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MEDICAL SCIENCES

INTRODUCTORY LECTURE

ON

HUMAN AND COMPARATIVE

PHYSIOLOGY.

DELIVERED AT THE NEW MEDICAL SCHOOL IN ALDERSGATE STREET.

BY PETER M. ROGET, M.D. F.R.S. &c.

CONSULTING PHYSICIAN TO THE QUEEN CHARLOTTE'S LYING-IN HOSPITAL, AND SENIOR PHYSICIAN TO THE NORTHERN DISPENSARY.

LONDON:

PRINTED FOR

LONGMAN, REES, ORME, BROWN, AND GREEN, PATERNOSTER-ROW.

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ADVERTISEMENT.

In venturing to publish the following Discourse, I have yielded to the solicitations of many of the Gentlemen who heard it delivered. I have also been influenced by the consideration, that the subject to which it relates has not, in the schools of this metropolis, been hitherto sufficiently regarded as a distinct and essential object of medical education; and by the hope that some utility may result to those who are commencing their course of studies, from an exposition, such as I have here attempted, of the objects and scope both of Human and

Comparative Physiology,—of the relations in which they stand to the other branches of medical science,—and of the elevated rank which they are entitled to hold among the departments of human knowledge. With these views I have here given to some topics more ample illustration than the time, within which the delivery of a lecture must be limited, could have allowed. I have also subjoined a tabular view of the Classification founded on physiological distinctions, which Cuvier has adopted in his "*Règne Animal*," with examples of animals belonging to each division; as I conceived the student might derive assistance from such a table in the prosecution of his inquiries.

Bernard Street, Russell Square,
November 7th, 1826.

INTRODUCTORY LECTURE

ON

HUMAN AND COMPARATIVE PHYSIOLOGY.

Delivered at the New Medical School, October 3d, 1826.

GENTLEMEN,

THE human body, in common with all living beings, presents to the philosophical observer a train of phenomena, which have a totally different character from the changes that take place in inanimate matter. To the ordinary properties possessed by all material bodies, beings endowed with life have other properties superadded. Our ideas of life imply the union of these characteristic properties: but although the general notion we acquire respecting each of them individually, is tolerably distinct, yet their combination is not sufficiently uniform to admit of any precise or logical definition. A certain mechanical configuration, or texture, consisting of a regular arrangement of fibres, or of laminæ, with interposed cavities, occupied by different kinds of fluids, and a certain symmetrical disposition of parts, which are observable in all living bodies, convey to us the idea of an individual system, more or less complicated, but always evidently adapted to particular purposes: and such we denominate an *Organized Structure*. The Chemical properties of the solids and fluids which compose these organized structures, are also widely different from those which distinguish the products of the mineral kingdom; and exhibit in the mode in which their elements are arranged and combined, a complexity at least as great as that which pervades their mechanism. If we follow the series of changes to which these bodies are subjected, a new order of phenomena presents itself, to which there exists nothing analogous in any other part of nature. From an imperceptible atom, we see the rudiments of a vegetable or animal arise; we behold them gradually dilating in all their dimensions; the semi-fluid portions acquiring cohesion, and giving rise to filaments; these filaments extending into membranes, and investing the yet tender solids. We observe these solids condensing by degrees into firmer organs, capable themselves of containing fluids, of impelling these fluids through numerous channels, of receiving other fluids in return, and of reiterating these actions with unwearied constancy. We see all the parts expand by a slow but uniform increase, and in regular proportion, till they have attained their prescribed dimensions. New organs are developed in succession, which unite their energies with those of the former, and give the last finish to the elaborate structure.

The growth of an organized being is a process totally different from the increase of a mineral body. The latter is the result of the simple law of aggregation, by which particles scattered through a fluid are brought together into one mass, either entirely solid, or consisting of a confused admixture of solid and fluid parts. The solid portions assume regular geometric figures, bounded by plane surfaces, which are inclined at certain angles, admitting of accurate mathematical determination. These polyhedral bodies, or crystals, are capable of indefinite augmentation of size by the accretion of new layers of materials, which apply themselves to its surfaces in the same regular order of arrangement as the nucleus they surround; and the crystal, whatever magnitude it may have attained, is still nothing more than an accumulation of minuter crystals, of the same determinate and invariable form. It is homogeneous throughout its whole extent; so that the mechanical separation of its parts, although it may destroy the form of the aggregate mass, yet effects no change in its chemical properties.

To this simple process, the increase of an animal or vegetable bears no real analogy. It is effected, indeed, by the addition of foreign materials; but these materials are first received into internal cavities, or vessels, where they undergo a slow and gradual alteration of their mechanical and chemical condition, and where they are subjected to a variety of processes, both of decomposition and of combination: processes which modify their nature, assimilate them to the properties of the organized system which operates these changes, and finally identify them with that structure.

I have more fully insisted on these differences, because they appear to be lost sight of in the celebrated definition of the three kingdoms of nature, framed by Linnæus; namely, that *Minerals grow; Vegetables grow and live; Animals grow, live, and feel:* a mode of expression which would seem to imply that the increase of minerals, and the growth of organized beings are analogous processes; when, in fact, there is no real similitude between them.

But the process of regular nutrition is not the only characteristic of the state of life. Many circumstances occur in the living system, which indicate a capability of continuing these actions, notwithstanding the occurrence of accidental obstacles, which may injure its mechanical structure, or de-range its operations. This power of accommodating itself to external situation and to the action of foreign agents, and also of repairing injuries, exists in a greater or less degree in every species of organized and living being.

A constant circle of actions and reactions is thus established, which continue their course, with various degrees of activity, for a certain period of time. But at length, even when placed under the most favourable circumstances, they are observed to proceed with more languor; the vital energies, by which they are sustained, decline; the fluids are gradually dissipating, and the repair of the substance of the body falls short of the waste: the solids dry up and harden: the moving powers become torpid. All motion finally ceases; and the materials of which the body had been composed, like those of a deserted edifice, fall to pieces, and moulder into their original elements; and while the parts that are most fitted to resist the ravages of time may still remain as rude monuments of the fabric they supported, the rest are scattered abroad, leaving no trace of their former existence.

But though individuals perish, nature is ever careful that the race shall be preserved. By a process veiled in unfathomable mystery, new beings are seen to spring, perfectly similar to those which gave them birth. These grow by the same powers of nutrition; they exhibit the same succession of phenomena; they yield sooner or later to the imperious law of mortality, inseparable from the gift of life; after having, in their turn, given rise to another race of beings, destined to run through the same perpetual cycle of changes and renovations.

Such are the leading features of those powers which are possessed in common by animals and by vegetables, and of which the assemblage is comprehended under the general term of LIFE. Of the nature of the link which unites these phenomena we are wholly ignorant; but it is natural to conceive that some such link exists; and on this assumed foundation has the term of *Vital Principle*, or *Principle of Life*, been introduced, to express the law of organized matter on which all the phenomena of life depend.

The Physical Sciences, including Natural Philosophy and Chemistry, are concerned with the properties of unorganized matter; and it is the object of those sciences to reduce the phenomena, resulting from these properties, to the smallest possible number of general laws, and to apply these laws to the explanation of other observed phenomena. The first step in this process is the classification of the phenomena as they naturally present themselves to our observation: the next, is to trace their connections by investigating the phenomena which result from artificial combinations of circumstances. By a series of well conducted experiments we aim at reducing each class of phenomena to its simplest conditions; and by afterwards recombining them in various ways, we are enabled to verify our theories, by comparing the results with the appearances presented by nature. The properties of dead matter being simple and definite, however variously they may be combined, it is in general possible to unravel these combinations.

But the application of the same methods to the Physiology of animal or vegetable life is attended with infinitely greater difficulty. The immense number of species of living beings, the variety and complexity of the appearances they present, and the extended chains of connection that pervade every part of organic nature, are strikingly contrasted with the simplicity, the constancy, and the uniformity of those physical forces which actuate the inorganic world. In the subjects of Natural Philosophy and of Chemistry, all is found to be in strict conformity to the mathematical relations of space and quantity ; all is measured out with the most exact precision ; all is conformable to the most rigid order. The principles which are concerned in these operations of nature are few and simple : their combinations are susceptible of rigorous calculation ; and therefore their effects can be predicted with unerring certainty. The earth revolves on its axis with a uniform and invariable velocity. It proceeds on its orbit round the sun, unaffected by the eruptions of volcanoes or the commotions of earthquakes. The seasons return at stated periods; the ocean swells and subsides in strict obedience to the laws of gravitation. The perturbations of the planets and their satellites are but the necessary consequences of the same general law, which, notwithstanding all the complex movements resulting from their mutual actions, imposes a necessary limit to their oscillations, and secures the stability of the whole solar system.

