Journal, viii. p. 654.
† Essays on Phrenology, p. 71.

and hair-breadth differences 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 almanac; 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 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, how-

ever, 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 resultant 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 ratiocination.

"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 development, 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* 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 organ, according to Mr. Combe, is to "incite young men to choose 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

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

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 craniosco-pical 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 developments, 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.

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