In the minutest mineral body we trace the same harmony and mathematical precision, that are displayed on so magnificent a scale in the construction of the heavens. The atoms of every crystalline body are found to arrange themselves in conformity with certain geometric laws. The figure of every drop of fluid is defined by analytical equations expressive of the balance of cohesive and repulsive forces.

The forces of Affinity, which are concerned in the phenomena of Chemistry, are no less constant and uniform in their operation. The union of elements in every chemical compound is regulated by the law of definite proportions, and the forces which actuate them have become the subjects of calculation. No where do we meet with a gradual modification of properties. All is defined, all is bounded. The great Architect of the Universe has every where employed the rule and the compass, and prescribed to every power and element its proper sphere and limit.

The scene totally changes when we survey the system of organized and living beings. On whatever side we turn our eyes, a boundless variety of objects bursts upon our view. A vast multiplicity of forms, a wonderful complexity of mechanism, a prodigious intricacy of effects conspire to dazzle our senses and perplex our understanding. The wider the expanse of our horizon, the more numerous are the anomalies which strike us. We feel ourselves ushered into a new world, where the simple order we had traced in the mineral kingdom no longer appears to exist; but, on the contrary, the most complex arrangement is manifest in the minutest subject. A variety of unknown powers are called forth; a number of new and subtle agencies are at work; and a totally different class of phenomena make their appearance. These phenomena are not capable of being explained simply by the laws of Mechanism or of Chemistry; they are of too complicated a character to admit of being reduced by inductive reasoning to one single principle, in the same way in which the movements of the celestial bodies are reducible to the single law of gravitation : they imply the operation of a number of principles quite distinct from those which govern inorganic matter.

Not only do we distinguish that several powers are in operation ; but we are able to trace in them a certain gradation of ascent, or of remoteness from the ordinary physical powers of matter. Thus the mechanical properties of cohesion, and of elasticity, which exist in the solid materials of the mineral kingdom, are modified in a very peculiar manner in organic products, in consequence of the singularly complex arrangement of the elements which constitute the texture of every part of an animal body.

In addition to these mechanical properties we find a power provided, which is quite peculiar to animal life ; for in no part of inorganic nature are we presented with any force analogous to it. It is a power which belongs to that particular animal structure, denominated the *Muscular fibre*, and which forms the basis of what are called *Muscles*. A muscle is a fleshy mass, consisting of fibres, endowed with the property of contracting in their length, under certain circumstances, and thus of bringing the two ends, and the parts to which those ends are attached, nearer to one another. This contraction is performed with astonishing quickness and force, so as to overcome considerable resistances, or to raise immense weights. The power which is thus inherent in the muscles of animals, is, as we shall afterwards find, totally different in its character from any of the powers which are met with in inorganic nature; and it appears to have been established in the system, as the great source of mechanical power required for the operations of the animal machine.

If, again, we view the animal economy in its chemical relations, we find that the affinities and attractions which govern the same elements, when unorganized, are modified and controlled by the agency of new powers, derived from the conditions of vitality, and by which changes are effected in the arrangements and combinations of those elements, differing totally from any thing which nature elsewhere presents, or from any thing which human art can produce.

A still more elevated order of phenomena force themselves upon our attention, in those which are derived from the energies of that part of the animal fabric which is termed the *Nervous system*. These phenomena are dependent upon a new and subtle agency, establishing extensive and rapid communications between distant parts, and connected on the one hand with the muscular power, already noticed, and with the sentient principle, on the other. It constitutes another class of those elementary powers distinguishing the living system from dead and inorganic matter.

The phenomena of life result from the conjoined and harmonized operation of these several powers; and it is one of the great objects of the science of Physiology to ascertain the laws of these physical powers, or to determine the order in which the phenomena stand related as causes and effects. This, which may be considered as the truly philosophical part of the science, has hitherto received less attention than its importance demands: and Physiologists have, in all ages, shown too great an eagerness to attempt the reduction of all the phenomena to a single principle, or law of life: and, neglecting the preliminary study of the several distinct powers, of which the operation may be traced in the changes occurring in the living animal system, have been guilty of too hasty and unwarrantable generalizations. These philosophical investigations, it is true, are attended with peculiar difficulty: for the resources of experimental inquiry are here extremely narrowed, in consequence of the close connections which subsist among the powers concerned, and which preclude us from opportunities of studying them in a separate or isolated state, and of ascertaining distinctly their respective modes of action.

But although the nature of the subject precludes our arriving at results of the same general and comprehensive nature in Physiology, as we have obtained in the purely physical sciences; it, on the other hand, opens to us other sources of knowledge, and other principles of arrangement. Although the immediate springs of this vast system of life may elude our research, there is unfolded to our view a new principle of order, which governs all these connected series of mutations, and pervades all these refined and artificial combinations of machinery. They are all strongly and indelibly impressed with the character of INTENTION. They are all manifestly directed to objects of utility. They bear the stamp of intelligence and of power extending far beyond the limited sphere of our comprehension.

Thus, independently of the relation of cause and effect by which in common with all the changes which we can see or conceive, the phenomena of life are connected, they also stand with regard to one another in the secondary relation of means to an end: and this new relation, which scarcely ever finds a place in the sciences of inorganic matter, becomes a leading principle of arrangement in Physiology. It presents the science under a new aspect, and creates an interest of a different, and superior kind to that which mere physical relations are calculated to inspire. Hence it has ever been one of the principal objects of Physiology to study the *Functions* of life; or in other words, to investigate the purposes to which the different structures of the body, and the actions they exhibit, are subservient in the animal economy.

But in pursuing these fascinating subjects of inquiry, Physiologists have too often lost sight of the essential line of distinction which should be drawn between the relation of means and ends, and that of causes and effects. In framing theories to explain the phenomena of life, they have most frequently satisfied themselves with pointing out their final causes, that is, the objects which are answered in the economy: and as the detection of this final cause often calls for the exertion of considerable sagacity, the inquiry has been suffered to terminate here; and it has not been perceived that the physical theory was left in as great obscurity as before. This proneness to substitute final for physical causes has been the source of frequent delusion, by insensibly leading the inquirer to believe that he is really in possession of the physical law on which the phenomenon in question is dependent, when in fact he has done nothing more than given to it a name with reference to the intelligent agency by which it was adjusted to its object. In their eagerness to grasp at this kind of knowledge, Physiologists have thus too often mistaken the shadow for the substance.

The writings of the older physiologists exhibit continual instances of this confusion of ideas. Thus the notion of an *archeus*, or *anima*, entertained by Van Helmont and Stahl; that is, of a presiding spirit, to the operation of which they referred all the vital actions; although perhaps naturally suggesting itself to the mind, is yet evidently an unphilosophical assumption, incompetent to explain the phenomena in question, and occasionally even at variance with these very phenomena. The *Vis medicatrix naturæ*, to which Hoffman and Cullen so frequently appeal in their pathological reasonings, and which supplied them with ready solutions for 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, the greatest

Physiologist since the days of Haller, ascribes to his diffused vital principle, we may continually trace the same want of discrimination between the intelligence, by which the conditions of animated nature were originally adjusted to a variety of contingent circumstances, and those physical laws and 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

* On the subject of the coagulation of the blood, Hunter uses the following expressions: "My opinion is, that it coagulates from an impression: that is, its fluidity under such circumstances, being improper, or no longer necessary, it coagulates to answer now the necessary purpose of solidity. This power seems to be influenced in a way, in some degree similar to muscular action, though probably not entirely of that kind; for I have reason to believe, that blood has the power of action within itself, according to the stimulus of necessity; which necessity arises out of its situation."—Hunter on the Blood, p. 25.

the final cause only, and not the physical cause of this phenomenon that is assigned: and it is also evident that no advance is thereby made towards the discovery of the latter.

In like manner, the principle of life is represented as a new power with which organized beings are endowed; a power which modifies and controls the operation of those simpler physical laws to which matter, in its unorganized state, is subjected; a power which imposes new cohesive forces on the materials of the solid structures of the body, which imparts to the fluids a new property of coagulation, which alters the order of chemical affinities between their elements, retaining them, contrary to their natural tendencies, in a certain state of equilibrium, and resisting the agency of several causes tending to destroy that equilibrium; and which, lastly, produces, in a degree somewhat corresponding to the wants of the system, either an evolution or an absorption of caloric. All these, it must be acknowledged, are purposes of manifest utility; being directly conducive to the welfare of the individual, and indeed essential to its continuance in the living state. As means conducive to a specific end, the reference of all these phenomena to the same class is unobjectionable. The fallacy lies in regarding it as a philosophical generalization of effects of a similar kind, indicative of the operation of a simple power in nature. Between many of the effects in question there exists not even the remotest analogy. 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 principle. Judging from the observed effects, therefore, which differ much from each other, as well as from other phenomena in nature, we ought to infer the agency of several distinct principles, the concurrence of which is required to produce all the complex phenomena of life. We are, no doubt, unavoidably led to view these phenomena as conjoined, because we readily perceive that they tend to the same object, the preservation and welfare of the beings to which they relate. But the unity of design is an attribute of intellect alone, and does not necessarily imply the unity of the agents employed in their production. However natural it may be to conceive the existence of a simple principle of life, and however possible it is that this hypothesis may ultimately be established as the true one by future discoveries, we should recollect, that, in the present state of our knowledge, it is a mere fiction of the mind, not countenanced by the phenomena themselves, in which we see so much diversity, and therefore not admissible as the result of a truly philosophical induction.

Bichat, who was impressed with the necessity of drawing certain lines of distinction between the powers of life, has nevertheless perplexed his system by taking final causes as the basis of his divisions, a principle which is incompatible with a philosophical analysis of those powers. Thus, the distinction which he labours to establish between the muscular contractility of animal life, and that of organic life, is founded, not upon any real difference in the nature of the power concerned; for, as I shall endeavour to show in a future part of the course, the power which resides in the muscles of the voluntary and of the involuntary motions is in all cases the same; but upon a difference in the application which is made of this power in the economy.

Dumas has been guilty of a more palpable error in thinking it necessary to add to his catalogue of principles, consisting of the acknowledged powers of sensibility and contractility, a third power, which he terms "force de résistance vitale"; thus associating a final cause with causes that are strictly physical. To multiply examples of this mistake would be endless; for it vitiates almost every physiological system that has yet been framed*.

It is evident that the foundation of all Physiological knowledge must be laid in a thorough acquaintance with the structure of animals. The study of Anatomy, indeed, derives its chief interest from its connection

* I have treated more at large on this subject, in the article "PHYSIOLOGY" of the new Supplement to the Encyclopædia Britannica, in which I have attempted an analysis of the principal laws, or ultimate facts to which the vital phenomena, considered simply as physical changes, are reducible.

with Physiology. The examination of the forms and properties of the parts of any machine, unless viewed with reference to their uses and applications, would be a task equally irksome and barren. Let us imagine, for example, a person, who had never seen a ship, and had no idea of the purpose for which it was made, to visit one for the first time, and to examine, at his leisure, every part of its rigging and internal construction. A restless curiosity might lead him to handle the ropes and blocks, to climb upon the masts, to descend below the deck, and minutely inspect every part of its fabric; or, in other words, to explore the whole anatomy of this stupendous product of human industry. But what would his labour avail him? The most complete survey would afford him no instruction, or leave any distinct impression, as long as he had no principle to connect the ideas in his mind. Let him now review the same objects with an experienced guide, instructing him, as he proceeds, concerning the general purposes of the whole machine, and the particular uses of every part, as well as the mode in which they operate and concur in the production of the intended effect. Now it is that he begins to feel an interest in the examination: now it is that he attaches 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 human body, or that of any 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 shapes, perforated in various places, and joined together in various ways. The soft parts are found to be composed of different kinds of textures, of which the elements appear to be collections of fibres or of 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, while we confine our attention to the mere Anatomy, all is perplexity and disorder; we are overwhelmed by the multiplicity of objects, and lost amidst the mass of unconnected details. But no sooner do we study the parts of the animal frame with reference to their uses, and their subserviency to the functions of the living body, than the whole appears under a new aspect. New light is thrown upon every branch of the subject, and new interest communicated to all its details. The complicated system of an animal, which, when viewed without relation to its Physiology, presented nothing but intricacy and confusion, will appear, when studied with reference to the purposes of its formation, as an elaborate machine, in which order and design are every where conspicuous, and which in the assemblage and disposal of organs, and even in the construction of the minutest fibre, displays an exquisite and transcendent skill.

As we had observed a gradation among the physical powers which actuate the different parts of the animal machine, so we may in like manner trace a regular subordination of the functions which they exercise. The great ends to which all the arrangements of the system, and all the movements of its parts evidently point, are the welfare and preservation of the individual being which they compose, and of the race to which it belongs. Sensation and Voluntary Motion are thus the primary objects to which all other functions are more or less directly subservient.

That the relative subserviency of each

function to these two great ends of animal existence may be clearly understood, I shall proceed to give you such a general sketch of the system of the animal economy, as may serve as a map of the country we are about to explore, and by which the relations and bearings of each object may be distinctly perceived.

Let it not be deemed presumptuous if, with the view of obtaining a more thorough insight into the plans of nature, we attempt, with all due humility, to anticipate her designs. Let us endeavour, by the aid of that reason with which she has endowed us, not merely to follow, but to precede her footsteps; let us ask ourselves what plans would have suggested themselves to us, if we had been gifted with the power of combining at pleasure the materials of the animal body, and if we were called upon to construct such organs as might appear to us necessary for the purposes of life.

The being to be formed should have two essential attributes, PERCEPTION and VOLUNTARY MOTION. For the first, it must have a susceptibility of being affected by external objects; it must have a capacity of feeling; it must be sensible to pleasure and to pain. Such, then, is the first problem we have to resolve: and the means that we may suppose given to us for that purpose exist in the singular properties of a peculiar organization of animal matter, called the medullary or nervous substance. The affections of this remarkable substance are in some inexplicable way connected with the sentient and intelligent principle; a principle which we cannot conceive but as wholly distinct from matter, though capable of being affected by it, when operating through the medium of this substance, and capable of reacting upon this matter in return.

Assuming, then, that this immediate organ of sensation, which we shall call the *Brain*, is provided for us, we are to devise means for establishing a communication between external objects and this organ, so that impressions of various kinds, made on different parts of the body, shall be immediately conveyed to it, without confusing each other, or losing their distinctive characters: for thus only can the mind which receives them, be able to discriminate each, and infer the existence and properties of the respective objects which occasion these impressions.

It is evidently highly expedient, nay absolutely indispensable, that these notices of the presence of objects should be transmitted instantly to the brain; the slightest delay in this transmission would be attended with the greatest evil, and might in many cases lead to fatal consequences. Now there are agents in nature of which the operation corresponds in some measure with the effect that is here wanted. Such an agent is Electricity; for electricity is transmitted along conducting wires with a velocity that exceeds all measurement. The combinations of organic matter supply us with the nervous agency, which is very analogous to electricity in this respect: it appears, however, so very different in its other properties, that we are by no means warranted in pronouncing it identical with electricity: and I beg to be understood as having introduced the comparison only for the sake of illustration.

The brain, then, must be supplied with a number of conductors for this subtle influence: these conductors we shall call the *Nerves*.

The diagrams which I have placed before you exhibit the plan of arrangement, and the general distribution of the several parts of the nervous system, including the brain, the spinal marrow, and the different nerves which establish these extensive connections between every part.

These nerves must extend from all those parts of the body which are to be rendered sensible, and unite in the brain; and they must have a structure adapted to the kind of impression they are designed to convey. It is more particularly of importance that the surface of the body should receive impressions from the contact of external bodies, and that, when thus affected, they should communicate the perceptions of touch. We shall, accordingly, distribute the largest share of nerves to the skin, and especially to those parts which we intend as more particularly the organs of touch.

These nerves must be susceptible of a variety of impressions besides that of mere pressure and resistance from solid bodies: they must be affected by variations of temperature; and they must immediately communicate pain, when acted upon in any way that may be injurious to the part impressed, or to the system at large. This latter property is absolutely requisite in order that the animal may be warned of the impending evil, and may adopt measures for averting it. The nerves of the skin act the part of sentinels, placed at the outposts, which give the signal of alarm on the approach of danger. Sensibility to pain is thus a necessary constituent among the animal functions, without which the others could not long continue to be performed, amidst the numerous casualties to which the system must perpetually be exposed. The occasional suffering to which the animal is thus subjected, is on the whole far more than counterbalanced by the capacities of pleasure, with which it has been beneficently provided that the healthy exercise of those functions shall be accompanied. Enjoyment appears to be the end, the rule, the natural and ordinary condition. Pain is the casualty, the exception, the necessary remedy, which is still tending to a remoter good, in subordination to a higher law of nature.

The internal organs must also have their share of sensibility, and must, therefore, also be furnished with nerves; though they are not required to be supplied with them in such abundance as the skin.

But we have as yet provided only for the lowest degree of sensitive existence. It is time to confer upon our animal a wider range of perception than is competent to the mere sense of touch, which imparts information only with regard to those objects that are actually in contact with the body. We must open channels of communication with distant objects; we must apprise him of danger while it is yet remote; we must inform him of the situation of those objects which are subservient to his wants, and which may procure him gratification. We must show him the surrounding world; we must lift up the curtain of darkness which conceals it, and admit him to the glorious spectacle of nature's scenery; we must make him sensible of his place in this great theatre of the universe, and apprise him of the eventful changes that are hourly transacting around him, and in which he is called upon to play his assigned part.

To the sense of touch, then, we add those of Sight and of Hearing. We first avail ourselves of the power of Light; that divine and almost spiritual essence, which seems specially formed for the use and enjoyment of intelligent and sentient beings. We study its properties; we form an organ expressly adapted to these properties; we prepare a finer texture of nerve to receive its delicate impressions. This nerve we distinguish by the name of the optic nerve. We must make it take its rise in the eye, in a thin expansion of membrane, the retina, on which it is to be spread out for the purpose of receiving, as on the canvass of a picture, the images of external objects. We must further provide transparent media, with refracting powers of the exact degree, and with spherical surfaces of the precise curvature required by the laws of optics for this purpose. We must form, in a word, a camera obscura, by which a faithful delineation of the external scene may be effected upon the retina; the impressions on which are to be conveyed by the optic nerve to the brain, where those changes are excited which give rise to the perception of vision.

As an auxiliary to this sense, which, however exquisite and enchanting, is yet limited to certain conditions in the situation of its objects, the sense of Hearing is to be added. We shall for this purpose have recourse to the elastic properties of the surrounding medium, whether air or water, by which vibrations are excited among its particles, and which vibrations are propagated on all sides and to a considerable distance. These we collect and strengthen by means of a trumpetshaped organ, where they can be made, through the intervention of a curious mechanism, to strike upon the delicate expansion of another nerve, which we shall call the auditory nerve, so that when conveyed to the brain, they may excite the perception of sound.

The subtle effluvia which float in the atmosphere, and are also indications of the existence of distant objects from which they arise, are, in like manner, to be received by the expanded filaments of another nerve, the olfactory; where they excite particular impressions, and become the objects of another sense, namely that of Smell.

Various chemical qualities of fluids, or of solid bodies which act through the medium of fluids, are in like manner perceptible by the sense of Taste, for which, as in the other cases, particular nerves must be provided to receive the impressions, and to convey them without confusion to the brain.

Thus far, then, will our animal be endowed with the power of perceiving external objects and of deriving from them pleasure and pain. But these perceptions of surrounding objects and these capacities of enjoyment and of suffering, would be fruitless, and even baneful endowments, unless accompanied with the power of securing the possession of useful objects, and of avoiding or rejecting such as are hurtful. The animal must, in addition, therefore, be gifted with the faculty of voluntary motion. The act of volition, which is a mental change, produces some corresponding change in the brain, which is the organ of volition as well as of sensation: this impression made in the brain must be transmitted to the parts of the body that are to be moved ; and a new set of nerves must be provided to be the vehicles of these impressions. While the nerves of sensation should properly be considered as commencing at the organs of sense, the nerves subservient to volition have their real origin in the brain, and are distributed to the organs of motion.

Let us next, then, direct our attention to the mechanism of these organs.

If, in any object of human art, it were requisite to employ a great quantity of machinery, for the execution of various kinds of work, some opposing great resistance, and therefore requiring the exertion of considerable power, others less laborious, but requiring delicacy and precision, we should naturally resort to some simple mechanical source of power, such as a fall of water, the action of the wind, or the still more regular and manageable force of steam, acting by the intervention of machinery. But none of the forces which are derived from the laws of inorganic matter could be conveniently applied in the animal machine. Nature has, however, furnished a source of power much surpassing any of these, in the contractile property, which I formerly alluded to, possessed by the fibres of muscles. As in a manufactory where the force of steam is the prime mover of the whole of its complicated machinery of wheels and levers, so in the animal system is the muscular power resorted to on every occasion where mechanical force is required. From its vast intensity, this power appears adequate to every purpose; and although it may, in some instances, appear to have been profusely lavished for the sake of slight additional convenience, in others it is carefully economised; and probably more accurate examination would show that it is in all cases exactly adjusted to the intended effects.

Those muscles, then, of which the contractions are to be governed by the will of the animal, must receive nerves of volition directly from the brain, in order to maintain their communication with that organ, which is the immediate instrument of volition.

Having obtained the moving power, and placed it under the guidance of the will, our next inquiry must be into the mode of disposing of this power so as to accomplish the required movements. The objects of these movements must be very various in different kinds of animals, according to the elements in which they are destined to reside, the situations in which they are likely to be placed, the mode of life allotted to them, and the nature of their respective wants. But among these we may particularize two principal purposes to which the mechanism of the frame is to be adapted : first, it is expedient that the animal should have the power of laying hold of, and of detaining particular objects that he may want; and secondly, it is requisite that he be able to transport his body from one place to another. The organs specially appropriated to the sense of touch, are generally also those of prehension; and the function of progressive motion is fulfilled by means of limbs, which act upon the ground, the waters, or the air, according to the element in which the animal is to reside.

In order to give effect to these movements, the agency of levers is required: we must have parts of a more solid and unyielding structure, capable of sustaining the weight of the trunk without bending, and furnishing fixed points of attachment to the muscles, or moving powers. Such, in all the higher classes of animals, is the office of the bones, which are lodged in the interior of the body, composing together the solid frame-work of the machine, like the beams and pillars of a building. This frame-work is the *Skeleton*. It is composed of a number of separate pieces, moveable in different degrees upon each other; being connected together by smooth surfaces, forming the *Joints*, which are limited in their motions, as well as secured from injury by firm bands or ligaments, bracing them on the sides where the strains are greatest, and wherever they might be in danger of being displaced.

The frame of animals belonging to the lower divisions, is adapted to a smaller standard of magnitude, and subject to mechanical conditions different from those of the vertebrated classes. The model of their conformation is accordingly reversed; and the solid structures are placed externally to the muscles and softer organs, constituting incasements of various degrees of hardness; as we see exemplified in the shells of mollusca, in the crusts of the lobster and the crab, and in the horny integuments of insects.

When the action of the power is wanted, while at the same time the presence of the muscle in that situation would be inconvenient, a particular contrivance is adopted, analogous to what mechanics are in the habit of employing. If the object to be moved be at too great a distance from the source of power to receive its immediate action, we use the intermedium of a rope or strap. In the animal frame the same office is performed by *Tendons*, which are long cords, attached at one end to the muscle, and at the other to the bone, or part to be moved. If the muscles which are to move the fingers, for example, had been placed in the palm or back of the hand, they would have enlarged those parts to an awkward and clumsy thickness, which would not only have destroyed the beauty and proportion of the organ, but impeded many of its uses as a mechanical instrument. These muscles are, accordingly, disposed high up in the arm, and their tendons pass along the wrist, to be affixed to the joints of the fingers they are severally to move.

Another advantage of tendons is that they enable a great number of muscular fibres to co-operate in their action, and to concentrate their united power 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, so that their combined strength is made to bear in the same action.

It is evident that a variety of mechanical arrangements will be necessary for enabling the several organs to execute their respective offices. The texture of each part must be adapted to the actions it has to perform. But however different may be the mechanical properties of these textures, one uniform plan has been in general followed in their formation; and nearly the same elementary basis of structure is adopted, though modified according to circumstances, in the building of the animal frame. All the solid parts of animals, with but few exceptions, are essentially composed of fibres, variously interwoven and united, so as to form, in some cases, a reticulated or spongy texture, and therefore termed *the Cellular Substance;* and on other occasions, being condensed into thin sheets or layers, a form in which it has received the name of *Membrane.* These two forms of animal substance are the foundations of almost all the solid parts of the body. The cellular substance is the universal medium of connection between adjacent organs; from its flexibility in all directions, it allows of their play, and diminishes the friction that would otherwise result from their motions: and its elasticity restores every part to its natural figure and situation, after the action which caused its alteration of form, or displacement, has ceased.

When organs require more effectual protection and support, membranes are employed, both to form an external covering, and to establish firmer connections with other parts. They are also used as barriers, intercepting the communication of fluids from one cavity to another. They compose receptacles for the retention of fluids, and tubes for their transmission to a distance. When a greater degree of solidity and toughness is required, the animal fibres are still more firmly compacted together, so as to form ligamentous, coriaceous, and horny structures. But where the utmost degree of hardness and rigidity is necessary, as in shell or bone, a new material, of a calcareous nature, is superadded to the animal basis of membrane.

I shall not at present attempt to describe these different structures more minutely, as they will form the subject of detailed consideration in subsequent lectures. In different parts of the course, I shall also have occasion to explain a great number of other mechanical expedients, that must be resorted to for various objects, which it is not necessary now to enumerate; such as those of facilitating motion, of economising power, and of accommodation to other functions that may happen to require particular forms of structure. All these objects I shall class together under the title of the MECHANICAL FUNCTIONS.

But however skilfully the body of an animal may have been mechanically constructed, it contains within itself the principles of decay and dissolution. Like every other machine, it will wear by use. Friction in the more rigid organs, and reiterated action in the flexible parts, will be attended with loss of substance. The expenditure of the muscular and nervous energies will be accompanied with corresponding changes, both in the mechanical organization and the chemical condition of the body, incompatible with the long continued exercise of the vital functions. The particles which have, in consequence of these actions, entered into new combinations, and been rendered useless, or even pernicious, must be removed, and their place supplied by fresh materials, derived from external sources. The chemical constitution of all organized bodies is such, that the equilibrium of the affinities retaining them in their healthy state is easily destroyed. There exists, indeed, in all animal substances, under the ordinary circumstances of warmth and moisture, a constant tendency to decomposition. This tendency manifests itself immediately on the extinction of life, and can only be counteracted, in the living system, by the perpetual renovation of their elements, which it must therefore be the object of a new set of functions to supply. In all the more perfect animals, the active energies of life require that the organs should be maintained in a proper temperature. This temperature is supported, as we shall afterwards find, by a chemical process analogous to combustion, and accordingly requiring for its continuance a supply of combustible materials. Part of the nutriment received into the body is appropriated to this object, and is consumed as fuel for maintaining the vital warmth.

During the period of growth, it is obvious that continual additions must be made to the substance of the body, of chemical elements of the same kind as those composing the several organs it already contains. The functions of nutrition must, therefore, be exerted with peculiar activity in the early part of life. But in addition to these demands, materials are also wanted to meet particular exigencies which may occur at different periods. Like a ship fitted out for a long voyage, the animal system, when launched into existence, should contain within itself a store of materials for the repair of numerous accidents that may befal it, and even for the restoration of parts that may happen to be injured or destroyed.

The objects, then, of these reparatory processes must be, first, to act upon the food that has been received into the body, so as to animalize it, or convert it into nutriment; that is, into a chemical compound analogous to the substance of the animal: secondly, to distribute this nutriment to the different organs wherever it may be wanted: and lastly, to apply it to the purposes of nutrition, in effecting the growth, in supplying the losses, in repairing the injuries, and in recruiting the exhausted energies of every part. As the nature of the changes thus effected is chiefly chemical, we may apply to these functions, generally, the term CHEMICAL FUNCTIONS, in contradistinction to those of which the objects, as in the case of locomotion, are strictly mechanical.

The system of organs which perform these functions may be compared to a chemical laboratory, where a variety of complex operations are going on at the same time. In the lowest orders of the animal creation, these functions are conducted in the simplest manner, and by the smallest number of organs. We may compare the reparatory system, in this case, to a manufactory on a frugal scale, conducted by ruder methods, with a scanty apparatus, and by the smallest possible number of workmen. In proportion as we ascend in the scale of animals, we find the processes extending in number and in refinement. The principle of the division of labour is introduced: the tasks before assigned to one and the same organ, being now apportioned among different sets of organs, the quality of the work is in the same proportion improved. In the higher classes of animals, the separation of offices becomes still more complete, and the products of one set of organs are passed on to the next in regular succession. The following is a sketch of this elaborate system of operations, when arrived at its state of greatest perfection.

Organs must, in the first place, be provided for laying hold of the food proper to the animal, and for receiving it into the body: and mechanical instruments must be at hand, immediately on its reception, for effecting its subdivision, and preparing it for the action of the chemical agents to which it is afterwards to be subjected. Hence the necessity of the *Mouth*, with its accompanying apparatus of *Jaws* and *Teeth;* hence the provision of fluids, prepared by the *Salivary Organs*, in the neighbourhood of the mouth, and supplied for the purpose of admixture with the food, so as to soften its texture, and to reduce it into a pulpy mass. The food, thus prepared, is to be swallowed by the action of the muscles of the tongue and throat, and conveyed along a tube, termed the *Œsophagus*, into the cavity of the *Stomach*. The stomach is a membranous bag, in which the aliment is made to undergo certain chemical changes, partly by the agency of a peculiar fluid formed by the coats of the stomach, and termed the gastric juice, and partly by other means. These changes constitute DIGESTION: and the digested aliment is then transferred to the canal of the *Intestine*, which is a tube continuous with the stomach, and in which still further chemical changes are effected in the aliment, by the agency of various secreted fluids, derived from organs in the vicinity, such as the liver and the pancreas, and also from peculiar structures in the coats of the intestine itself.

The nutritious portion of the food, when thus elaborated, appears in the form of a milky fluid, which is the *Chyle*. This fluid is taken up and collected by a particular set of tubes called the *Lacteals*, and is by them conveyed into the general reservoir of nourishment, which is the Sanguiferous System. These lacteal tubes or vessels are exceeding numerous and curiously constructed; they are provided with numerous valves. They arise from the inner surface of the intestine, where they absorb, or drink up the milky chyle. They unite, as they ascend, into larger and larger branches, till they form one main trunk, called the *Thoracic Duct*, which opens into the cavities belonging to the second great series of organs subservient to the Chemical functions; namely, those of which the office is to distribute the nutritious fluids throughout the system. The Chyle, soon after its passage into these latter organs, which consist of the *Heart*, the *Arteries*, and the *Veins*, from being of a pearly white, acquires a brilliant red colour, and in this state it constitutes the *Blood*.

The Blood may be regarded as the nutriment in its last stage of preparation, almost completely assimilated in its chemical properties to the solids and fluids of the body, into which it is afterwards to be converted. This vital fluid, after filling the heart, which may be considered as the centre of the sanguiferous system, is impelled, by the vigorous contraction of that organ, into the main trunk of the arterial system of vessels, which proceed from the heart, and which divide and ramify in every direction, till their minute branches have penetrated to every part of the body, so as to supply every organ with the materials necessary for the performance of their respective functions. The superfluous blood is brought back by other vessels, called Veins, which collect it into one or two large tubes, and pour it back again into the cavities of the heart, thus completing what is called the CIRCULATION OF THE BLOOD.

But it is still requisite that those particles of the body which had become useless by the wear and tear of its complicated machinery, and by the continual progress of decay, or by injuries arising from occasional violence, should be removed from the situations they occupy to the prejudice of the system; and, as they may still perhaps be usefully disposed of in other ways before being finally ejected from the body, it is expedient that they be conveyed into the general reservoir of circulating fluids. This office is performed by a third set of vessels, called the *Lymphatics*, which arise from every part of the body, as the Lacteals do from the intestines; and uniting, like them, into larger and larger trunks, at length terminate either in the thoracic duct, or in the principal veins leading to the heart: so that, in either case, their contents finds its way to that organ. This function, performed by the Lymphatics, is termed ABSORPTION.

The chemical products, which are wanted in different parts of the economy, frequently require a particular apparatus of vessels, and a more elaborate mechanical arrangement, for their production. The organs constructed for the purpose of carrying on these processes, are termed *Glands*, and are composed of a congeries of minute vessels, conjoined with a cellular tissue; the whole forming very refined and artificial structures. The office they perform, and which is termed SECRETION, is to separate from the blood the elements required for the formation of particular products, and to combine those elements so as to compose these products. It is necessary to observe that the term *Secretion* is applied also to the product itself, as well as to the process by which it has been formed: as mistakes might otherwise arise from the employment of a word of such equivocal signification. A great number of glands and secreting apparatus exist in different parts of the body, their structure being various, according to the chemical nature of the secretion to be produced.

The secreted matter is in some cases

directly useful for the performance of some function; in other instances it is of a noxious quality, and has been separated from the blood for the express purpose of being thrown off from the system: this is the case with the perspiration, the urine, and in part also with the bile. While the former are properly termed the Secretions, the latter are classed under the head of *Excretions*. The organs which perform this office are termed the *Emunctories* of the body. Lastly, secreted matter is applied for the nutrition and growth of the several parts of the body; and when the supply is greater than the wants of the system require, the superabundant portion is laid up in store for future use, in the form of an oily fluid. This fluid, which is the fat, is deposited in various parts of the body, and wherever it can be conveniently lodged. Besides its primary use in being a magazine of nourishment for occasional consumption, it serves also the secondary purpose of furnishing a soft cushion for the defence and security of delicate organs and for the commodious packing of the parts, by filling up vacuities which would otherwise occur in various situations. The use of accumulations of fat is particularly seen in those animals, which, like the marmot and the dormouse, pass the winter in a torpid state. Being deprived of food during the whole of this long period, the system can only be nourished at the expense of the fat which had been collected in large quantities previous to the torpidity of the animal, and nearly the whole of which is found to be consumed when it is about to resume its activity.

But the chyle, or rather the blood which is formed from it, contains a greater proportion of carbon than the animal solids and fluids, into which it is ultimately converted by the processes of nutrition and secretion; for its expenditure, during these processes, is chiefly in oxygen, hydrogen, and azote. This superabundant carbon must therefore accumulate in the course of circulation; and we find, indeed, that it gives the blood that dark purple colour, which it assumes by the time it has reached the veins. The blood, therefore, returns to the heart in a state in which it is not fit to be again circulated; for if it were sent, thus loaded with carbonaceous matter, to the various organs of the body, it would prove exceedingly injurious to them. For the purpose of removing this noxious ingredient, and of restoring to the blood the salutary qualities which it ought to have before it be allowed to circulate through the arteries, the function of RESPIRATION must be called into play. The object of this new function is to expose the blood, on its return by the veins, to the action of atmospheric air, which carries off the carbon, and perhaps also other ingredients, and which may also possibly impart some salutary element in return. The removal of the carbon is effected by its combination with oxygen, which converts it into carbonic acid gas; and this gas is thrown off from the body along with the air respired. The pulmonary organs are appropriated for this office; the air being admitted to them from without, either directly, as in land animals, or through the medium of water, in aquatic animals; and the blood being brought to them, and again returned into the general circulation, by distinct sets of blood vessels. In the two highest classes of animals, namely the mammalia, and birds, this consumption of the redundant carbon, which is a process very analogous to slow combustion, appears to be accompanied with the evolution of caloric, and thus serves to maintain the proper temperature of the body. Advantage is also taken of the mechanical actions required for carrying on respiration; for the same powers that maintain these actions will also supply a force which may be employed in aid of those concerned in the circulation of the blood, and the absorption of fluids by the lacteals and lymphatics. Extensive use appears to have been made of these auxiliary means in the higher orders of animals*.

The function of Respiration is of the greatest importance in the economy of every animal; and more particularly in the higher classes of animals: to them, indeed, air is more immediately necessary than food for the maintenance of life. But it is to be observed that all the functions of this class are so closely linked together,

* See Dr. Barry's "Experimental Researches," lately published.

that an interruption in any one of them is soon followed by the cessation of the rest.

As it is evidently of the greatest consequence that the actions of these vital organs should proceed with regularity, they must be exempted from all interference from the will of the animal. With this design, the nerves belonging to those organs have, in general, no very direct communication with those parts of the brain which exercise the functions of sensation and volition. They compose a system of themselves, of great extent and importance, and establish the necessary connections between all the organs concerned in the nutritive functions. They are variously united and interwoven with each other at particular points, forming what are called *Ganglions*, or knots, which have been regarded as secondary centres of nervous influence; and which have also circuitous communications with every part of the brain and spinal marrow; so as to establish extensive *sympathies* between distant organs, and to unite the whole into one individual and harmonious system.

Such, then, are the objects, and such the provisions for their accomplishment, which constitute the Chemical Functions of the Economy. Much as the exquisitely beautiful mechanism of the animal fabric is calculated to excite our admiration; the survey of that extensive series of refined and delicate chemical processes, which nature silently conducts in the organized laboratory of living beings, reveals a superior order of perfections, and exalts to a still higher degree our ideas of the consummate art and foresight which pervade all the departments of the animal economy.

The functions we have been reviewing

refer exclusively to the internal condition of the animal, regarded as a solitary being. But a multitude of objects conducive to his welfare also present themselves, which involve external relations with other species of animals, or ithw other individuals of the same species, and are more or less connected with the faculties of perception and voluntary motion. Among these we may distinguish the expression of their sensations and wants by certain signs, and especially by the production of sounds, for which an express apparatus is provided in the organs of *Voice*. These organs are constructed on a model combining the principles of wind instruments, and of those which act by vibration. For this purpose, advantage is again taken of the mechanical agents concerned in respiration; tense membranes being stretched across the passages for air, which are made to vibrate by its action, and which also, in their turn, modulate the current of air so as to give rise to sonorous undulations. In animals which do not breathe air, provision is also sometimes made for the production of sound; but this must of course be effected by a mechanism of a totally different kind.

The various HOSTILITIES carried on among animals, constitute another division of the class of functions we are now considering. It includes the various modes of attack and of defence resorted to, whether by open violence, as in the tiger; by the insidious operation of poison, as in the rattle-snake; or by the paralyzing agency of electricity, as in the torpedo; for all which purposes special instruments and organs have been supplied. Sometimes very peculiar devices and stratagems are resorted to by animals for the purposes of deceiving or entrapping their enemies, or of concealment from their pursuit. As an example may be mentioned the remarkable secretion of the cuttle-fish, which is of an intensely dark colour, and is collected in a special reservoir, for the purpose of being, on the approach of an enemy, effused into the surrounding water, which it renders turbid to a considerable distance, and by concealing the animal, enables it to escape unperceived.

Thus far we have provided for the life and welfare of the individual. But that life, even should it not be prematurely arrested by accident or disease, has a certain limit assigned by nature for its duration: and measures must be taken for the continuance of the race, and the multiplication of its numbers. Hence the necessity of a distinct class of functions; those, namely, which relate to GENERATION, and which are universally met with in all the classes of the animal kingdom, although exercised according to different plans, and in very different modes. Hence, also, the distinctions of sex; hence the various processes of FECUNDATION, and the various modes of EVOLUTION, of GESTATION, and of PARTURITION. Hence the variety of provisions for the protection and nourishment of the young animal, and the temporary structures which are subservient to its future and more perfect condition. It will be evident how extensive is the field of inquiry relating to this class of functions, and how curious and interesting are the subjects it comprehends.

I have thus endeavoured to delineate the outline of that assemblage of functions which constitutes animal life in its most complete and perfect form, with a view of pointing out their respective purposes and objects. But in treating of them at large I intend to follow an order somewhat different from that in which I have now enumerated them. I shall begin with the consideration of the mechanical functions, which are the simplest in their nature; and proceed next to the chemical functions, which relate to nutrition: these will better prepare us for the study of the class of sensitive functions, which though so interesting and important, are more complex and obscure than the preceding: and I shall in the last place treat of the functions of reproduction, and evolution. I shall conclude with a general review of the combinations of structures and of functions which characterize the different classes and orders of the animal kingdom, which mark their successive gradations in the scale of perfection, and which exhibit such conspicuous proofs of the order and beneficent design pervading this part of the creation.

The study of Nature, in all her various departments, supplies a rich and inexhaustible fountain of intellectual enjoyment. Considered as an object of mere amusement, what branch of knowledge can offer more general interest than the history of animated beings? The Mathematical Sciences, and the several branches of Natural Philosophy which are dependent on Mathematics, hold, indeed, a most exalted rank among the exertions of human intellect; but their abstruse nature must ever place them above the level of ordinary and uncultivated understandings; and their study cannot be successfully achieved without considerable mental labour, and long-continued application. But the subjects embraced by Natural History are within the reach of the most moderate capacity; and as they refer constantly to objects that strike the senses, require no extraordinary effort of attention for their comprehension. Can there be a more delightful relaxation to a mind fatigued with the toils and anxieties of an arduous profession, wearied with the drudgery of monotonous occupations, or exhausted by the contentions incident to our dealings with mankind, than the refreshing view of Nature's scenery, and the calm contemplation of her works, unbounded as they are in variety, in riches, and in splendour; and leading to the most enlarged views of the creation, and to the loftiest and most sublime topics of speculation?

Magnificent, indeed, is the spectacle, on whatever side we turn our eyes, which nature unfolds to our view! If we raise them to the heavens, and reflect upon the immensity of celestial space, through which are scattered such countless myriads of suns, and planetary worlds, our imagination is overwhelmed with so vast an idea. The globe we inhabit, when estimated by a scale of such stupendous magnitude, dwindles into a mere atom: and yet what scenes of wonder and enchantment are displayed in every corner of this comparatively insignificant portion of the creation! Life, in its various forms, meets the eye in every region to which our researches can extend. How infinite the number and diversity of the plants and animals which are spread over every quarter of the globe*. All climates have their peculiar productions; all

* The number of species of insects alone, which are already determined, has been reckoned at upwards of 80,000: the other classes of animals comprise altogether nearly 25,000 species: so that we may fairly estimate the total number of species in the animal kingdom as being upwards of 100,000, each having their distinct and peculiar forms, organizations, and faculties.

the parts of the earth are peopled by their respective inhabitants. From the icy region of the pole to the scorching sands of the line; from the lofty summit of the mountain to the dark abysses of the deep; the shades of the forest, the subterranean recesses of the earth, and hidden caverns of the ocean, as well as the cultivated theatres of human industry,—all teem with life, all are replete with enjoyment. Every element is the abode of different orders of living beings, who have received from the bounteous hand of their Creator the gift of existence, and the means of happiness. Wherever life can be sustained, we find life produced. Even in the minutest drop of water we may discover, by the microscope, innumerable animalculæ, each endowed with spontaneous powers of motion, and giving unequivocal signs of individual animation. Thus each race of animals has its station allotted to it; each fulfils its respective destiny, and occupies its proper sphere in the system of creation. Can we behold with apathy so interesting a spectacle? Must not our curiosity be most powerfully excited by the busy and ever changing scene which the animal world exhibits to our view?

We are more especially attracted to these inquiries by the striking analogies, which the inferior animals present to our own species: creating a sympathetic interest and curiosity, which the examination of inorganic nature, or even of the vegetable creation, is unable to inspire. We cannot view but with feelings of sympathy beings endowed, like ourselves, with individual consciousness, and with faculties of sensation, perception and voluntary motion; susceptible, as we are, both of pleasure and of pain; impelled by motives and passions similar to those of which we feel the influence in our own breasts; participating with us in the bounties of Providence; and alike exposed to suffer from the destructive agency of physical causes.

At no period of our lives can the study of Zoology be devoid of interest. From our earliest infancy it is a source of innocent and of rational recreation, and is peculiarly fitted to be the foundation of solid instruction. It opens, at a maturer age, an ample field for the exercise of our reasoning powers: and by its numerous practical applications, and extensive connections with various departments of science, contributes material accessions to the power and happiness of man.

Comparative Physiology, though it must necessarily be founded on the previous study of the natural history of animals, tends in its turn to reflect the most important light on the science of Zoology, and more especially on what must ever constitute the foundation of the science, namely, the Classification of Animals.

Cuvier has justly remarked, that a perfect natural method of classification ought to 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. Thus we obtain more or less comprehensive statements, or, as it were, Zoological Laws, enabling us both to acquire and 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. It is evident that for the discovery of those analogies, on which the arrangement into natural families is founded, we must resort to the aid of Comparative Physiology: for 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 essential 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.

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 with that which followed it. Linnæus was even impressed with the belief that Nature, in the formation of animals, had never passed abruptly from one kind of structure to another. The idea of a chain, or continuous gradation of beings, 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 no one has carried it to so extravagant a length as Lamarck, in his "*Philosophie Zoologique*". He conceives that there was originally no distinction of species, but that each race has, in the course of ages, been derived from some other less perfect than itself, by a spontaneous improvement in the race. Thus he supposes that the animalculæ of infusions gave birth, by successive transformations, to all other animals: aquatic animals acquiring by degrees, and from their own efforts, feet and legs, fitting them for walking on the ground; and these, after a time, being converted into wings, merely from the long continued operation of a desire to walk and to fly.

But the truth is, that instead of there being any 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 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 and oblique lines of connection. On this subject Mr. MacLeay* has advanced a hypothesis, which he supports with great ingenuity and semblance of truth; namely, that the real types or models of structures are correctly represented by circular or recurring arrangements; and he gives numerous instances in which this principle applies with singular felicity. It must be evident, however, that it can only be on the supposition of an extensive comparison of organs having been instituted throughout the whole of the animal kingdom, that any satisfactory conclusions can be attained on these curious subjects of speculation.

A scientific knowledge of the organiza-

* See his "*Horæ Entomologicæ.*"

tion and functions of animals is valuable, not only in its applications to Zoology, but also in reference to many other sciences, with which it might, at first sight, appear to have but little connection. The light which has been thrown on Geology by these inquiries is a striking illustration of this remark. By attending to the arrangement of mineral bodies as they occur in nature, we obtain sufficient proofs that the earth has undergone frequent and considerable changes prior to the existence of any living beings. But we find, moreover, 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, multitudes of fossil bones and teeth of various Quadrupeds and Reptiles; and occasionally, but more rarely, of Fish and Birds. 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 parts of living or recent animals, to discover their differences or identity, and to deduce certain conclusions with regard to the nature, habits, and character of the animals to which they had belonged. By studying their relations with the strata in which they are met with, we are also led to inferences with regard to the changes that must have taken place in those portions of the earth. These inferences are of the highest importance towards establishing a correct theory of those changes.

The difficulties attending researches of this nature are, of course, exceedingly great, but they have been in many instances surmounted by the persevering zeal and industry of modern naturalists. In these arduous investigations Cuvier stands pre-eminent; and his labours have been rewarded with a number of highly interesting results. The great principle which he has assumed as the foundation of his researches, is that every organized individual constitutes a system in 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 that of every other organ; so that by the careful application of certain rules deduced from this observed reciprocal dependance 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. The successful solution of these difficult problems is one of the greatest triumphs of Comparative Anatomy.

The study of the fossil remains of animals in connection with Physiology, has also extended our views of the animal kingdom, and has, in many instances, supplied the chasms which occur in the natural series of living species ; and has enlarged our ideas of the extent of creation.

Another important conclusion which has resulted, is that the human race has been the last created ; for amidst the universal wreck of such a multiplicity of animal beings, we no where find any vestiges of human bones. These researches tend, therefore, 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, and which Voltaire, and other modern philosophers, had so zealously defended. Geology and Comparative Physiology concur with the sacred 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 satisfactory 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, as well as the surest test of truth.

I trust it is unnecessary to remind you that Physiology is a most important and essential branch of medical study. The accurate knowledge of diseased functions necessarily implies a previous acquaintance with the same functions in their healthy state. Anatomy and Physiology are, indeed, the foundations of the healing art; and it were much to be wished that the latter science, in particular, were more diligently cultivated, and more generally studied as a distinct and essential branch of medical education.

Neither will it be requisite for me to enlarge upon the advantage of extending your views to the examination of the animal kingdom in general, with reference to the Physiology of man: for it is obvious that our knowledge of the functions and structure of the human body would be very imperfect without a comparative investigation of those of animals. Indeed all the important discoveries of modern times, with regard to the human economy, have been derived from observations made on the lower animals. Among the many examples of the truth of this proposition, we may cite the discovery of the circulation of the blood, by which the name of Harvey has been immortalized; that of the lacteals by Asellius; and that of the thoracic duct by Pecquet; all of which were obtained from this source. The works of Haller bear ample testimony to the advantage which has resulted to Physiology from the cultivation of this wider field of inquiry.

The splendid Museum, now in possession of the Royal College of Surgeons, and which was formed by the individual exertions of Hunter, sufficiently attests the importance which that great man attached to the study of Comparative Anatomy, and the zeal and perseverance with which he devoted himself to its pursuit.

The human race composes a part of the great family of Nature, and we ourselves, as individuals of that race, are under the governance of those general laws which regulate 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 life itself, are implicated in the physical conditions of our bodily frame, and are wholly dependent on minute circumstances which maintain it in a healthy state. Comparative Physiology, therefore, claims our attention, not merely as an ornamental branch of speculative knowledge, but as a subject of real practical utility, to which none of us can be wholly indifferent.

The various combinations of faculties, which occur in the different tribes of animals, exhibit in the most striking point of view the mutual dependence and relations of the functions of life. As if with the express design of assisting us in our physiological researches on the nature of vitality, which elude experimental investigation, nature has offered to our view, in the structure of the different orders of animals, a series of varied experiments, by exhibiting each organ under every degree of simplicity and complication of structure, and in every possible mode of combination. It is only by the observation of such a comparative series that we can arrive at any just notions of the extent and wisdom of the plans manifested in that part of the creation which we are permitted to contemplate. These researches illustrate the connection and relationship of every part with the rest of the system: they establish the unity of design with which that system has been planned and executed; and they afford proofs of the perfection with which all its parts are mutually adjusted, and of the harmony that pervades the whole.

The evidences of express design and contrivance are so distinct and palpable, that they may almost be said to obtrude themselves on our notice; and they so multiply and accumulate upon us as we advance, that we cannot avoid being impressed with the idea of its being intended that we should observe them*. While the purpose

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* The analogies of form discernible in corresponding organs throughout a very extensive series of tribes, have been lately traced and developed with extraordinary industry by the modern naturalists of the French school: and especially by Cuvier, Blainville, Savigny, and Geoffroy St. Hilaire. The conclusions they have drawn from their labours, though they may perhaps sometimes appear problematical, 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.

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 exalted intelligence with which that power is wielded. In proportion as we extend our inquiries, we discern new traces of intention, and a greater range of design and comprehensiveness of plans than we could have at first conceived. It is impossible to view without a feeling of astonishment the immense chain of causes and effects, which are thus rendered instrumental in the accomplishment of distant purposes. The ultimate objects, however remote or contingent they may appear to us, have evidently been foreseen, and carefully provided for; although the agents employed to produce them can operate only through the intervention of a long series of changes.

Nor is it possible to overlook the general purpose to which every thing so manifestly tends in the system of animal existence. Every element, in every part of the habitable globe, teems with life; and that life is replete with enjoyment. The benevolence thus predominant in the design of creation is no less conspicuous, than the wisdom which regulates, and the energy which sustains, its continued government.

THE END.

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OUTLINE OF CUVIER'S CLASSIFICATION OF ANIMALS;

with Examples of Species belonging to each Division.

I. VERTEBRATA.

1. Mammalia.

Bimana	*Man,*
Quadrumana .	*Monkey, Ape, Lemur.*
Cheiroptera . .	*Bat, Colugo.*
Insectivora . .	*Hedge-hog, Shrew, Mole.*
Plantigrada . .	*Bear, Badger, Glutton.*
Digitigrada . .	*Dog, Lion, Cat, Martin, Weasel, Otter.*
Amphibia . .	*Seal, Walrus.*
Marsupialia . .	*Opossum, Kanguroo.*
Rodentia . .	*Beaver, Rat, Squirrel, Porcupine, Hare.*
Edentata . .	*Sloth, Armadillo, Ant-eater, Pangolin.*
Pachydermata .	*Elephant, Hog, Rhinoceros, Tapir, Horse.*
Ruminantia . .	*Camel, Musk, Deer, Giraffe, Antelope, Goat, Sheep, Ox.*
Cetacea . . .	*Dolphin, Whale.*

2. Aves.

Accipitres . .	*Vulture, Eagle, Owl.*
Passeres . . .	*Thrush, Swallow, Lark, Crow, Sparrow, Wren.*
Scansores . .	*Woodpecker, Cuckow, Toucan, Parrot.*
Gallinæ . . .	*Peacock, Pheasant, Grouse, Pigeon.*
Grallæ . . .	*Plover, Stork, Snipe, Ibis, Flamingo.*
Palmipedes . .	*Auk, Grebe, Gull, Pelican, Swan, Duck.*

3. Reptilia.

Chelonia . . .	*Tortoise, Turtle.*
Sauria . . .	*Crocodile, Lizard, Chamelion.*
Ophidia . . .	*Serpents, Boa, Viper.*
Batrachia . .	*Frog, Salamander, Proteus, Siren.*

4. Pisces.

Chondropterygii	*Lamprey, Shark, Ray, Sturgeon.*
Plectognathi .	*Sun-fish, Trunk-fish.*
Lophobranchi .	*Pipe-fish, Pegasus.*
Malacopterygii .	*Salmon, Herring, Pike, Carp, Silurus, Cod, Sole, Remora, Eel.*
Acanthopterygii	*Perch, Mackerel, Sword-fish.*

II. MOLLUSCA.

Cephalopoda .	*Sepia, Nautilus.*
Pteropoda . .	*Clio, Hyalæa.*
Gasteropoda .	*Slug, Snail, Limpet.*
Acephala . . .	*Oyster, Muscle, Ascidia, Pyrosoma.*
Brachiopoda .	*Lingula, Terebratula.*
Cirrhopoda . .	*Barnacle.*

III. ARTICULATA.

1. Annelides, or Vermes.

Tubicolæ . .	*Serpula, Sabella.*
Dorsibranchiæ .	*Nereis, Aphrodite.*
Abranchiæ . .	*Earth-worm, Leech.*

2. Crustacea.

Decapoda . .	*Crab, Lobster, Prawn.*
Stomapoda . .	*Squill.*
Amphipoda .	*Gammarus.*
Isopoda . . .	*Asellus.*
Branchiopoda .	*Monoculus.*

3. Arachnida.

Pulmonalia . .	*Spider, Scorpion.*
Trachealia . .	*Phalangium, Mite.*

4. Insecta.

Aptera . . .	*Centipede, Podura.*
Coleoptera . .	*Beetle, Glow-worm.*
Orthoptera . .	*Grasshopper, Locust.*
Hemiptera . .	*Fire-fly, Aphis.*
Neuroptera . .	*Dragon-fly, Ephemera.*
Hymenoptera .	*Bee, Wasp, Ant.*
Lepidoptera . .	*Butterfly, Moth.*
Rhipiptera . .	*Xenos, Stylops.*
Diptera . . .	*Gnat, House-fly.*

IV. ZOOPHYTA.

Echinodermata .	*Starfish, Echinus.*
Entozoa . . .	*Fluke, Tænia, Hydatid.*
Acalephæ . .	*Actinia, Medusa.*
Polypi . . .	*Hydra, Coralline, Pennatula, Sponge.*
Infusoria . .	*Brachionus, Vibrio, Proteus, Monas.*

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